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The Impact of Drought and Temperature Stress on Wheat and Maize

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DEDICATIONS

I dedicate this dissertation to my loving brother, Ali, whose unwavering support, sacrifices, and encouragement have been the cornerstone of my whole life and academic journey, my dear Ali – I love you to death more than myself, I swear (ياخوي ياطيب الخوه, اللهم عجل التحاقي باخيي علاوي). To my parents and siblings, whose sacrifices and belief in me have fueled my determination. Even though you are not alive anymore, I feel your spirits inside me, around me, in front of my eyes, and in my back all the time. My honest wish is to be with you wherever you are right now as soon as possible. I dedicate also to my son, Ali, for his understanding and motivation during the challenging times.

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I dedicate this work to the future generations of scholars and scientists; may it contribute in some small way to the advancement of knowledge and the betterment of our world.

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LIST OF ABBREVIATIONS

ABA	Abscisic Acid
ANOVA	Analysis of Variance
APAD	Active Photosynthetic Area Density
ATP	Adenosine Triphosphate
BNF	Biological Nitrogen Fixation
DNA	Deoxyribo Nucleic Acid
EM	Effective Microorganisms
FAO	Food and Agriculture Organization
FN	Falling Number
Gas	Gibberellins
GABA	Gamma-aminobutyric Acid
GenStat	General Statistics software package
HI	Harvest Index
HLM	Hectolitre mass
HWW	Hard winter wheat
IPCC	International Panel on Climate Change
KCl	Potassium Chloride
KNO_3	Potassium Nitrate
LAI	Leaf Area Index
N_2O	Nitrous Oxide
NaCl	Sodium Chloride
NIR	Near-infrared
NUE	Nitrogen Usage Efficiency
PDs	Petri dishes
RCBD	Randomized Complete Block Design
RNA	Ribo Nucleic Acid
RNS	Reactive Nitrogen Species
ROS	Reactive Oxygen Species
S.A.S	Statistical Analysis System
SA	Salicylic Acid
SDS	Sedimentation volume

SPSS	Statistical Package for Social Sciences
TKW	Thousand Kernel Weight
WUE	Water Use Efficiency

1 INTRODUCTION

Plants are subject to a range of environmental stresses, encompassing abiotic stresses, which refer to non-biological factors that can have detrimental effects on plant growth and development. Wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) are the most essential and cultivated field crops worldwide. Abiotic stresses, including but not limited to drought, extreme temperatures, flooding, and exposure to chemicals, have been observed to result in substantial declines in crop productivity, quality, and yield. These adverse effects have been found to have significant economic implications for the agricultural sector, leading to financial losses. In the year 2022, the agricultural sector in Hungary experienced a significant decline in production due to the substantial effects of drought. Similarly, the United States encountered a substantial impact on approximately 85% of its cropland, leading to agricultural losses amounting to 22.2 billion US dollars according to the United States Department of Agriculture.

These environmental restrictions do not seem to be diminishing. Increased temperatures and decreasing precipitation are predicted by global climate change, which is likely to intensify the negative consequences of water shortage on agriculture. Less rainfall will increase the extent of irrigated land, leading to soil salinization.

Abiotic stresses can induce various physiological, biochemical, and molecular responses in plants, including changes in gene expression, protein synthesis, osmolyte accumulation, and reactive oxygen species (ROS) scavenging. These responses minimize stress-induced damage and promote plant survival under harsh circumstances. Nevertheless, chronic exposure to stress may cause irreparable tissue damage, decreasing plant development and yield.

Germination is a physiological process that initiates and develops a seedling by triggering a cascade of biological and biochemical reactions. Germination affects both the ultimate production and quality of a crop. Successful production requires the growth of sturdy, well-developed seedlings, and one of the main goals of seedling production is to produce a viable plant from any single seed. Temperature and water availability significantly affect the biological and biochemical enzymatic activities in germination and seedling growth stages.

Seed priming is a technique that involves soaking seeds in a solution to initiate the germination process before planting. The strategy aims to improve seedling emergence, plant growth, and tolerance to various environmental stresses, including abiotic stresses such as drought, flood, and extreme temperatures. Seeds exposed to abiotic stresses during their development often become dormant and have reduced germination rates. Seed priming can help overcome these challenges by triggering the metabolic processes required for germination before planting. This method enhances the seed's ability to germinate and grow under unfavorable environmental conditions. Seed priming can be an effective method for enhancing plant growth and improving yield under stress conditions. This technique is gaining popularity in agriculture as a sustainable and cost-effective approach to enhancing crop productivity and reducing the negative impact of abiotic stresses on plant growth.

In recent years, significant advances have been made in understanding the mechanisms underlying plant responses to abiotic stresses. Molecular and genomic studies have identified genes and pathways involved in stress sensing, signal transduction, and stress adaptation. Furthermore, physiological and morphological studies have been ongoing to cope with the increased impact of these stresses.

Additionally, plant-microbe interactions have been shown to be important in improving plant tolerance to abiotic stresses.

This dissertation aims to review the current understanding of plant responses to abiotic stresses, focusing on drought and heat stress and novelizing new strategies to face these conditions. This study also focuses on the seed priming technique to enhance germination and plant tolerance in the later stages of wheat and maize life. The study also investigates the role of plant-microbe interactions in improving plant tolerance to abiotic stresses. Drought and temperature stress signaling is an important area concerning increased plant productivity. However, our knowledge of the techniques underlying the responses of plants to such environmental stresses is still somewhat limited.

The findings of this study contribute to a better understanding of plant responses to abiotic stresses and aid in developing novel strategies for improving plant tolerance to adverse environmental conditions. Thus, it is essential to investigate the plant mechanisms of stress tolerance in order to identify novel management components and techniques for enhancing crop resistance and tolerance.

1.1 The Study Importance

Drought, heat, and waterlogging are the three major abiotic factors that may reversely impact the establishment, growth, development, and yield of wheat and maize crops. These crops are primary food sources and are extensively farmed around the globe, improving their resistance to these pressures essential for global food security. However, these abiotic factors can diminish plant growth, agricultural output, and crop failure, affecting food security and farmer income.

Overall, it is impossible to overlook the significance of these abiotic factors on wheat and maize crops. Therefore, it is crucial to develop strategies and technologies to mitigate their effects on crop productivity and quality. Novel agriculture practices can be used to develop management techniques of drought-, waterlogging-, and heat-tolerant, along with agronomic practices, including crop rotation, soil management, and irrigation can also lessen the effect of these pressures on agricultural output.

1.2 The Study Problem

Significant obstacles to the development and productivity of wheat and maize are posed by abiotic factors such as drought, heat, and waterlogging. This research topic aims to comprehend how these environmental stressors impact plants' growth, development, and productivity. Furthermore, as the frequency of severe weather events increases due to global warming, it is crucial to examine the effect of these stresses on plants and their capacity to withstand them.

A water shortage in the soil causes drought stress, which may restrict plant development and reduce agricultural production. Heat stress may wreak havoc on plant tissues and cells, resulting in stunted development and decreased yield. Waterlogging stress occurs when the soil gets saturated with water, restricting the availability of oxygen to plant roots and resulting in decreased growth and yield. These abiotic stressors may lead to decreased crop yields, diminished crop quality, and even crop failure, resulting in economic losses for farmers and threatening global food security. Therefore, developing strategies to mitigate the impact of these abiotic stresses on crop productivity and quality, such as developing drought-, heat-, and waterlogging-tolerant crop varieties and implementing suitable agronomic practices, is essential for ensuring sustainable agriculture and global food security.

2 OBJECTIVES TO ACHIEVE

This study directed to investigate the following objectives:

1. Determining the effect of abiotic stress on wheat and maize seed germination under controlled laboratory conditions, and optimizing the germination, seedlings growth, and antifungal application techniques. A novel technique can be written down and instructed?
2. Investigating the effect of the seed priming technique on enhancing seed germination and plant tolerance in the later stages of wheat life. Could this technique induce tolerance or stimulate certain defense plant mechanisms to different abiotic stresses?
3. Evaluating the effects of abiotic stress on the morphological parameters of plant growth and development, including tillers number, leaf area, and plant height. What are the affected traits and what are the best treatments used?
4. In field trials, determining the influence of abiotic stress on yield and yield components, including grain yield, number of ears per plant, and number of grains per ear in wheat and maize. Can determine the effect of abiotic stress on the yield quantity and quality?
5. Examine wheat and maize's physiological and biochemical responses to abiotic stress, including photosynthesis activity and chlorophyll concentration alterations. Is there a certain agricultural technique may help enhance plant production and environmental resilience by understanding plant response to abiotic stress?
6. Evaluate in-crop nitrogen uptake, assimilation, and mobilization in plants under abiotic stress. Do nitrogen fertilizer application rates, splitting, and timings have an effect on improving nitrogen use efficiency (NUE) and mitigating the reverse effect of abiotic stress on crop productivity? What about the microorganism’s application on mitigating the impact of abiotic stresses?
7. Evaluate the effect of irrigation in different growth stages on yield components, quality, and quantity. Is there any effect of timing and frequency of irrigation throughout growth stages may significantly affect yield components, quality, and quantity?

The primary objective of this study is to provide a comprehensive analysis of the impact of abiotic stress on the growth and development of wheat and maize, while also exploring strategies to improve the resilience of these crops under stressful environmental conditions. Ensuring food security in the context of climate change necessitates the implementation of various management strategies. These strategies encompass optimizing seed germination and emergence, employing seed priming techniques, harnessing the potential of microorganisms, adopting diverse nitrogen application and splitting methods, and implementing varied irrigation regimes.

3 LITERATURE OVERVIEW

It is projected that by the year 2050, there will be a substantial increase of approximately 50% in the worldwide demand for food and various agricultural commodities (FAO, 2017). Nevertheless, the existing agricultural lands are constrained, presenting a formidable obstacle for agricultural production to satisfy this escalating demand. In addition, it is worth noting that global agricultural productivity experiences negative impacts due to various factors, including climate conditions and limitations in soil quality (DAS *et al.*, 2021). Therefore, we must enhance crop management practices to ensure future food security to achieve maximum productivity. In addition, it is anticipated that climate extremes would have a detrimental influence on crop growth and productivity throughout the globe (FAYE *et al.*, 2023; HEGEDŰS *et al.*, 2020). Global warming and climate change have significant implications for crops, including altered temperature patterns, precipitation, and extreme weather events such as droughts, floods, and heat waves (WAKATSUKI *et al.*, 2023). These climate abnormalities can reversely affect crop growth and productivity, leading to food insecurity and decreased agricultural output. Therefore, developing techniques and technology to reduce the impacts of climate change on crops and future generations' food security is crucial.

Wheat is the predominant grain crop and a mainstay source of food for most of the world's population (LIAN *et al.*, 2020; NAGY *et al.*, 2023). This field crop is nutritionally essential globally, ranking second only after maize production (YANG *et al.*, 2021). It is involved in many bakery and pastry industries (BETA *et al.*, 2020). It is commonly utilized to produce flour, malt, and various food products, including bread, pasta, and morning cereals (YANG *et al.*, 2021). Wheat is a primary source of protein and starch, providing 20-30% of daily caloric intake in most societies (LEMMENS *et al.*, 2019). Because of its widespread in many different ecosystems, plants face various abiotic challenges, such as drought and rising temperature, due to global warming, which results in huge yield loss (YAN *et al.*, 2020). While stress circumstances may decrease seed germination percentages, they may also trigger an adaptive response (HERMAN *et al.*, 2012).

Maize is one of the most important crops worldwide, and it is a staple cereal grown globally under a broad spectrum of soil and climatic conditions in temperate and tropical regions (XUE *et al.*, 2021; BOJTOR *et al.*, 2022). It is a nutritional, globally essential cereal crop that ranks first in production ahead of wheat and rice production (YANG *et al.*, 2021). Maize is not only consumed directly in the human diet but is also extensively utilized in biofuels; animal feed; and a wide range of industrial products, including syrup and corn starch (XUE *et al.*, 2021). The grains of maize contain nearly 72% starch, 10% protein, and 4% fat, providing an energy density of 1.53 MJ 100 g^{-1} (WANG *et al.*, 2021a). Maize is a C4 crop species that belongs to the *Poaceae* family, which is moderately sensitive to abiotic stresses, such as drought and temperature. Since it is used worldwide in different ecosystems, the maize crop confronts a wide range of environmental abiotic stresses, including drought and increased temperatures because of climate change, which results in numerous yield losses. Abiotic stress and soil and environmental conditions may reduce the seed germination percentage of maize, meanwhile can cause adaptation to induced stress (WANG *et al.*, 2021a; SZÉLES *et al.*, 2023).

In Hungary, the cultivation of hard winter wheat (HWW) is undertaken for feed and to produce flour, while maize is grown for various purposes. Wheat and maize are widely recognized as the primary cash crops of the state. However, the hard winter wheat typically produced in the region is under the growing climate of Hungary. Recently, with the rise of the locavore (local food) movement, bakers are increasingly interested in a local source of bread flour from high-protein wheat for local bread production. Historically, HWW is grown in Hungary. Commonly, HWW is characterized by high yield. As a result, farmers tended to produce HWW wheat to make almost all baking products bread that favors wheat with favorable protein content. Recently, local Hungarian bakers have been interested in using their bread flour from locally grown wheat. Therefore, a new strategy needs to be taken toward improving nutrients, protein content, plant growth, and plant tolerance to abiotic and biotic factors by using eco-friendly and cost-effective methods such as bio-fertilizer. This creates a significant opportunity for research focused on producing wheat with desirable grain qualities that address other concerns for sustainable production, including using organic and /or eco-friendly methods. One promising strategy for the goals is adopting biofertilizers for sustainable crop production facing the abiotic stress; another is to pre-sow seed priming to induce tolerance strategy; the third is to use different irrigation and agriculture practices to mitigate the abiotic stressors and improve crop productivity and flour quality.

3.1 Abiotic Stressors

Abiotic stress severely threatens agriculture, reversely impacting cellular homeostasis and ultimately stunting plant growth, development, and yield productivity (FADIJI *et al.*, 2023; TÓTH *et al.*, 2022). Moreover, abiotic stressors, including drought and excessive temperatures, are anticipated to occur more frequently due to global warming and climate change, which would diminish the yields of essential crops such as maize and wheat, which could jeopardize food security (FADIJI *et al.*, 2023). The physiology of plants is influenced and altered by many abiotic stresses. Abiotic stress induces many physiological changes in plants, which may be adaptive responses to the surrounding environment (ZHANG *et al.*, 2022). These alterations may include germination, growth, developmental transition, shoot architecture, and crop yield quality and quantity. Examples of abiotic stressors include drought, waterlogging, and excessive heat or cold that induce stress (DAS *et al.*, 2021). In addition, plants may use a range of defensive mechanisms to defend themselves against the harmful effects of these abiotic variables, including the generation of osmolytes, alterations to their root architecture, and an increase in antioxidant production. However, severe abiotic stress that endures for a lengthy period may still significantly impact the growth and production of plants (ZHANG *et al.*, 2022; KISS *et al.*, 2021).

Subsequently, plants are frequently exposed to a wide range of environmental stressors, including drought, temperature, and waterlogging, which significantly reverse crop production worldwide. As a consequence of global climate change and other abiotic stresses, the Food and Agriculture Organization estimated in 2016 that the yields of the main cereal crops would fall by 20–45% for maize, 5–50% for wheat, and 20–30% for rice by the year 2100 (FAO, 2016). Abiotic stressors' direct and indirect effects exponentially negatively affect agricultural productivity. The safety of the world's food supply is in jeopardy as a result of both the tremendous climate changes that are now occurring throughout the planet and the immense population growth that is occurring worldwide (LESK et al., 2016). To satisfy the needs of a growing population, it is vital to increase the resistance of crops to abiotic stressors and novel agriculture practices to cope with these changes and to provide a high agricultural yield under adverse environmental conditions (PEREIRA, 2016; GYŐRI *et al.*, 2023).

3.1.1 The Combined Impact of Abiotic Stresses on Crop Plants

The physical surroundings in which plants undergo growth and development exhibit ongoing variations. The growth and maturation of a plant necessitate the presence of water, mineral nutrients, light energy, and carbon as its principal constituent (KHAEIM, *et al.*, 2022; FÁBIÁN, *et al.*, 2022). Many environmental conditions, including drought, salt, radiation, extreme temperature, water floods, and nutritional shortage, may have a detrimental influence on the development and growth of plants (KUL *et al.*, 2020). An example of combined abiotic conditions that affect a plant's performance is extreme temperatures, insufficient water, soil nutrients, salinity, and excessive light (ZHANG *et al.*, 2022). Nearly half of all agricultural land on the planet is badly affected by salinity and drought conditions concurrently (ABDELRAHEEM *et al.*, 2019). Therefore, plant scientists have been interested in investigating the abiotic stress responses of crop plants. Both reversible and permanent changes may occur in the manner in which plants react to abiotic factors (ZHANG *et al.*, 2022). Investigations of plant abiotic responses at the biochemical, physiological, and molecular levels indicate a complex biological reaction to environmental stresses. In addition, the severity of the response may be substantially affected by the length of the stress and its intensity, whether the stress is acute or chronic (ZHANG *et al.*, 2022). Abiotic factors reversibly affect plant production's physiological, biochemical, and morphological activities (YADAV *et al.*, 2020; KŐRÖSI, *et al.*, 2021).

Drought stress exerts a detrimental impact on all phases of plant growth and development in a reverse manner (ABDELRAHEEM *et al.*, 2019). Water deficiency significantly affects photosynthesis and respiration, which restrains plant growth. All cellular activities were halted by low-temperature stress that decreased electrolyte leakage, plasmolysis, and protoplasmic streaming (YADAV *et al.*, 2020). In addition to causing osmotic stress, drought, and salinity induces ionic toxicity, which is linked to nutrient availability and oxidative damage.

The combined effects of abiotic stressors can alter numerous physiological processes in plants, such as photosynthesis and nitrogen fixation. These alterations ultimately lead to a reduction in crop production (FAROOQ *et al.*, 2015). Moreover, stress-induced damage decreases the plant's ability to withstand further stress, leading to nutritional imbalances and decreases in water and leaf osmotic potential. This can result in various physiological reactions, such as reduced leaf area and transpiration rate disturbance (REDDY *et al.*, 2021). Drought stress, in particular, can lead to a decrease in turgor pressure, which is an essential physiological process impacting cell growth (YADAV *et al.*, 2020). As a result, drought stress can cause stretched cells, weak mitosis, and stunted plant growth, among other detrimental impacts (ISMAIL *et al.*, 2021).

As a defense mechanism against drought, plant cells mobilize metabolites to alter their osmotic balance (GULL *et al.*, 2019). Osmotic adjustment may help mitigate the detrimental effects of stress by ensuring that cellular water equilibrium is maintained (ZHAO *et al.*, 2021). Plant growth and development are stymied when cold stress causes cells and tissues to dry up and crystallize (BAHAR *et al.*, 2021). Water scarcity initially lowers respiration, followed by a photosynthetic activity, before slowing growth. Due to the vital nature of the freshly divided cells surrounding the xylem, these cells restrict the plant's growth zones. The development and growth of plants are affected by high temperatures and the stresses linked to drought, which may eventually lead to plant mortality (HUSSAIN *et al.*, 2019). During reproduction, high-temperature stress can cause cells to be nonfunctioning (GULL *et al.*, 2019; CSEUZ, *et al.*, 2019).

Many molecular and intercellular pathways cross-talk and interact with one another during the plant's reaction to abiotic stressors. ROS and RNS (reactive nitrogen species) are significantly crucial as different abiotic stress responses, such as the control of gene expression and the activity of enzymes (BAILLY, 2019). In reaction to ROS, plant cells engage in several responses, such as boosting the expression of genes, creating stress proteins, and activating antioxidant enzymes (BAILLY, 2019). Abiotic stress is mitigated by genes that induce detoxification, such as ascorbate peroxidase. Hormones, like abscisic acid and ethylene, among others, may also regulate abiotic stress reactions in plants (YAN *et al.*, 2020). Abscisic acid, often known as ABA, is a critical component of several plant species' osmotic stress defense systems. The development, germination, and defense processes are examples of delayed ABA responses. Different pathways are involved in transmitting cold stress signals, involving ROS, protein phosphate, Ca^{2+}, and ABA; nevertheless, ABA seems to be the most effective of these systems (GULL *et al.*, 2019). When a seed is dehydrated, it endures a period of water stress that causes very high levels of late embryogenesis abundant proteins, often known as LEA, to accumulate during early embryogenesis (GULL *et al.*, 2019). In addition to its role in ozone and drought, ethylene contributes to cold, UV radiation exposure, and floods (FADIJI *et al.*, 2023).

3.1.2 Drought Stress

The average global temperature and the amount of carbon dioxide in the atmosphere are steadily rising, which has resulted in widespread alterations to the planet's climate (GULL *et al.*, 2019; Csajbók *et al.*, 2014). Climate change and global warming have resulted in a distribution of precipitation, which contributes to a major source of stress in the form of drought (FAYE *et al.*, 2023). Due to the severe drought circumstances, the quantity of plant-accessible soil water has been steadily increasing, resulting in the premature mortality of plants. After being exposed to drought, the agricultural plants' initial reaction is to stop growing, which is the first response subjected to the plants. In drought, plant development of new shoots and the metabolic processes required by the plant decrease. Following this, drought-stricken plants synthesize defensive compounds by mobilizing the metabolites necessary for osmotic adjustment (GULL *et al.*, 2019).

The reduction in accessible water is one of the most prominent impacts of drought stress on agricultural plants, which may hinder photosynthesis, nitrogen absorption, and other critical physiological processes (FAYE *et al.*, 2023). Many studies have investigated the effects of drought stress on several crops, including wheat and maize. For instance, BOUARD and HOUDE (2022) examined the impacts of drought stress on wheat and found that it led to a decline in yield, grain weight, and protein content. In a similar line, BHEEMANAHALLI *et al.* (2022) discovered that drought stress influenced the growth, yield, kernel weight, and ear length of maize. Adopting drought-resistant cultivars, improved water management practices, and applying plant growth regulators and other biostimulants have all been recommended to reduce the harmful effects of drought stress. For instance, NADERI *et al.*, (2022) investigated the effects of applying a biostimulant to drought-stressed wheat plants and found that it increased photosynthetic activity and yield. Similarly, Zhang, *et al.* (2015) discovered that drought stress on maize yields might be alleviated by modifying irrigation management practices.

There exist three discrete categories of mechanisms that confer resistance to drought (MITRA, 2001): drought escape, drought tolerance, and drought avoidance. However, agricultural plants use many mechanisms simultaneously to withstand dryness (AGARWAL *et al.*, 2013). The capacity of a plant to complete its life cycle before the development of severe soil and plant water deficiencies is the definition of drought resistance. It is characterized by rapid early blooming and maturity, developmental flexibility, and the remobilization of pre-anthesis assimilates to grain (CHENG *et al.*, 2021).

Drought tolerance refers to the ability to withstand a scarcity of water while maintaining a relatively low tissue water potential (ZHAO *et al.*, 2021). Their drought tolerance is determined by the reactions of plants to tissue water deprivation. The mechanisms of drought tolerance include osmotic turgor maintenance, increased cellular flexibility, reduced cell size, and protoplasmic resistance for desiccation tolerance (CHENG *et al.*, 2021). Osmotic adjustment promotes drought tolerance by maintaining plant turgor. However, the higher solute concentration responsible for osmotic adjustment may have a negative consequence in addition to requiring energy for osmotic adjustment (ALIAKBARI *et al.*, 2021).

The capacity of plants to retain a reasonably high tissue water potential despite a lack of soil moisture called drought resistance (HOSSEINI et al., 2021). Techniques for enhancing water absorption, storing water in plant cells, and minimizing water loss provide drought resistance. For example, maintaining turgor through increased rooting depth, an efficient root system, and increased hydraulic conductance, as well as reducing water loss through decreased epidermal conductance, reduced absorption of radiation through leaf rolling or folding, and decreased evaporation surface, prevents drought (CHENG *et al.*, 2021).

A delicate balance between maintaining turgor and minimizing water loss allows plants to endure dry conditions (BASHIR *et al.*, 2016). Nevertheless, the majority of these drought adaptations have downsides. For example, the processes that give drought tolerance by decreasing water loss, including stomatal closure and decreased leaf area, often result in diminished carbon dioxide absorption (CHENG *et al.*, 2021).

In addition to absorbing water and nutrients, anchoring the plant to the soil, and establishing biotic interactions in the rhizosphere, plant root systems conduct a number of vital adaptive activities (KHAEIM *et al.*, 2022). When plants are exposed to low water potential, leaves and stems develop more slowly (HAJ SGHAIER *et al.*, 2022). In contrast, roots may grow at low levels that prevent shoot development (KHAEIM *et al.*, 2022). As prolonged root extension improves water absorption from the soil, this differential response of roots and shoots toward the low water potential is considered an adaptation of plants to endure dry circumstances (YADAV *et al.*, 2020; He *et al.*, 2022).

The initial phases of drought exert a greater impact on the vegetative system in comparison to the root system (KHAEIM, *et al.*, 2022). Hence, the presence of drought conditions exerts an influence on the relationship between the carbon content found in photosynthetic organs, such as leaves, and heterotrophic organs, including roots and seeds, across different species. As a result, the processes associated with carbon allocation become vulnerable to the effects of drought stress, as stated by PAUL, (2016). These alterations result in the failure of reproductive structures and a decline in biomass accumulation in storage organs, ultimately leading to reduced crop yields, according to KHAN *et al.*, (2023).

Gaining a comprehensive understanding of the physiological impacts of drought stress on plants is imperative in order to devise effective strategies for mitigating its adverse effects on crop productivity. Furthermore, the development of drought-resistant cultivars and the enhancement of water management practices are crucial in order to devise innovative strategies for crop management in diverse environmental circumstances.

3.1.3 Temperature Extremes

Temperature is the most influential environmental element in plant growth and development globally. Low and high temperatures are considered the most significant environmental stressors for plant growth (CRAFTS-BRANDNER and SALVUCCI, 2002). Changes in the global climate have increased the incidence and frequency of temperature extremes; thus, these stressors are becoming the primary focus of plant scientists worldwide. Both of these pressures severely affect plant metabolism, development, and growth. From the beginning of the industrial revolution, the average global temperature has been rising at a pace of 0.15 to 0.17 °C every decade.

Consequently, the temperature affects agricultural crop yields (KHAN *et al.*, 2021). Thus, thermotolerance measures are required to ensure agricultural output sustainability at increased temperatures. Nevertheless, enhancing the plant's thermotolerance is difficult for agricultural experts. As indicated by the international panel on climate change (IPCC), the global temperature has climbed by around 1.5 °C since the 1970s, with the same accelerating trend in all areas, and is expected to rise by between 2.5 and 5.8 °C by 2100 (IPCC, 2014; EICKEMEIER *et al.*, 2019). Furthermore, from the 1880s and 1970s, the average annual global temperature has grown by 0.04–0.07 °C and 0.15–0.17 °C each decade, respectively, according to the National Oceanic and Atmospheric Administration (KHAN *et al.*, 2021). Thus, global warming, characterized by high temperatures, poses the challenge of maximizing agricultural productivity.

The optimal temperatures for plant growth, development, and reproduction exhibit variation across different species, as the processes of plant growth and development are temperature-dependent (KHAEIM *et al.*, 2022). Wheat is an important staple food, the cheapest energy source of 8–20% of protein and 70–75% of calories in the usual diet (DAY, 2013; VARGA *et al.*, 2021), but a high temperature prevents the wheat crop from expressing its full genetic potential. Thus, it is of the utmost importance to comprehend the wheat's sensitivity to high temperatures and to devise an appropriate approach to increase its output. The optimal range for wheat seed germination is 20 °C with a prolonged range till 15 °C (KHAEIM *et al.*, 2022). 16 ± 2.3 °C, 23 ± 1.75 °C, and 26 ± 1.53 °C, respectively, are the optimal temperatures for wheat development during the heading, anthesis, and grain-filling phases (KHAN *et al.*, 2021). The high temperature negatively affects crops' phenology, growth, and development (HAJ SGHAIER *et al.*, 2022). High temperatures before anthesis inhibit pollen viability, seed production, and embryo development (BALLA *et al.*, 2011). The high temperature after anthesis reduces the formation of starch granules, stem reserve carbohydrates, and the transfer of photosynthates into grains (POUDEL *et al*., 2019). Temperatures exceeding 40 degrees Celsius restrict photosynthesis by causing damage to photosystem I, photosystem II, and the electron transport chain (KHAN *et al.*, 2021).

High temperature impacts wheat production in tropical, subtropical, arid, and semi-arid parts of the globe. (HAYES *et al.*, 2020). During the germination and early development phases, the high temperature in tropical regions is an unavoidable limitation for wheat, but in the Mediterranean area, the reproductive stage is very responsive (AKTER and RAFIQUL ISLAM, 2017). Wheat yield in Asia is reduced by 10–50% when grain filling occurs at temperatures 3–4 °C above the optimal temperature (HUSSAIN *et al.*, 2018). Depending on the wheat type, a decrease of 0.07% per degree

Celsius in grain production is caused by high temperatures (KHAN *et al.*, 2021). Each degree of rise in grain-filling temperature affects wheat production by 6% worldwide and 3–17% in South Asia, including India and Pakistan (ASSENG *et al.*, 2014). It is attributed directly or indirectly to the disruption in several cellular, physiological, and metabolic networks connected with wheat grain yield (KHAN *et al.*, 2021).

Wheat bread's protein quality, quantity, and glutenin content impact its backing quality (LABUSCHAGNE *et al*, 2016). High temperature increases the overall protein content but decreases the quality of the protein used in the final product (LABUSCHAGNE *et al.*, 2016), which is dependent on the grain protein concentration. High temperature during grain filling reduces albumin and globulin levels while increasing gliadin levels at the cost of glutenin levels in wheat (NUTTALL *et al.*, 2017). In addition, high temperature raises the protein content but decreases the formation of glutenin, sedimentation index (BALLA *et al.*, 2011; KHAN *et al.*, 2021), and critical amino acids such as lysine, methionine, and tryptophan, which regulate the viscoelastic characteristics of wheat bread (NUTTALL *et al.*, 2017).

Daytime and nighttime temperatures must vary for optimum maize growth and development throughout the growing season. The ideal temperature ranges from 25 to 33 °C during the day and from 17 to 23 °C at night; the average optimal temperature for the whole growing season is 20–22 °C (WAQAS *et al.*, 2021). Therefore, maize plants germinate optimally at 25–28 °C (FAROOQ *et al.*, 2008). The reproductive phase is particularly vulnerable to suboptimal and excessive temperatures. A deviation from the ideal temperature, which causes high-temperature stress, considerably reduces the development rate and grain production by reducing the seed setting ratio and disrupting various physiological processes (WAQAS *et al.*, 2021). Therefore, maize plants germinate optimally between 25–28 °C (FAROOQ *et al.*, 2008).

The leaf growth of maize grows at temperatures between 10 and 35 °C but begins to decline at temperatures beyond 35 °C (KHALID *et al.*, 2021). Temperatures between 33 and 36 °C diminish the CO_2 exchange rate by approximately 17%, crop growth rate by 17–29%, grain number 7–45%, and grain yield by 10–45% in maize pre- and post-flowering regimes, respectively (NEIFF *et al.*, 2016). During blooming, high temperatures have a deleterious impact on the number of florets, silks, and grains (RATTALINO EDREIRA *et al.*, 2011). Over 35 °C, maize ovary fertilization and grain filling are inhibited, directly related to the final grain yield (WAQAS *et al.*, 2021). Heat stress shortens the tasselling and pollen release duration and lengthens the anthesis-silking interval to lower pollen viability and quantity (WAQAS *et al.*, 2021). In addition, heat-stressed maize plants cannot convert photosynthates into starch in the pollen. Consequently, reducing pollen quantity, viability, and starch synthesis contributes to distorted fertilization (WANG *et al.*, 2019). Heat stress produces leaf fire, tassel blast and sterility, and senescence in tropical maize, resulting in decreased output (ALAM *et al.*, 2017).

Heat stress during the reproduction of maize causes silk desiccation, pollen sterility, and poor seed setting, reducing yield (SÁNCHEZ *et al*., 2014). Heat stress reduces reproductive phase productivity, grain number, and weight (NEIFF *et al.*, 2016). When the daytime temperature was 35 °C, waxy maize yields dropped by 31% due to lower grain number and weight (YANG *et al.*, 2017). A plant's defense system uses phenotypic plasticity to avoid heat stress, which shortens grain filling (WAQAS *et al.*, 2021). The maize plant only grows faster endosperm at higher day- and nighttime temperatures (WAQAS *et al.*, 2021), indicating that heat stress depends on the time of day and the degree of stress.

Low-temperature stress during grain filling may diminish amylose content, reducing water solubility, swelling power, and rising gelatinization temperatures (CICCHINO *et al.*, 2010). The photosynthetic system, sucrose phosphate synthase, and phosphoenolpyruvate carboxylase slow down at temperatures below 15 °C in the late reproductive stage (LU *et al.*, 2014). Low temperature at the stage of germination either prevents or delays germination. A temperature of around 10 °C delay germination, and lower than 5 °C prevent seed germination of maize (KHAEIM *et al.*, 2022).

3.2 Seed Germination

Germination is a physiological process that initiates and develops a seedling by triggering a cascade of biological and biochemical reactions (POUDEL *et al*., 2019). In the early stages of germination, known as imbibition, seeds absorb water rapidly, causing the seed coat to expand and soften at optimal temperatures (FU et al., 2021). Next, the seed's inner physiological activities are activated, and the seed's respiration starts (BENTSINK and LEÓNIE, 2008). Finally, the broken seed coats allow for the initiation of radicles and plumula. Therefore, it starts with water uptake by the quiescent dry seed and is accomplished by radicle emergence through elongation of the embryo axis (MASUBELELE *et al.*, 2005). This process involves a series of organized physiological and morphogenetic processes, including seed energy transfer, endospermic nutrient ingestion, and physiological and metabolic alterations (ITROUTWAR *et al.*, 2020). The primary indications of germination are restoring critical activities, such as transcription, translation, and DNA repair, followed by cell elongation and division (SHAH *et al.*, 2019).

Germination affects both the ultimate production and quality of maize (XUE *et al.*, 2021). Fundamentally, plants grow from a single seed into a plant (LARA-NÚÑEZ *et al.*, 2021). Germination is controlled by the interplay of environmental factors, the physiological status of the seeds, and the germ (MCCORMICK *et al.*, 2016). The need for the various abiotic factors depends primarily on the genotype in response to these surrounding abiotic factors and these abiotic factors as a collective (FU et al., 2021). Maize germination requires favorable environmental conditions, and a specific range of these factors is necessary for optimal germination (CHIU *et al.*, 2012). Conditions including temperature, light, and water availability influence germination (RIZZARDI *et al.*, 2009). The seeds' physiological reaction to overlapping extrinsic abiotic factors determines propagation success; thus, seed germination reflects population size, distribution, and abundance (MCCORMICK *et al.*, 2016). Germination does not need these abiotic variables individually since the demand for one component is dependent on the requirement of another, as shown for light overlapping temperature (PRERNA *et al.*, 2021).

Successful production requires the growth of sturdy, well-developed seedlings, and one of the main goals of seedling production is to produce a viable plant from any single seed (MIRANSARI and SMITH, 2014). The availability and mobility of endosperm storage resources are essential determinants in the seedling establishment (DENG *et al.*, 2016). Enzymatic activity is required for endospermic-reserved carbohydrates and lipid degradation to mobilize conserved resources during germination and early seedling growth (KHALID *et al.*, 2021). Temperature and water availability significantly affect the biological and biochemical enzymatic activities in germination and seedling growth stages (PRERNA *et al.*, 2021).

Temperature is one of the most necessary factors for seed germination, and it affects all individual reactions and stages of germination (PRERNA *et al.*, 2021). The cell energy status and some enzymes' activity (e.g., lipase, alanine aminotransferase, aspartate aminotransferase, and especially ribonuclease) change as the temperature increases and the ATP content rises (KHALID *et al.*, 2021). The rate of protein synthesis decreases as the temperature level increases (GONG *et al.*, 2001a). Temperature stress enhances the transcription, translation, and activity of ROS-scavenging enzymes in maize, resulting in the buildup of H_2O_2 (GONG *et al.*, 2001a). The optimum temperature results in germination in the shortest time possible (DADACH *et al*., 2015). Since germination involves several stages, each has its cardinal temperature scale; the temperature response can differ during the germination period because of its complexity (DADACH *et al*., 2015). The temperature reaction of a seed depends on variety, seed quality, the length of time after harvest, and some other factors (ANDRONIS *et al.*, 2014). During germination, temperature changes significantly impact respiration rate and sugar metabolism. The homeostasis of reactive oxygen species (ROS) necessary for seed germination is disrupted by abnormal respiration (DADACH *et al*., 2015). Temperature plays a significant role in specifying seed germination duration, which means the time from subjecting a seed to water to the initiation of germination (B. GUAN *et al.*, 2009).

Water is necessary to hydrate protoplasmic metabolism activities, provide dissolved O_2 to the seed embryo, soften the seed's outer coat, and improve seed permeability (PRERNA *et al.*, 2021). Water aids in the rupturing of the seed and converts the insoluble endospermic-stored materials into soluble status through enzyme activation, breakdown, and translocation and reserving storage materials in the endosperm and then translocating them to the growing embryo (KHALID *et al.*, 2021). Water contributes to the subsequent germination metabolic stages, and its level has more complicated effects on germination (CRAFTS-BRANDNER *et al*., 2002). Water stress lowers enzymatic activity, which has a detrimental impact on carbohydrate metabolism, decreases water potential and soluble calcium and potassium, and alters the hormones of seeds (CRAFTS-BRANDNER *et al*., 2002). Maize seeds are described as being low in moisture and metabolically dormant in their quiescence state. Therefore, the seeds may retain minimal metabolic activity during storage to ensure long-term survival (ADEROUNMU *et al*., 2020).

Since wheat and maize are used worldwide in different ecosystems, the maize crop confronts a wide range of environmental abiotic stresses, including drought and increased temperatures because of climate change, which results in numerous yield losses (WANG *et al.*, 2021b). Abiotic stress and soil and environmental conditions may reduce seed germination percentage meanwhile can cause adaptation to induced stress (PANGAPANGA-PHIRI and MUNGATANA, 2021).

3.3 Pre-Sowing Seed Priming

Pre-sowing seed priming is an efficient and straightforward way to confer stress tolerance to plants (SEN and PUTHUR, 2020; JANDA *et al.*, 2022). Before sowing, seed priming involves priming the seeds in water with or without chemical, hormonal, and biological substances, followed by drying. Priming, and hydrating seeds, reduce the effect of environmental challenges via improved crop establishment, resulting in greater agricultural yields. Seed priming alleviates abiotic stress by using many mechanisms, including early mobilization of seed-stored materials, elongation of embryo cells, and endosperm weakening, which boost the pre-germination metabolic processes, resulting in a uniform and high germination rates (SAHA *et al.*, 2022). Stress before germination induces stress memory in seeds, enabling the seeds to adapt to the stress in their environments (WANG *et al.*, 2022). Priming promotes stress-responsive genes and ultimately accelerates the induction of resistance. In addition, it induces the creation of jasmonate-linked defensive responses by increasing the gene expression of transcription factors and critical signaling proteins, resulting in epigenetic modifications and the activation of defense mechanisms (RAJORA *et al.*, 2022).

Priming has a crucial role in enhancing germination and development in a range of crops exposed to diverse abiotic stresses (SAHA *et al.*, 2022). It stimulates several stress-responsive genes, allowing for quicker germination and increased tolerance to abiotic stress. Seed priming enhances the pace, proportion, and consistency of germination or seedling emergence despite poor environmental circumstances (FATHI *et al.*, 2023). Seed germination rate and seedling establishment play significant roles in agriculture, particularly under stressful situations. Moreover, it includes the upregulation of proteins and genes involved in cell division, cytoskeletal remodeling, RNA expression, reserve mobilization, oxidative stress response, water transporters, and DNA and membrane repair (WANG *et al.*, 2022). Priming inhibits the formation of reactive oxygen species and promotes cross-tolerance to abiotic stressors through activating enzymes and osmotic adjustment. This stress tolerance approach acts as a "priming memory" that reactivates after stress exposure and enables plants to respond more effectively to further stress tolerance (SAHA *et al.*, 2022). The activation of a genetically programmed defensive response and a priming-related signaling network occurs in response to stress (SEN and PUTHUR, 2020).

Priming seeds is a simple, low-cost, and low-risk approach for promoting the growth and development of plants, particularly in situations when the environment is not optimal for plant growth. Several priming techniques for seeds and seedlings include hydropriming, osmopriming, chemical priming, hormone priming, biological priming, redox priming, and solid matrix priming, among others (SEN and PUTHUR, 2020). The efficacy of various priming chemicals relies on the kind of agricultural plant and environmental stressors (BENADJAOUD *et al.*, 2022). Seed priming often includes using several different chemicals, including NaCl, KNO_3, KCl, and $CaCl_2$ (FAROOQ et al., 2006).In recent years, non-protein amino acids such as gamma-aminobutyric acid (GABA) have been used to primate seeds for various crops to protect them against biotic and abiotic stress(JISHA and PUTHUR, 2016).

This study was conducted in part to examine the impact of seed priming with plant growth regulators of gibberellins (GAs) and salicylic acid (SA) on the abiotic stress tolerance of wheat to drought. In addition, it investigates the morphological, physiological, and yield quality and quantity changes of primed and non-primed wheat plants exposed to unstressed and stressed conditions at different levels of drought.

Gibberellic acid, $C_{19}H_{22}O_6$, is a growth-stimulating plant hormone. It changes the distribution of hemicellulosic fibrils found in cell walls by increasing their flexibility and decreasing their stiffness, hence facilitating the proliferation of cells (ZHOU and UNDERHILL, 2016). Gibberellic acid acts to raise the cell's contents, which leads to an increase in the cell's tumescent and osmotic pressure as well as an increase in the cell's water intake, causing the cell to expand (KANG *et al.*, 2015). GAs functions in germination via two processes: decreasing the mechanical resistance of the exterior tissues surrounding the embryo and enhancing the embryo's development and growth capacity (KANG *et al.*, 2015). Gibberellic acid functions in water absorption and cell division, which leads to a rise in their growth by increasing their protoplasmic content and, therefore, the plant's surface area and size (CHEN *et al.*, 2022).

Throughout seed development phases, gibberellic acid inside the seed naturally diminishes the lateness and the inhibitory influence imposed by abscisic acid (CHEN *et al.*, 2022). In addition, gibberellic acid and auxin have a synergistic function in producing enzymes that break down the cell wall (EL HAMDAOUI *et al.*, 2021). Gibberellic acid is a critical substance in seed germination. GAs resists salts and reduces the harmful effects of stress. Phytohormones have a crucial role in adapting plants to withstand biotic and abiotic stressors and are thus crucial elements in sorghum plants' tolerance (TOH *et al.*, 2008).

GAs is implicated in the adaptation response to abiotic stressors, including cold, salt, heat, floods, and drought (KANG *et al.*, 2015). Nonetheless, the significance of GAs in response to drought stress remains unclear. Under drought circumstances, GAs levels in maize and wheat decrease (GAION *et al.*, 2018). In addition, applying GAs might restore plant development under stressful circumstances, resulting in increased growth and maintenance of photosynthesis and decreased oxidative stress (GAION *et al.*, 2018). On the other hand, a number of studies indicate that lower sensitivity of GAs may result in increased tolerance to water stress. For example, wheat Rht8, Rht-1b, and Rht-D1b mutants with decreased GAs sensitivity were more drought tolerant than wild-type ones (ALGHABARI *et al.*, 2016). Unfortunately, little is known about the role of GAs signaling in root-to-shoot communication to coordinate growth and development at the whole-plant level in response to drought stress.

Salicylic acid is a naturally occurring phenolic molecule that controls plant growth and development and reacts to biotic and abiotic challenges such as drought and low temperature (RASKIN, 1992). Salicylic acid enhances plant stress tolerance by altering reactive oxygen species, proline, and hormones in drought-stressed plants (HONGNA *et al.*, 2021). Salicylic acid priming increased the capacity to scavenge reactive oxygen species by promoting antioxidant enzyme activities and also altered the distribution of plant hormones, proline production, nitrogen assimilation, and photosynthesis, thereby protecting the wheat plant from abiotic stresses (HONGNA *et al.*, 2021). It is regarded as an exogenous addition with considerable agronomic potential for enhancing plant stress tolerance; however, it is seldom employed as a seed priming agent. The application effects of SA as a priming agent were primarily investigated using omics measurements on seeds. Salicylic acid boosts seed vigor by assuring the quality of protein translation, priming the seed metabolism, stimulating the production of antioxidant enzymes, and encouraging the mobilization of seed storage proteins (RAJJOU *et al.*, 2006). Salicylic acid enhances the germination of Limonium bicolor seeds under salt stress by upregulating the expression of critical genes involved in GAs biosynthesis (HONGNA *et al.*, 2021). In addition, the application dose of salicylic acid has varying impacts on plants. In general, moderate amounts of salicylic acid may increase the antioxidant activity of plants, but large quantities of salicylic acid may induce cell death due to their vulnerability to abiotic stressors (KILIÇ, 2023).

Growth and yield parameters are going to be studied to understand the pre-sowing seed priming role in the effect of the stressors to answer the following questions:

I. Seed germination and seedling growth stage are the most sensitive to stress. How do they respond?
II. The effect of temperature and different drought levels on tillering and shooting stages are the most important in the final yield contribution. In which direction will they be affected? Positively or negatively?
III. Will seed priming stimulate early seedling metabolic processes and provide faster and synchronized germination?
IV. Will seed priming develop different defense mechanisms in seeds against stresses?

V. Compare different sorts of priming factors that affect stress tolerance in primed seeds.

VI. Are plants produced from stimulated seeds generally characterized by early emergence of seedlings and more significant numbers, with solid abundance, flowering, and ripening early, and often giving a higher yield than plants obtained from non-stimulated seeds?

Studying the physiological and biochemical changes related to priming with GAs and SA provides essential information on the plant metabolic processes, which may be necessary for plants to combat stress.

3.4 Effective Microorganisms

Beneficial microorganisms, effective microorganisms (EM), play crucial roles in abiotic stress mitigation in agricultural plants by diminishing oxidative stress, generating plant hormones, modulating signaling pathways, and enhancing nutrient and water intake, resulting in increased crop yield (SHANMUGAM, 2022; SZALAI et al., 2023). Even though biofertilizer application is a remarkable practice, formulations with a consistent effect under field circumstances pose a substantial barrier to its widespread adoption. Optimal formulations based on plant-beneficial microorganisms should permit the delivery of dormant and metabolically active bacteria to crops under key abiotic challenges, including drought, salt, heat, and cold stress (SHANMUGAM, 2022).

In recent years, several effective attempts have been undertaken to at least partly replace synthetic agrochemicals with natural molecules to mitigate their harmful effects and the effect of abiotic stresses (HU and QI, 2013). HIGA (1991), who extracted several helpful bacteria from the soil and termed them effective microorganisms (EM), discovered one successful case. Over 80 microorganisms, including photosynthetic bacteria, lactic acid bacteria, yeasts, actinomycetes, and fermenting fungi such as *Aspergillus* and *Penicillium*, are present in EM (HU and QI, 2013). Effective microorganisms may boost crop development and output by improving photosynthesis, creating bioactive chemicals such as hormones and enzymes, regulating soil illnesses, and speeding the degradation of lignin components in the soil (KINATI *et al.*, 2022).

Many researches revealed that applying EM boosted crop growth and production (HIGA, 1991; HU and QI, 2013; KINATI *et al.*, 2022). Nevertheless, there were contradictory findings on the impact of EM application on crop growth and yield (DAISS *et al.*, 2008). The influence of EM on crop growth, yield, and/or quality is often not noticeable (DAISS *et al.*, 2008). Unfortunately, these researches only examined the influence of EM on crop development and production for a single growing season. Many investigations have shown that these limitations may be solved by applying beneficial microorganisms periodically and repeatedly (FADIJI *et al.*, 2023). Unfortunately, few studies have examined the impact of EM treatment on crop development and output during abiotic stresses.

Plant-associated microorganisms frequently promote plant health and growth through a variety of plant growth-promoting mechanisms, including improvement of mineral solubility (LEMANCEAU *et al.*, 2017); altering the signaling of phytohormones such as auxin, cytokinin, and gibberellin (SPAEPEN and VANDERLEYDEN, 2023); and directly supplying nutrients (FADIJI *et al.*, 2023). Researchers are interested in using plant-associated microbes in agriculture because they affect plant physiological parameters under abiotic stress conditions and promote plant growth and tolerance to abiotic pressures (HIGA, 1991; HU and QI, 2013; KINATI *et al.*, 2022; FADIJI *et al.*, 2023).

Biofertilizers or microbial inoculants can generally be defined as a composition that contains living or latent cells of efficient strains of nitrogen-fixing or phosphate-solubilizing microorganisms applied to seeds, soil, or plants to increase the benefit of the microbial community role in the agroecosystem in enhancing the availability of nutrients. The biofertilizers can be applied alone or in combination (BORASTE et al., 2009).

Biofertilizers also have the potential to preserve the productivity and sustainability of soil resources and could be considered as alternatives to chemical-based fertilizers that may cause a severe threat to human health and the environment (REDDY *et al.*, 2021; NADERI *et al.*, 2022). Furthermore, chemical fertilizers are fossil fuel based; thus, their price fluctuates depending on non-renewable resources. Consequently, there is a global trend toward using biofertilizers as they have a longer-lasting impact on nutrient availability than chemical fertilizers.

In this regard, MOHAMMADI and SOHRABI (2012) reported that soil infertility is the essential constraint limiting crop yield worldwide, especially for farmers with limited resources. Therefore, maintaining soil quality can play a crucial role in reducing the problems of land degradation, decreasing soil fertility, and rapidly declining production levels in large parts of the world that need the basic principles of good farming- practices. Furthermore, SHARMA *et al*., (2016) mentioned that beneficial microorganisms could increase the amount of plant growth by direct or indirect mechanisms via the secretion of vitamins and amino acids, auxin, and fixing atmospheric N by *Bacillus, Azotobacter,* and *Azospirillum*. Moreover, biofertilizers significantly reduce the application of chemical nitrogen fertilizers and decrease the environmental pollution output, such as those resulting from nitrogen losses (volatilized or leaching). Therefore, increasing attention has been paid to biological nitrogen fixation (BNF) to meet the N requirements and improve soil fertility to sustain crop yield (CANBOLAT *et al.*, 2007).

A study was conducted by ESMAILPOUR et al., (2019) to investigate the effects of livestock manure, chemical nitrogen, and *Azotobacter* on yield and yield components of wheat. They found a significant impact on the characteristics of growth, yield, and biological yield by a rate of 9% in wheat when all the three mentioned fertilizers above are combined, also benefiting from decreasing the amount of chemical fertilizer in case it was added alone. Correspondingly, MEENA *et al.* (2021) conducted a field experiment in Uttar Pradesh, India, to investigate the effect of using a different type of biofertilizer on the growth and productivity of wheat. They indicated a similar trend of a considerable increase in plant height over all the treatments when they applied combined biofertilizers and the same increases in yield components. Furthermore, inoculation of *Azospirillum* and *Azotobacter* has increased N supply through BNF in rice-based cropping systems in an organic environment (MEENA *et al.*, 2021).

Research conducted in the United Kingdom to quantify the effect of microbial uses on crop productivity showed the possibility of enhancing various plant growth mechanisms and improving crop productivity via mixing different types of soil organisms (DODD *et at.,* 2012). In this regard, a formulation of a microbial consortium, which they developed from mixtures of microbial isolates containing particular groups of bacteria, fungi, and yeast, which are *Pseudomonas* fluorescens, *Pseudomonas striata*, *Bacillus polymyxa*, *Bacillus subtilis*, *Azospirillum*, *Rhizobium*, *Azotobacter*, *Trichoderma viride*, *Saccharomyces cerevisiae,* and nutrients. This formulation produced a strong response, including root and shoot length elongation, an early and high germination rate, a high yield, a reduction in pathogenic soil load, and an improvement in soil micro- and macronutrient quality

(KINATI *et al.*, 2022). Furthermore, a global meta-analysis to investigate the improvement of crop productivity and nutrient use efficiency by biofertilizers has been done; the meta-analysis exposes arbuscular mycorrhizal fungi and combined application of P-solubilizers and N-fixers are the best inoculants. In addition, a higher yield is achieved by application combinations between the traits of N fixation and P solubilization (MOHAMMADI and SOHRABI, 2012).

Likewise, yeast is a promising plant growth promoter for different crops. Some of the studied yeast strains include *Saccharomyces cerevisiae*, *Candida sake*, *Saccharomyces exiguous*, *Pichia membranifaciens*, and *Cryptococcus laurentii*. Despite the relatively small number of yeasts compared to other microorganisms, many researchers believe that this group of organisms plays a crucial role in soil fertility and is capable of producing growth-promoting substances such as hormones, amino acids, vitamins, protein, organic acids, and soluble and volatile exudates (MOHAMMADI and SOHRABI, 2012). In this regard, an investigation study using amino acid and yeast extract conducted on wheat indicated that the highest yield and yield components were achieved by foliar application of yeast at a rate of 5 g/liter (MANAL *et al.*, 2018).

The main objective of this part of the study is to evaluate how biofertilizers incorporated in combination with inorganic fertilizers under abiotic stress enhance protein content and nutrient uptake to improve bread-baking quality in Hungarian hard winter wheat. In addition, this foundational study evaluates the effect of a subset of biofertilizers on wheat and maize under abiotic stresses.

3.5 In-Crop Nitrogen Splitting under Drought

Nitrogen (N) is an essential macronutrient required for plant development (HE *et al.*, 2022; PEPÓ et al., 2020). There are two kinds of nitrogen: organic and inorganic. In nature, nitrogen cycles between these two forms. Nitrate and ammonium are plants' most prevalent inorganic N sources, while amino acids and urea are organic N sources (SAJJAD *et al.*, 2021). N in the form of nitrates and other states where it works as a signal molecule may also regulate the expression of genes for growth and development, plants' physiological and metabolic activities, and their nutritional function (SAJJAD *et al.*, 2021). While many genes are known to be expressed/repressed in response to an increase or decrease in N, the mechanism of N signaling in the control of gene expression is not entirely understood. Organic and inorganic forms of nitrogen are found in amino acids and peptides. The plants' nitrogen consumption is modified according to their needs, resulting in a geographical and temporal equilibrium (ZHAO *et al.*, 2021). Variables such as environmental change, temperature, fertilizer, soil pH, and precipitation influence N absorption (ANTONIOU *et al.*, 2016).

Most plants meet their nitrogen requirements via bacterial nitrification and fertilization (MOHAMMADI *et al*., 2012). The levels through which plants utilize nitrogen include absorption, assimilation, translocation, aging, recycling, and remobilization. Environmental factors such as the invasion of pathogens or the presence of heavy metals trigger spontaneous senescence and remobilization of nitrogen. GLN1, GDH, and ASN are genes expressed in response to biotic stressors (SAJJAD *et al.*, 2021). According to several studies, they improve the process of N remobilization. The uptake and absorption of N by plants are affected by abiotic stimuli, such as salt stress, drought stress, and extreme temperature stress (COLLING *et al*., 2010). Abiotic stressors such as drought, aluminum toxicity, and nutrient deficiency (especially P and N) are the primary causes of crop losses of up to 50 percent globally. Abiotic stressors such as salt, high temperature, aluminum toxicity, drought, and floods also affect nitrogen fixation in legumes. Drought stress profoundly affects nitrogen fixation, which is very vulnerable to it, and nitrogen fixation diminishes even before leaf photosynthesis (COLLING *et al*., 2010; SAJJAD *et al.*, 2021).

Throughout its development cycle, wheat's susceptibility to water deficiencies and hot temperatures changes (TOMAZ *et al.*, 2021). Wheat response to water stress is more evident from stem elongation to grain-filling (ZHANG and OWEIS, 1999). During stem elongation and booting, it can affect the potential grain number per unit area; during the reproductive stages of anthesis and grain filling, the photosynthesis rate can be significantly affected, thereby reducing the amount of assimilates available to the grains, mainly if they occur around anthesis (TOMAZ *et al.*, 2021). Therefore, water stress and nitrogen (N) deficit may reduce the quantity of grains per unit area, grain yield, and nitrogen usage efficiency (NUE) (LIU *et al.*, 2018). In addition, nitrogen concentration is often regarded as the most critical component influencing protein storage and wheat grain quality (LIU *et al.*, 2018). Adapted agronomic approaches have the ability to maintain and/or boost wheat yields in different parts of the world, including Hungary, by increasing Water Use Efficiency (WUE), Net Utilization Efficiency (NUE), and grain quality (PATANITA *et al.*, 2019).

Splitting N fertilizer application between growth stages can equal or increase the quantity and quality of wheat yields, increase economic flexibility, and reduce environmental losses (SCHWENKE *et al.*, 2022). Variations in yield responses to split N treatment are likely attributable to varying weather conditions throughout crop development. A split N application method tries to minimize N losses during the early months after fertilizer application, when denitrification and leaching losses of mineral N may occur in the soil. Nitrogen fertilizer treatment seeks to closely mirror the rhythm of crop N absorption, which is initially modest during establishment and peaks as blooming begins. Splitting N fertilizer applications has also been suggested to decrease nitrous oxide (N_2O) emissions and water quality implications (YAO *et al.*, 2023). Even though splitting nitrogen decreases N_2O emissions during pre-sowing nitrogen treatment, overall N_2O emissions may be the same or higher for the whole season (SCHWENKE *et al.*, 2022; Yao *et al.*, 2023).

In a recent poll of Australian producers, just 18% of farmers applied all of the 2019–20 season's nitrogen fertilizer before sowing the crop, while 74% utilized a split N approach, and 7% decided to apply all of the nitrogen fertilizer in-crop. Those that used the split N technique applied 64% of the N fertilizer in the pre-season and the remaining in-crop. Various split N ratios (pre-sowing: in-crop) have been evaluated, discovering that 30:70 offered a greater seed production, N absorption, and N usage efficiency than 50:50 or 70:30 ratios while lowering excess N in the soil. In contrast, recent Australian field research indicated no difference in lint production between 70:30, 30:70, and 0:100 split ratios. However, all split ratios generated more than 100:0 in one of the two study years (SCHWENKE *et al.*, 2022).

Numerous research studies involving in-crop N treatments have used a single- or two-stage application technique, with the first in-crop N application occurring at the onset of flowering and any further applications occurring throughout the peak heading phase. There is a little study comparing in-crop nitrogen application techniques. The varied in-crop treatment techniques and products may alter crop yield due to changes in N distribution throughout the soil profile. In addition, N fertilizers are subject to a variety of potential loss pathways upon application in the field, including volatilization, runoff, leaching, denitrification, and immobilization with the primary mechanism for N loss and, consequently, N fertilizer use efficiency dependent on soil type, fertilizer type, application method and timing, and abiotic stresses (SCHWENKE *et al.*, 2022; RUAN *et al.*, 2023).

In this study, we aim to mitigate the effect of abiotic stresses such as drought and heat, combined with the reverse result of applying the whole amount of N fertilizer simultaneously, which may affect the crop. On the same side, we aim to efficiently use the nitrogen fertilizers under stressed conditions by splitting it and applying it during critical growth times. We suggest applying nitrogen fertilizer on the growth stages of Feekes 3 (tillering stage) and Feekes 10 (heading stage). The other point we aim to understand is whether applying N during the late growth stage positively affects flour quality and grain yield.

Overall, this study aims to understand the behavior of plants, wheat and maize, under abiotic stresses. It seeks novel agricultural practices and strategies to mitigate the effect of abiotic stresses such as drought, extreme temperature, and waterlogging. Some systems are tested here, including pre-sowing seed priming, nitrogen splitting, effective microorganism application, and irrigation. In addition, germination optimization and a novel methodology of seed germination practices were conducted. Plants are constantly exposed to various environmental stresses, including abiotic stresses, which are non-biological factors that can negatively impact plant growth and development.

These environmental restrictions do not seem to be diminishing. Increased temperatures and decreasing precipitation are predicted by global climate change, which is likely to intensify the negative consequences of water shortage on agriculture. Less rainfall will increase the extent of irrigated land, leading to soil salinization.

Germination is a physiological process that initiates and develops a seedling by triggering a cascade of biological and biochemical reactions. Germination affects both the ultimate production and quality of a crop. Successful production requires the growth of sturdy, well-developed seedlings, and one of the main goals of seedling production is to produce a viable plant from any single seed. Temperature and water availability significantly affect the biological and biochemical enzymatic activities in germination and seedling growth stages.

Understanding the mechanisms underlying plant responses to abiotic stresses is essential. Physiological and morphological studies have been ongoing to cope with the increased impact of these stresses. Additionally, plant-microbe interactions have been shown to be important in improving plant tolerance to abiotic stresses.

3.6 Dissertation Aims

This dissertation aims to overview the current understanding of plant responses to abiotic stresses, focusing on drought and heat stress and novelizing new strategies to face these conditions. This study also focuses on the seed priming technique to enhance germination and plant tolerance in the later stages of wheat and maize life. The study also investigates the role of plant-microbe interactions in improving plant tolerance to abiotic stresses. Drought and temperature stress signaling is an essential area concerning increased plant productivity. However, our knowledge of the techniques underlying the responses of plants to such environmental stresses is still somewhat limited.

The findings of this study contribute to a better understanding of plant responses to abiotic stresses and aid in developing novel strategies for improving plant tolerance to adverse environmental conditions. Thus, it is essential to investigate the plant stress tolerance mechanisms to identify novel management components and techniques for enhancing crop resistance and tolerance.

Overall, it is impossible to overlook the significance of these abiotic factors on wheat and maize crops. Therefore, it is crucial to develop strategies and technologies to mitigate their effects on crop productivity and quality. Novel agriculture practices can be used to develop management techniques of drought-, waterlogging-, and heat-tolerant, along with agronomic practices, including crop rotation, soil management, and irrigation, which can also lessen the effect of these pressures on agricultural output.

3.7 Dissertation Hypothesis based on the literature review.

The hypothesis of the dissertation in accordance with its goals and objectives based on the presented above scientific facts in the literature review are as the fellow:

1. Determine the effect of abiotic stress on wheat and maize seed germination and emergence under controlled laboratory conditions.

The effects of temperatures on germination, germination duration, and the seedling growth of maize and wheat seeds woule be investigated at eight different temperature levels. It also aimed to determine the minimum, optimum, and maximum water amount required for germination based on the volume of water amounts of one-milliliter intervals and the thousand kernel weight (TKW) since the size of the individual seed has importance in seed germination quality. In addition, the effect of the number of seeds and seedling density in a Petri dish on germination percentage would be investigated. Finally, it also investigated the effect of using the seed priming technique before planting or adding an antifungal to the growth media on seedling growth for laboratory tests.

2. Evaluate the effect of the seed priming technique on enhancing seed germination and plant tolerance in the later stages of wheat and maize life.

Seed priming with gibberellins (GAs) and salicylic acid (SA) is a strategy used to boost a plant's capacity to deal with abiotic stressors. Primed plants suppose to produce protective enzymes, antioxidant defense systems, and osmolytes to respond to environmental challenges. These adaptations help the plant save water, preserve cell membrane integrity, and decrease abiotic stress-induced oxidative damage. Seed priming with GAs and SA suppose to improve a plant's tolerance to abiotic stressors and production, making it beneficial for sustainable agriculture in environmentally challenged areas.

3. In field trials, the effects of abiotic stress on the morphological parameters of plant growth and development, including tillers number, leaf area, and plant height would be evaluated.

Tillers number, leaf area, and plant height would be monitored to assess the impact of abiotic stress on plant growth and development. In addition, a plant's tillers might indicate its capacity to respond to environmental conditions. For example, stress-induced variations in stomatal conductance and water consumption efficiency affect leaf area, which indicates the plant's photosynthetic capability. In addition, stress-induced cell elongation and division decrease impact plant height.

4. In field trials, the influence of abiotic stress on yield and yield components, including grain yield, number of ears per plant, and number of grains per ear in wheat and maize would be determined.

Grain yield is a crucial statistic representing a plant's capacity to produce viable seeds and is normally assessed in terms of grain weight per unit area. The number of ears per plant is also crucial since it directly impacts overall grain production. The quantity of grains per ear indicates the plant's capacity to produce viable seeds and is controlled by nutrition availability, water availability, and temperature. The gathered data from these trials may be evaluated to establish the degree to which abiotic stress affects each parameter and to detect any interactions between various stress components and their effect on crop output.

5. Wheat and maize's physiological and biochemical responses to abiotic stress, including photosynthetic activity and chlorophyll concentration alterations would be examined.

Photosynthesis can be limited due to abiotic stress by impairing light absorption or destroying photosynthetic structures. The plant's capacity to generate photosynthetic pigments, and chlorophyll concentration, is another critical measure of health. Abiotic stress alters chlorophyll concentration, affecting leaf color, photosynthesis, and other physiological responses. This knowledge by this study may help enhance plant production and environmental resilience by understanding plant response to abiotic stress.

6. In-crop nitrogen uptake, assimilation, and mobilization in plants under abiotic stress would be evaluated.

Morphological and quality parameters can be compared among various nitrogen application rates and timings to identify the most effective nitrogen application strategy under drought and irrigation. In addition, the result can inform crop management techniques, including nitrogen fertilizer application rates, splitting, and timings, aimed at improving nitrogen use efficiency (NUE) and mitigating the reverse effect of abiotic stress on crop productivity. Evaluate the effect of microorganisms on mitigating the impact of abiotic stresses.

Via the synthesis of growth-promoting chemicals, such as phytohormones, microbes may buffer the effects of abiotic stressors. Furthermore, by fixing atmospheric nitrogen and solubilizing minerals, microorganisms may also boost plant nutrient absorption, especially in nutrient-deficient soils. The microorganisms would be applied in different environments of irrigated and not irrigated field trials in different stages of life in combination with different nitrogen applications to understand their role in enhancing plant growth, development, and productivity.

7. The effect of irrigation in different growth stages on yield components, quality, and quantity would be evaluated.

Timing and frequency of irrigation throughout growth stages may significantly affect yield components, quality, and quantity. Proper irrigation promotes leaf area, photosynthesis, and yield during vegetative growth. Overwatering may result in waterlogging and oxygen shortage, harming root growth and plant health. Furthermore, irrigation influences the size and number of seeds during reproduction. Appropriate irrigation at this stage improves water use efficiency and seed production per plant, hence enhancing yield. On the other hand, water stress during this stage may alter the seeds' size, quantity, and yield. Different irrigation regimes were tested in this study in different aspects to optimize the use of the resources, including water in areas with water shortage. We aimed to novel suitable irrigation management in necessary conditions to optimize crop productivity of wheat and maize and ensure sustainable water use.

The primary objective of this study is to provide a comprehensive analysis of the impact of abiotic stress on the growth and development of wheat and maize, while also exploring strategies to improve the resilience of these crops under stressful environmental conditions. Ensuring food security in the context of climate change necessitates the implementation of various management strategies. These strategies encompass optimizing seed germination and emergence, employing seed priming techniques, harnessing the potential of microorganisms, adopting diverse nitrogen application and splitting methods, and implementing varied irrigation regimes.

4 MATERIALS AND METHODS

The research methodology employed in this study pertains to the systematic approach and techniques utilized to design, conduct, and analyze a research investigation. The provided statement delineates the sequential actions, methodologies, and instruments employed in collecting and examining data to address research inquiries or validate hypotheses. An appropriately structured research methodology guarantees the study's dependability, validity, and credibility, thereby ensuring the reliability and generalizability of the findings to a broader population. The laboratory and field experiments were conducted in the experimental labs and fields belonging to the Agronomy Institute – Hungarian University of Agriculture and Life Sciences, located in Gödöllő, Pest, Hungary (coordinates: 47.594315° N, 19.368984° E).

4.1 Plant Materials

I. Margitta, maize hybrid: The most significant benefit of the Margitta hybrid is the swift water loss. The FAO number falls in the middle of the 300 group; this means a higher potential yield, but due to the fast water loss, it ripens earlier than others in the same group. Margitta has a robust appearance and ripening on a green stem. Typically, the cobs bend down while ripening. Due to its remarkable stress tolerance, this hybrid’s optimal sowing and harvesting range is wide. This dentiform maize hybrid plants at a density of 65–70,000 plant/ha, the number of seed rows on a cob is 16–18 with a seed-cob ratio of 86.8%, and the cob length is 21–22 cm.

II. Alföld 90, wheat variety: The seeds of a regionally commonly grown variety of Hungarian wheat named Alföld 90 were obtained from a grower and used. It is a high winter tolerance wheat variety with a 75–95 cm plant height and awed spikes. Alföld 90 is sensitive to powdery mildew disease and has a total tolerance to stem rust disease. It is an early Hungarian variety and is cultivated in dry regions.

III. Mv Felleg, wheat variety: A new, high-yielding early milling wheat variety that approaches the premium baking category in quality. Its excellent technological quality is due to its ancestor, the popular Mv Kolo variety, but it is far superior to its predecessor in yield. It is productivity of 8.5-9.5 t/ha. Its typical quality characterizations are: hard kernel type, TKW is 40-45 g, crude protein content is 13-15%, wet gluten content is 25-35%, and farinograph group A1-A2. In addition, it has a total resistance level to stem rust, with excellent resistance to fusarium head blight, leave-plight, leave rust, yellow rust, and powdery mildew. The recommended fertilizer dose is 140-170 kg of nitrogen as an active ingredient per hectare.

IV. Mv Menrot, wheat variety: An early, high-yielding variety with excellent yield stability. A top variety when intensive technology is applied. Depending on cultivation intensity, baking quality may vary between B1 and A2 per harvest year. It has a complex and good disease resistance. It is productivity of 9.00-10.0 t/ha. Its typical quality characterizations are: large steely kernels type, TKW is 45-50 g, crude protein content is 12-14%, wet gluten content is 29-32%, and farinograph group is A2. In addition, it has a total resistance level to stem rust, with good resistance to fusarium head plight, leave-plight, leave rust, yellow rust, and powdery mildew. The recommended fertilizer dose is 150-180 kg of nitrogen ingredient per hectare.

V. Mv Nemere, wheat variety: A high-yielding, mid-season maturing milling wheat variety with good disease tolerance and stable yields. Under favorable conditions, yields can exceed 10 t/ha. It is one of the three top Martonvásár wheat varieties grown in the most prominent areas, along with Mv Nádor and Mv Menrot. Agricultural Innovation Award winner in 2018. It is productivity of 9.00-10.5 t/ha. Its typical quality characterizations are hard kernel type, TKW is 45-50 g, crude protein content is 12-13%, wet gluten content is 30-32%, and farinograph group is A2. In addition, it has a good disease resistance level to stem rust, fusarium head plight, leave-plight, leave rust, yellow rust, and powdery mildew. The recommended fertilizer rate is 140-170 kg/ha of nitrogen as an active ingredient.

4.2 Agrotechnical Factors in Field Experiments

I. Forecrop: The crop grown in the field before the wheat experiment was the soybean, and sunflower was the forecrop of the maize experiment.
II. Tillage: The field soil was tilled using a disk and plow to incorporate the residue further into the soil. Afterwards, the soil was smoothed, and suitable seedbed prepped.
III. Crop Protection: Total herbicide (Medallon) was applied for the maize field after planting in both years. For wheat crop, only on the first-year herbicide (Corte SE) was applied. Weeds were eliminated by hand when needed.
IV. Fertilization: The type, amount, and timing of fertilizers applied are specified as treatments for each experiment and detailed in the following sections.
V. Irrigation: Irrigation regimes, including timing and amount of water applied, are specified as treatments for each experiment and detailed in the following sections.
VI. Sowing: Sowing machine was used to sow wheat seeds on the 19th of November 2021 and on the 19th of November 2022. Planting machines were utilized to plant maize seeds by the conclusion of April. The planting density was 65000, with a row spacing of 75 cm and a within-row spacing of 20 cm.
VII. Harvesting: By the mid of July, wheat crop was harvested in both year with a combine machine. Maize yield was sampled by hand on the mid of October.
VIII. Crop Rotation: The sequence of various crops grown in the experimental field over time to improve soil health and reduce disease pressure was in this order: soybean – wheat – sunflower - maize.
IX. Meteorological status: Data and patterns of the meteorological status and climate overview and their elements are presented in the appendix, Figures B.5. 13—B.5. 25.

4.3 Research Experiments

The research investigation was divided into a series of experiments:

4.3.1 Pre-Sowing Seed Priming Experiment

Seed priming with gibberellin (GAs) and salicylic acid (SA) to encounter abiotic stresses of drought and waterlogging and heat tolerance of Hungarian wheat. Seed priming technology, which means soaking the seeds before sowing, with plant growth regulators to benefit linked between the stimulation process of seed germination and the germination process itself. It can improve and homogenize emergence, giving a robust homogeneous arrangement and better early field foundation. The pre-adaptation response may help counter various stresses present, including water shortage and waterlogging, thus reducing the damage caused by this stress on the plant's growth and yield. Moreover, this technology is simple, cost-effective, and risk-free.

Martonvásár, the Center for Agricultural Research, supplied wheat seeds of the Mv Nemere and Mv Felleg varieties, and the Alföld was obtained from a producer. The experiment aims to determine the varying responses of wheat cultivars to stimulus parameters. Three replicates of the factorial experiment were conducted in the field using a Randomized Complete Block Design (RCBD). The main plots were irrigated in levels based on the field capacity to examine water stresses. The split main plots were given 20 mm water for each sub-section every 3, 6, and 9 days, and the control. The experimental setup is depicted in the field map, as illustrated in Figure B.4. 1 (A).

Priming solutions were prepared at a concentration of 600 ppm for the GAs and 80 ppm for the SA. The concentrations were determined based on a preliminary germination experiment that was conducted, which included two sets of concentration levels. Wheat seeds were treated with growth regulators GAs, SA, and distilled water three days before planting. They were soaked into the prepared solutions for 8 hours before air drying for two days. The three types of primed seeds of the three wheat varieties were sown in the field in the main 4 plots (total 9 sub-plots for each irrigation treatment). Irrigation was regularly given to the main plots according to the proposed durations. Hand hose sprinkler irrigation systems were used. Growth and yield parameters were monitored throughout the agricultural season, and data for different growth and yield parameters were recorded at various stages. Data regarding germination time, emergence time, seedling vigor, tillers number, plant height, and yield component, including spikes number, grain number per spike, and grain filling (thousand-grain weight (TKW)) were recorded.

After harvest, the grain yield was cleaned to remove impurities or foreign materials. Then, the yield was calculated, and the pre-test was made on the same harvest day using a Near-infrared (NIR) device, which provides data including protein content, gluten content, moisture percentage, and Zeleny index. The grain yield is stored for one month before conducting the quality tests to give enough time for the material composition and formation into the seed. Then, the quality examinations were conducted a month after harvest, including TKW, hectoliter weight, Zeleny index, gluten content using a gluten wash device, falling number, whole flour NIR test for moisture, protein, and gluten, and whole grain NIR test for Zeleny index, moisture, protein, and gluten

After data were collected for analysis, they were sorted according to the study proposal, checked for data validity, and run with statistical computing programs.

4.3.2 Germination Experiment

The present study examined the impacts of temperature, drought, waterlogging, and seedling density on germination's vigor and seedlings' development. Furthermore, an investigation into the inhibition of fungal growth was also conducted. The seeds of Alföld 90, a variety of Hungarian wheat widely cultivated in the region, and Margitta, a type of maize, were acquired from the Martonvásár research institute and subsequently utilized. The research was split into four experiments, which were carried out as described in the subsections below.

4.3.2.1 Temperature Sub-Experiment

This research examined the germination of six different temperatures: 5, 10, 15, 20, 25, and 30 ˚C for wheat and maize seeds at eight different temperatures: 5, 10, 15, 20, 25, 30, 35, and 40 °C. The media were prepared; the Petri dishes were labeled, and each one was filled with ten maize seeds and subjected to the same quantity of distilled water, 9 ml after the distilled water was tested for conductivity. The number of non-germinated seeds was counted, and all seedlings' radicle and plumule lengths were measured. Twenty wheat seeds per petri dish were used in this experiment. The measurement started when around 75% of the Petri dishes (PDs) seedlings reached a length of 1 cm. Daily, four Petri dishes were taken out of the chamber for physical measurements at each temperature level.

4.3.2.2 Water Amount Sub-Experiment

In sterile petri dishes with a 9 cm diameter lined with a single sterile filter paper, maize seeds were subjected to 13 distilled water amounts based on milliliter intervals and 16 distilled water amounts based on TKW. Wheat seeds were subjected to 12 distilled water amounts based on milliliter intervals and 13 distilled water amounts based on TKW. The TKW was obtained using a seed counter instrument, and it was 235.2 g for the maize and for the wheat seeds was 42.76 g.

Eq. I $$TKW * \text{Seed } n/100{,}000 = 1\% \text{ of the proposed water amount}$$

$$235.2 * 10 = 2352/100{,}000 = 0.02352 \quad \text{for the maize}$$
$$42.76 * 20 = 855.2,\ 855.2 / 100000 = 0.008552 \quad \text{for the wheat}$$

The Eq. I (KHAEIM *et al.*, 2022) result represents 1%. This outcome was multiplied by the proposed percentage for each water treatment, as shown in Table 4.1. Petri dishes were labeled, and 10 seeds of maize and 20 seeds of wheat were placed in each one with 5 replicates for each of the 30 treatments. This experiment was conducted in one set at a constant chamber temperature of 20 °C for wheat and 20 °C and 25 °C for maize. Physical measurements and evaluations were conducted after an incubation period of 10 days. Petri dishes were taken out of the chambers, and radicle length and plumule length were measured for all seedlings, in addition to counting the number of non-germinated seeds. These radicles and plumules were labeled and subjected to 65 °C for 48 h in an oven. Finally, the radicles and plumules of the ten seedlings of each experimental unit were weighed, and the dry weights were obtained using a high-precision 3-digit digital scale.

Table 4.1: The experimental treatments based on the bases' milliliter intervals and TKW %.

Amount of water based on 1 ml interval		**Amount of water based on the T.G.W. %**			
[a] Treatment numbers	[b] Water amount ml	[a] Treatment numbers	[c] Proposed % of Water amount	[d] Amount of water ml	[e] Rounded amount of water ml
		Water for wheat			
1	0	14	75%	0.641	0.65
2	1	15	150%	1.282	1.30
3	2	16	225%	1.924	1.90
4	3	17	300%	2.565	2.55
5	4	18	375%	3.207	3.20
6	5	19	450%	3.834	3.85
7	6	20	525%	4.489	4.45
8	7	21	600%	5.131	5.15
9	8	22	675%	5.772	5.75
10	9	23	750%	6.414	6.40
11	10	24	825%	7.055	7.00
12	11	25	900%	7.696	7.50
13	12				
		Water for Maize			
1	0	14	25%	0.588	0.6
2	1	15	50%	1.176	1.2
3	2	16	75%	1.765	1.75
4	3	17	100%	2.352	2.35
5	4	18	125%	2.94	2.95
6	5	19	150%	3.528	3.55
7	6	20	175%	4.116	4.20
8	7	21	200%	4.704	4.70
9	8	22	225%	5.292	5.30
10	9	23	250%	5.88	5.90
11	10	24	275%	6.468	6.50
12	11	25	300%	7.056	7.00
13	12	27	325%	7.644	7.65
		28	350%	8.232	8.25
		29	375%	8.82	8.80
		30	400%	9.408	9.40

a The treatment number on the two water bases, b the applied water amount based on 1 ml intervals from 1 to 12 ml, c the proposed percentage of water in ml regarding the TKW in g, d the amount of water in ml corresponding to the proposed percentage of water to TKW, and e the rounded amount of water to the closest available pipette digit.

4.3.2.3 Seed Number Sub-Experiment

This section of the experiment was designed to investigate the effect of the number of seeds on germination performance and seedling growth when applying the same amount of water. Four seed sets 10, 15, 20, and 25 for wheat were incubated in a germination chamber at a constant temperature of 20 °C, and 6, 8, 10, and 12 seeds per PD for the maize 20 °C and 25 °C. They were supplied with the same amount of distilled water, 6 ml for the maize and 7 ml for wheat. Ten replications were carried out for each treatment of each set to decrease the experiment's experimental error and increase the accuracy of the overall measurements. After ten days of incubation, they were taken out of the chamber for physical measurements of the proposed parameters. The measured parameters were classified into five categories: number of non-germinated seeds, started to germinate, germinated seeds with only radicle, seedling with a short plumule (shorter than approximately 4 cm), and normal seedling. These classifications, maize, and wheat, were created to obtain an aggregated value following Equations II and III, respectively (Haj Sghaier *et al.*, 2022; Khaeim *et al.*, 2022; Khaeim *et al.*, 2022):

Eq. II $$\text{Aggregated value} = (\text{NO-G} * 0) + (S * 0.1) + (R * 0.25) + (SP * 0.65) + (NP * 1)$$

Eq. III $$\text{Aggregated value} = (\text{NO-G} * 0) + (R * 0.33) + (SP * 0.67) + (NP * 1)$$

where NO-G is non-germinated seeds, S is the start to initiate germination, R is the number of seeds germinated with radicle only, SP is the number of seeds germinated with short plumules, NP is the number of seeds germinated with normal plumule length.

4.3.2.4 Antifungal Experiment

to investigate which sterilization techniques fit the best for laboratory experiments, a fungicide, Amistar Xtra, in different concentrations, two different techniques, and Hypo were used to investigate their effect on inhibiting fungal growth in petri dishes. The active agents for this fungicide are 200 g/L azoxystrobin and 80 g/L cyproconazole, which Syngenta produces. The first technique was to apply 4 different concentrations of the fungicide, that is, 10, 100, 1000, and 10000 ppm, to the growth media. The other technique was to sterilize the seeds into the prepared solutions of 1000 ppm of Amistar Xtra and 5% of Hypo, separately, for 3 min; afterward, they were rinsed with distilled water. Two sets of ten replications for each treatment were incubated at 20 and 40 °C, respectively. Physical measurements and evaluations were conducted after the incubation period of 10 days. The petri dishes were taken out of the growth chambers, radicle length and plumule length were measured for all maize seedlings, and the number of germinated seeds was counted.

4.3.3 Effective Microorganisms Experiment

The objective of this experiment was to assess the interplay between microorganisms, nitrogen fertilizer (specifically ammonium nitrate, NH_4NO_3), and irrigation in wheat plants, with the goal of alleviating the effects of abiotic stresses. The evaluation was undertaken to examine the impact of these factors on both the quantity and quality of yield. Microbes can potentially mitigate the effects of abiotic stressors by synthesizing growth-promoting chemicals, such as phytohormones. Moreover, microorganisms have the potential to enhance plant nutrient absorption, particularly in soils that are lacking in nutrients, through the processes of fixing atmospheric nitrogen and solubilizing mineral minerals. The microorganisms were utilized in various environments of irrigated and non-irrigated field trials, in conjunction with different nitrogen applications, to investigate their impact on promoting plant growth, development, and productivity.

A number of potentially beneficial microorganisms have been identified as soil inoculants. These include *azotobacter* and *azospirillum*, which are non-symbiotic, associative nitrogen fixers that are known to benefit a wide variety of crops due to their abilities to fix atmospheric nitrogen, as well as the effects on the soil ecosystem from their secretion of growth-promoting substances, including vitamins and antifungal metabolites. Another potentially beneficial microorganism that has been widely documented is yeast, which is considered a new promising plant growth fungus for promoting growth for different crops. Yeast has been documented as a potential source of many growth-promoting substances, such as thiamine and riboflavin, and it promotes the metabolism of protein and carbohydrates in agricultural production systems.

This factorial field experiment of effective microorganisms' application was conducted during the agricultural season of 2021-2022 as the first growing season. Seeds of wheat varieties of Alföld, Menrot, and Nemere were sown in the field on the 19th of November 2021. The experiment was designed following a Randomized Complete Block Design (RCBD). Three replications for each treatment were implemented. The field was divided into two main sections and three sub-sections. Each sub-section has 9 plots. The plot (experimental units) dimeters is 1×4 m^2. The sub-sections were treated separately with either EM application, EM + N application, or N application. The N was applied on Feekes 10 (booting stage). The EM was applied at 0.125 ml of EM per square meter, 5 ml:4 l (EM:water) two days after ammonium nitrate application. The main section of the experiment was irrigated at the critical growth stages of water shortage, heading, and grain filling and ripening. Each time, the field was irrigated with 15 mm of water. The field map depicts the experimental setup, as illustrated in Figure B.4. 2 (A).

Throughout the subsequent agricultural cycle, 2022 - 2023, the proposed plan underwent a process of development, updating, and modification. The present study incorporated the application of nitrogen doses. A total of six nitrogen doses, namely 0, 40, 80, 120, 160, and 200 kg/ha, were employed as an active agent of NH_4NO_3. The experimental setup is depicted in the field map, as illustrated in Figure B.4. 1 (C). On the 20th of November 2022, the field was sown with seeds of wheat varieties of MV Felleg. The experiment was conducted using the Randomized Complete Block Design (RCBD) methodology. Three replications were conducted for each treatment. The field was partitioned into three distinct sections. The dimensions of the plot are 1 meter by 4 meters squared. The proposed dose of N was administered to all experimental units across all sections at Feekes 3. In the context of the EM application, the initial section was subjected to 0EM treatment, the subsequent section was subjected to a single instance of EM application at F3, and the final section underwent two instances of EM application at F3 and F6. The EM treatment was administered at a rate of 0.125 milliliters of EM per square meter, using a ratio of 5 milliliters of EM to 4 liters of water, two days following the application of ammonium nitrate.

The primary focus of the initial season was the investigation of the impact of drought on yield and quality parameters, specifically in relation to the application of N and EM. The second year of the study was dedicated to examining drought conditions, varying nitrogen doses, and the application of EM on various vegetative parameters and yield and quality parameters. The parameters assessed during the vegetative phase include APAD (active photosynthetic area density), quantum yield (QY), leaf area, number of tillers, spikes, spikelets, and plant height. The measurements of these parameters were conducted during the booting, anthesis, and seed-filling growth stages.

The field was harvested for the first year on July 15th, 2022, and July 17^{th,} 2023, for the second year. The plots were harvested with a combine, and grains were put in labeled bags. Each bag's harvested yield was directly cleaned, weighted, and tested with whole grain NIR machine, and the estimated values of protein content, gluten content, moisture percentage, and Zeleny index were obtained. The harvested yield was stored for one month and then brought to the experimental lab belonging to the Agronomy Institute at the Hungarian University of Agriculture and Life Sciences. The quality tests were made as described at the end of this chapter. The tested wheat quality parameters were repeating the same whole NIR to provide the same four indexes and TKW, hectoliter weight, Zeleny index, gluten content using a gluten wash device, falling number, and whole flour and whole grain tests of moisture, protein, and gluten. The data were obtained, organized, tested for validity, and prepared for statistical analysis.

4.3.4 In-Crop N-Splitting-Timing Experiment

This study aimed to assess the in-crop nitrogen uptake, assimilation, and mobilization in wheat plants subjected to abiotic stress conditions. The comparison of morphological and quality parameters across different nitrogen application rates and timings enables the identification of the optimal nitrogen application strategy in the context of both drought and irrigation conditions. Furthermore, the outcomes of this study can provide valuable insights into crop management strategies, specifically pertaining to the application rates, timing, and division of nitrogen fertilizers. These strategies aim to enhance nitrogen use efficiency (NUE) and counteract the adverse impact of abiotic stress on crop productivity.

This factorial experiment was designed to investigate the effect of irrigation and nitrogen splitting on wheat growth, development, and quality. According to RCBD, the field was divided into two main sections (irrigated and not irrigated), each split into three subsections: A single N application, two times N application, and three times N application. Each subsection contains 9 plots. The area of each plot is 4 m^2 (1 × 4 m). The experimental setup is depicted in the field map, as illustrated in Figure B.4. 1 (B). The first N application (NH_4NO_3) was applied at Feekes 3 (tillering stage), Feekes 6 (jointing stage), and Feekes 10 (booting stage) as described in Table 4.2.

Table 4.2: Nitrogen timing and splitting treatments according to the wheat growth stages.

N Application Time	**Feekes 3**	**Feekes 6**	**Feekes 10**
Single Time	160 kg/ha N		
Two Time	80 kg/ha N	80 kg/ha N	
Three Time	53.33 kg/ha N	53.33 kg/ha N	53.33 kg/ha N

The exact amount of N was either not divided or divided two or three times following the growth stages of the wheat crop.

Irrigation (20 mm of water) was implemented as necessary, particularly in instances of drought and high temperatures starting from stem elongation growth stage (Feekes 6). Various growth stages were assessed to determine vegetative growth traits, such as the number of plant tillers, plant height, and yield traits, including the number of spikes and grains per spike. In July 2023, the wheat crop was harvested using a combine.

Following the completion of the harvest, the grain yield underwent a cleaning process to eliminate any impurities or extraneous substances. Subsequently, the yield was computed, and the pre-test was conducted on the identical day of harvest utilizing near-infrared spectroscopy (NIR). Subsequently, the harvested grain yield was subjected to a storage period of one month prior to the commencement of quality assessments. This duration was allotted to allow for adequate material composition and seed formation processes to occur. Subsequently, a series of quality assessments were performed approximately one-month post-harvest. These assessments encompassed various parameters such as TKW, hectoliter weight, Zeleny index, gluten content determined through the utilization of a gluten wash device, falling number, NIR test of the whole flour with Dickey-John (InstaLab 600) to measure moisture, protein, and gluten levels, as well as NIR testing for both whole grain and flour samples to determine the respective NIR indexes. The methodology used to measure these traits will be elaborated upon in subsequent sections of this chapter.

4.3.5 Nitrogen Doses- Wheat Quality- Abiotic-Stresses Experiment

The primary aim of this research was to evaluate the nitrogen acquisition, assimilation, and mobilization processes during the later developmental phases of wheat plants (post-Feekes 10) under abiotic stress conditions. Examining morphological and quality parameters under varying nitrogen application rates allows for determining the most effective nitrogen application approach in relation to abiotic stresses. Moreover, the findings of this study can offer significant contributions to understanding crop management techniques, particularly concerning the optimal dosage of nitrogen fertilizers. These strategies aim to improve NUE and mitigate the adverse effects of abiotic stress on crop productivity.

The field trial was conducted during the agricultural season of 2021-2022, with the plantation date set for the 19^{th} of November, 2021. The experiment utilized the locally cultivated wheat variety known as Menrot. The surface area of each plot measures 4 m^2 (1×4 m). The field map depicts the experimental setup, as illustrated in Figure B.4. 2 (B). The NH_4NO_3 application, specifically at Feekes 10, was utilized to examine the impact of nitrogen application on crop yield and yield quality. After harvest, the grain yield underwent a post-harvest cleaning procedure intending to remove any impurities or extraneous substances. The yield was calculated, and the pre-test was carried out on the same day of harvest using NIR. Following this, the collected grain yield underwent a storage duration of one month before the initiation of quality evaluations. The allocated time frame was designated to facilitate the occurrence of sufficient material composition and seed formation processes. Following this, quality evaluations were conducted approximately one month after the harvest. The evaluations included a range of parameters, including TKW, hectoliter weight, Zeleny index, gluten content determined using a gluten wash device, falling number, NIR tests for measuring moisture, protein, and gluten levels, and NIR testing for both whole grain and flour samples to determine the respective NIR indexes. The subsequent sections of this chapter will provide a detailed explanation of the methodology employed to measure these traits.

4.3.6 Maize Field Experiment

The field trial was conducted during the summer growing season of 2022 and subsequently replicated on a larger scale during the summer growing season of 2023. This study aimed to examine various abiotic stressors that impact the performance of maize plants. The field was partitioned into irrigated and non-irrigated sections, delineated by borders both surrounding and separating them. In both years, the experimental treatments consisted of separate applications of nitrogen from different sources, namely organic (organic matter (OM) of N active agent of 9%) and conventional (ammonium nitrate (AN) N active agent of 34%), at a rate of 160 kg/ha N active agent in 2022. The study was developed in the following year, 2023, and fertilizer doses were introduced as a factor. The applied rates of N doses from both sources were 80, 160, 240, and 320 kg/ha active agents.

Also, effective microorganisms (EM) were applied individually and combined with the aforementioned nitrogen sources. These treatments and a control group were implemented in the field as depicted in Figure B.4. 3, the field map. The seeds of a regionally widely used variety of Hungarian maize called Margitta were obtained from a the Martonvásár research Institute.

In both years, the experimental planting machines were utilized to plant maize seeds by the conclusion of April. The planting density was 65000, with a row spacing of 75 cm and a within-row spacing of 20 cm. Following the random distribution of the experimental units among the sub-sections, the treatments were administered to the experimental plots, which were 3 meters, and replicated three times during the vegetative growth stage V4. The categories included in the study were control, EM, AN, GOM, EM + AN, and EM + GOM. The irrigated area received a consistent water supply of 20 mm every 5 days starting from the V4 growth stage. Weekly measurements were taken to assess various growth traits of the plant, including the number of leaves per plant, stem diameter, SPAD value, Quantum yield (QY) value, and plant height. For each plot, plant samples were chosen randomly to conduct measurements. Following the completion of the harvest, the recorded yield data was obtained, and the maize kernels were subsequently transported to the laboratory for quality testing.

4.4 Traits Measurements Methodology

Following is the description of the growth, yield, and yield quality of the tested traits in different sub-experiments:

I. Number of wheat tillers (spike/m^2): The tiller count was quantified by randomly selecting a representative sample of 10 wheat plants from each plot, and subsequently enumerating the number of tillers present on each plant. Tillers are the secondary shoots that emerge from the basal region of the wheat plant. To determine the average tiller number for each plot, the total number of tillers was divided by the number of plant samples (10). Subsequently, the values were transformed based on the measurement of wheat tillers per square meter.

II. Number of wheat spikes (spike/m^2): The measurement involved randomly selecting a 40 cm line segment and quantifying the number of spikes within this measured distance. The experiment involved conducting three repetitions for each plot and subsequently recording the mean values.

III. Number of wheat grains ($spike^{-1}$): A random selection of 5 wheat plants from each plot ensured the sample was representative. Subsequently, spikelets and grains per spikelet on each individual spike were quantified. The variability in the number of grains per spikelet is contingent upon the specific wheat variety and the applied treatments. The total quantity of grains in the sample was calculated by multiplying the number of spikes by the mean quantity of spikelets per spike and the mean quantity of grains per spikelet.

IV. Leaf area index (LAI): It measure light transmittance through the canopy and calculate LAI based on the light interception model using Sunfleck Ceptometers (AccuPAR 80, Decagon Devices, Pullman WA 99163 USA). Measure the LAI at multiple points within each plot at the respective growth stages (anthesis for wheat, flowering for maize).

V. SPAD: The photosynthesis activity measurements were conducted after randomly selecting 10 wheat plants and 4 maize plants from each plot. The photosynthesis activity of each plant was assessed by measuring both the lower and upper leaves and 3 leaves from the middle of the plant. These measurements were conducted using the SPAD device, and the resulting averages were recorded.

VI. Quantum yield (QY): It measures photosynthesis II efficiency. QY is equivalent to F_v / F_m in dark-adopted samples and F_v^1 / F_m^1 in light-adapted samples. The Photosynthesis System Instrument

(PSI) was used for this measurement. The measurements with this FluorPen FP 110 were done after 20 minutes of blocking the photosynthesis activity with a special room adopter to measure in the dark.

VII. Leave number: The maize leaves were quantified weekly to discern variations in plant performance and growth rate across different conditions.

VIII. Stem diameter (cm): The stem diameter of maize plants was assessed using a Vernier caliper, precisely measuring from the lower portion of the stem, 10 cm above the ground. This measurement was taken to indicate the accumulation of cellulose, which indicates the plant's performance under different environmental conditions.

IX. Plant height (cm): After a random selection process, a representative sample of 10 wheat and 3 maize plants was obtained from each plot. The height of each plant, measured from the base of the stem to the head for the wheat and to the tip of the last leaf for the maize, was recorded using a scaled 2-meter wooden roller. Measuring the height on the same day and under similar weather conditions is imperative to maintain consistency. The recorded data included the height measurements for each plant in the sample. Subsequently, the determination of the mean height of the plants was conducted through the summation of all height measurements, followed by division by the sample size.

X. Weight of 1000 kernels (TKW) (g): 5,000 wheat and maize grains were enumerated using a seed counter machine. Subsequently, the 5000 grains of wheat or maize were measured in terms of weight utilizing a digital scale. Ultimately, the values were divided by a factor of 5 to derive the 1000-grain weight. A seed-counter instrument manufactured by Pfeuffer GMPH in Kitzingen, Germany, was utilized in this study.

XI. Hectoliter weight (test weight) (kg/hl): The hectoliter weight is a metric used to quantify the volume of wheat. Elevated hectoliter weights indicate cereals that possess higher density and weight, often associated with increased protein content, upon collecting a sample of wheat grains that is both representative and devoid of any visible impurities and has been thoroughly dried. A hectoliter weight measuring device was utilized in conjunction with a kilogram-based scale. The experiment was conducted under standard laboratory conditions, with the ambient temperature maintained at approximately 20 degrees Celsius. The hydration content of the wheat sample was found to range between 12% and 14%. If the sample deviates from the standard temperature and moisture content, conversion tables are utilized to adjust the results. The weighing scale was employed to ascertain the mass of the empty hectoliter weight measuring device, which was recorded in kilograms. The wheat samples were carefully poured into the hectoliter weight measuring instrument up to its rim, ensuring no compression or shaking was applied to avoid compaction. The weight of the hectoliter weight measuring device, filled with the wheat sample, was recorded for each individual sample. The weight of the wheat sample was measured in kilograms. The kilograms per hectoliter ($kghl^{-1}$) value was calculated by dividing the net weight by the volume of the hectoliter weight measuring device in liters, Eq. IV.

Eq. IV Hectoliter weight ($kghl^{-1}$) = (Weight of filled hectoliter device - Weight of empty device) / Volume of hectoliter device in liters

The calculated hectoliter weight represents 100 liters (1 hectoliter) of wheat. Higher hectoliter weights indicate typically denser and heavier grains, which are frequently associated with a higher protein content and a higher quality of wheat. Lower hectoliter weights may signify lesser kernels and a lower quality of wheat.

XII. Protein content (%): The protein content was measured thrice, each time focusing on different aspects. Wheat flour's protein content was measured using a near-infrared (NIR) grain analyzer. This analysis involved obtaining representative sub-samples of wheat grains from each harvested sample on two occasions: once on the day of harvest and again one month after the harvest day. The third iteration of protein quantification involved the utilization of a near-infrared (NIR) flour analyzer, specifically the DICKEY-John model. To prepare the wheat grains for analysis, they were finely ground into a powder using a milling apparatus. Subsequently, the flour was introduced into the near-infrared (NIR) machine. The percentage of protein was determined.

XIII. Gluten content (%): Following selecting a representative sub-sample from the harvested wheat grains, a cleaning process was conducted to eliminate impurities and foreign substances. The grains were pulverized into a fine powder utilizing a milling apparatus. A quantity of ten grams of the wheat flour sample was measured and transferred into a small kneading bowl. Subsequently, 5 ml of distilled water was introduced into the beaker and agitated to produce a cohesive mixture resembling dough. The dough underwent a 30-second kneading process using a vibrating kneader device, resulting in a smooth texture. Subsequently, the dough was subjected to a gluten washer, which underwent a washing process utilizing running water containing 2% sodium chloride (NaCl) for 20 minutes. The gluten that had been washed was subsequently gathered on filter paper, and its weight was determined following a centrifugation process lasting 2 minutes. Subsequently, the gluten sample was weighed, and the corresponding measurements were duly documented. Sadkiewicz Instruments is a brand associated with the bakery industry LTD research institute (ZBPP). This brand specializes in producing various instruments used in gluten analysis, including the gluten wash machine, vibrating kneader (type sz-1), and the gluten centrifuge.

XIV. Falling Number, Hagberg number (second): The wheat grain under examination was ground according to the specifications outlined in the PN-ISO 3093 standard, as any deviation from the prescribed procedure may impact the outcome of the test. A 7-gram analytical sample of the flour was obtained for testing, with a moisture content of 15%, as indicated by a reference table. The analytical sample was transferred into the viscometric test tube with 25 ml of distilled water, maintaining a temperature of 20±5 °C. The test tube was sealed using a rubber stopper, and the sample was manually agitated for 20 seconds using vertical and horizontal movements to achieve a uniform mixture. The closure was removed, and the stirrer was inserted into the test tube, effectively scraping the flour from the inner walls of the test tube and incorporating it into the slurry. The test tube, equipped with a stirrer, was carefully immersed in the boiling water bath tank of the falling number device. Following a duration of 60 seconds, the stirrer was automatically disengaged from the drive unit, and subsequently, the obtained results were documented. The instrument utilized for the falling time assays is manufactured by Sadkiewicz Instruments (ZBPP).

XV. Near-infrared (NIR) Tests: Two different NIR instruments were used, the NIR for grain analyzer and the NIR for flour analyzer. The grain analyzer was used after preparing a clean sample, filling the instrument's glass container, and placing it into it. Within about 2 minutes, the results of Gluten content, moisture percentage, protein content, and Zeleny index were obtained and recorded in the prepared Excel file. NIR flour analyzer (DICKEY-john) was used after grinding the grain with a mill, placing the flour into the testing tool, and placing it into the device. The values of moisture percentage, protein content, and gluten content of the flour were obtained within 3 minutes. These values were recorded in the prepared Excel file.

4.5 Statistical Analysis

The results and data presented are expressed as a mean value for each sub-experimental section. Analysis of variance (ANOVA) and Fisher's test of least significant differences were used to determine significant differences at the 5% probability level for the water quantity experiment, seedling density experiment, and antifungal growth experiment using computing programs (GenStat twelfth edition, GenStat Procedure Library Release PL20.1m, and MS Excel 365). A sigmoid curve model was applied using statistical computing programs (J.M.P. Pro 13.2.1 of S.A.S. by SAS Institute, Canberra, the USA, and MS Excel 365) to fit the data and plot the best-fit temperature levels. The data were checked for normality using Skewness and Kurtosis in SPSS v27, IBM, New York, the USA.

5 RESULTS AND THEIR DISCUSSION

This study investigates the impact of abiotic factors, such as drought or heat and waterlogging stresses, on the germination, crop establishment, growth, and development across different life stages of wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) in field and laboratory conditions. The findings of this study enhance our comprehension of how plants react to abiotic stresses and aid in developing novel strategies. Thus, it is essential to investigate the plant stress tolerance mechanisms to identify novel management components and techniques for enhancing crop resistance and tolerance. Hereafter the result will come just in the order of each experiment described in the last chapter.

5.1 Pre-Sowing Seed Priming Experiment

Seed priming with gibberellin (GAs) and salicylic acid (SA) to encounter abiotic stresses of drought and waterlogging and heat tolerance of wheat. Seed priming technology, which means soaking the seeds before sowing, with plant growth regulators to benefit linked between the stimulation process of seed germination and the germination process itself. It can improve and homogenize emergence, giving a robust homogeneous arrangement and better early field foundation. The pre-adaptation response may help counter various stresses present, including water shortage and waterlogging, thus reducing the damage caused by this stress on the plant's growth and yield. Moreover, this technology is simple, cost-effective, and risk-free. The experiment aims to determine the varying responses of wheat cultivars to stimulus parameters.

The treatments, especially salicylic acid (SA), present a remarkable phenotypic seedling vigor compared to the control. The seedlings emerged faster, and they were taller than their competitors. Notwithstanding the impact of irrigation, the application of SA priming to wheat seedlings resulted in a cereal yield increase of 0.37%, Table 5.1. In contrast, the GAs exhibited the maximum yield production of 2797.8 kg/ha under no irrigation, a 3.90% increase compared to the control group that received the same irrigation regime. This result is consistent with the measurement of the green yield (measured before cleaning the yield directly from the harvester machine), Table B.5. 1. This suggests that GAs exhibits greater efficacy under severely desiccated conditions, whereas SA demonstrates greater significance under dry to normal conditions. Irrigation regime (starting from Feekes 6 of 20 mm of water at different irrigation regime) and irrigation frequency (every 3, 6, and 9 days) are more important than the treatment in drought stress. Irrigation frequency of every 6 days significantly increased the grain yield by 82.70% compared to the control. Irrigation every 6 days made a substantially higher yield than the 3- and 9-day irrigation frequency of 6154.8 and 6272 kg/ha, respectively, Table 5.1. It means that irrigation every 3 days negatively affects plant growth due to waterlogging, and SA is more effective in facing waterlogging than GAs at this irrigation level. It seemed that irrigation of every 9 days (20 mm water) is insufficient due to the applied water quantity or the duration itself. We attributed it to the irrigation duration since the duration of 6 days was mainly in soils of sandy texture. The variety significantly affects plant final yield, where the modern produced varieties Nemere and Felleg resulted in considerably higher yields than the old variety of Alföld of 20.02% and 19.69%, respectively. However, Nemere resulted in a significantly higher grain yield, 5766.7 kg/ha, than the Felleg, 5747 kg/ha, with an LSD of 5.92, Table 5.1. It means genetics is essential in interacting with environmental factors, including abiotic stresses and priming treatment.

Table 5.1. The impact of gibberellin and salicylic acid on the yield kg/ha of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	2350.0	6443.3	7356.7	6850.0	5750.0	
	GAs	2900.0	5740.0	7050.0	6740.0	5607.5	
	SA	2653.3	6256.7	7303.3	7556.7	5942.5	
Alföld	Cont.	2101.7	5049.7	5452.0	5403.3	4501.7	
	GAs	2443.3	5803.3	5500.0	5300.0	4761.7	
	SA	2050.0	5750.0	5750.0	6000.0	4887.5	
Felleg	Cont.	3620.0	7300.0	6800.0	6450.0	6042.5	
	GAs	3050.0	6700.0	6850.0	6100.0	5675.0	
	SA	3150.0	6350.0	6550.0	6050.0	5525.0	
LSD_{V*T*I}		20.51				LSD_{V*T}	10.26
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		2634.4	6146.7	7236.7	7048.9	5766.7 a	
Alföld		2198.3	5534.3	5567.3	7048.9	4716.9 c	
Felleg		3273.3	6783.3	6733.3	6200.0	5747.5 b	
LSD_{V*I}		11.84				LSD_{V}	5.92
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		2690.6	6264.3	6536.2	6234.4	5431.4 b	
GAs		2797.8	6081.1	6466.7	6046.7	5348.1 c	
SA		2617.8	6118.9	6534.4	6535.6	5451.7 a	
LSD_{T*I}		11.84				LSD_{T}	5.92
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		2702.0 d	6154.8 c	6512.4 a	6272.2 b		
LSD_{I}		6.84					

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, and T*I is the interaction between the treatments and irrigation.

Thousand-kernel weight (TKW) is a crucial physical yield indicator. The seed priming treatments and irrigation affected it. SA and GAs increased the TKW by 2.42% and 2.18%, respectively, Table 5.2. An irrigation interval of 6 days under dry circumstances seems optimal for favorably influencing the thousand-grain weight of wheat, as compared to shorter or longer intervals. The value saw a substantial increase of 5.85% after a 3-day irrigation period, followed by an additional boost of 1.19%. Waterlogging stress seems to impact the TKW significantly more than drought stress. The differences among the varieties are evident, with Nemere having the highest TKW of 46.5 g, followed substantially by Felleg at 39.9 gm, and then by Alföld at 37.6 gm with an LSD of 0.433, Table 5.2 and Table B.5. 2.

Elevated hectoliter weights are indicative of cereals that possess higher density and weight. The hectoliter weight, a metric used to measure the volume of wheat, did not exhibit any significant differences due to the priming treatments of SA and GAs, as shown in Table B.5. 3. However, irrigation affects the test weight value when the control had a significantly higher value than the 3, 6, and 9 days irrigation duration by 2.61%, 1.03%, and 1.95%, respectively. It is reasonable since the control produced seeds with lower TKW. Varieties differ in this measure, where Alföld had the heist value 77.2 kg $hl^{-1,}$ significantly followed by Felleg 76.6 kg $hl^{-1,}$ significantly followed by 75.8 kg hl^{-1}, Table B.5. 3. It means drought and old varieties resulted in height seed density and higher weight per mass, but lower grain size and total yield.

Table 5.2. The impact of gibberellin and salicylic acid on the TKW (g) of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T
		0	3 Days	6 Days	9 Days	
Nemere	Cont.	43.6	44.8	48.9	46.6	46.0
	GAs	45.6	47.2	46.8	43.4	45.7
	SA	49.9	46.3	47.3	47.7	47.8
Alföld	Cont.	37.8	35.4	37.0	37.9	37.0
	GAs	38.1	36.8	38.7	41.5	38.8
	SA	37.8	36.6	37.5	36.3	37.1
Felleg	Cont.	38.4	37.9	39.7	40.9	39.2
	GAs	42.2	37.7	41.9	39.5	40.4
	SA	41.7	35.3	42.2	41.7	40.2
LSD $_{V*T*I}$		1.501				LSD $_{V*T}$ 0.751
V * I						
Varieties		0	3 Days	6 Days	9 Days	Variety means
Nemere		46.4	46.1	47.7	45.9	46.5 a
Alföld		37.9	36.3	37.7	45.9	37.6 c
Felleg		40.8	37.0	41.3	40.7	39.9 b
LSD $_{V*I}$		0.867				LSD $_{V}$ 0.433
T * I						
Treatments		0	3 Days	6 Days	9 Days	T. mean
Cont.		39.9	39.3	41.9	41.8	40.7 b
GAs		42.0	40.6	42.5	41.5	41.6 a
SA		43.2	39.4	42.3	41.9	41.7 a
LSD $_{T*I}$		0.867				LSD $_{T}$ 0.433
I						
Irrigation		0	3 Days	6 Days	9 Days	
Irrigation means		41.7 b	39.8 c	42.2 a	41.7 b	
LSD $_{I}$		0.5				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, and T*I is the interaction between the treatments and irrigation.

Leaf area index (LAI) is a quantitative measure of the total leaf surface area per unit ground area. It indicates plant health and may provide insights into the plant's response to various stressors and nutrient availability. The application of seed priming with SA and GAs does not substantially impact the LAI, but in combination with irrigation. Nevertheless, irrigation substantially influenced the LAI, with irrigation intervals of 3 and 6 days resulting in considerably larger values than the control group (no irrigation) and the group with a 9-day irrigation interval. Applying irrigation of 20 mm at intervals of 3, 6, and 9 days resulted in a significant increase in LAI by 79.08%, 77.31%, and 63.55%, respectively, Table 5.3. It suggests that irrigation every less than 9 days in the Hungarian climate prevents drought from affecting the leaf area index and, ultimately, the yield output.

Table 5.3. The impact of gibberellin and salicylic acid on the leaf area (m^2) of *Triticum aestivum* L. is influenced by seed priming interventions and irrigation and drought cycles measured at anthesis in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	0.76	3.04	3.21	2.93	2.49	
	GAs	1.17	3.22	3.84	1.88	2.53	
	SA	1.38	1.93	3.36	3.79	2.62	
Alföld	Cont.	1.49	3.14	2.99	3.34	2.74	
	GAs	1.70	3.14	2.82	2.33	2.50	
	SA	1.82	3.48	2.79	2.82	2.73	
Felleg	Cont.	1.88	3.09	4.95	2.49	3.10	
	GAs	1.35	4.56	3.38	2.15	2.86	
	SA	1.61	4.71	2.34	3.68	3.09	
LSD $_{V*T*I}$		0.55				LSD $_{V*T}$	N.S
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		1.10	2.73	3.47	2.87	2.54 b	
Alföld		1.67	3.25	2.87	2.87	2.66 b	
Felleg		1.61	4.12	3.56	2.77	3.02 a	
LSD $_{V*I}$		0.32				LSD $_{V}$	0.16
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		1.38	3.09	3.72	2.92	2.78 a	
GAs		1.41	3.64	3.35	2.12	2.63 a	
SA		1.60	3.37	2.83	3.43	2.81 a	
LSD $_{T*I}$		0.32				LSD $_{T}$	N.S
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		1.46 c	3.37 a	3.30 a	2.82 b		
LSD $_{I}$		0.18					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, and T*I is the interaction between the treatments and irrigation.

Photosynthesis is significantly influenced by abiotic stress, particularly drought. Seed priming treatments with SA and GAs did not impact the photosynthetic of wheat plants, as shown in Table 5.4.. Nevertheless, irrigation significantly enhances the rate of photosynthesis. Applying 20 mm irrigation every 3 days led to a considerably higher SPAD value than the control and 6 and 9 days, by 29.39%, 14.80%, and 12.80%, respectively, Table 5.4. It signifies that when drought stress increases, the photosynthetic process is more severely affected, particularly when the soil texture has a significant proportion of sand. There was a noticeable variation among the varieties in their photosynthetic rate when exposed to drought stress. Nemere significantly has the highest SPAD value compared to Felleg and Alföld, with a respective increase of 6.73% and 11.08%. This may account for the superior ultimate output of Nemere compared to the other used varieties. It may be inferred that drought stress significantly impacts photosynthetic activity, and the interaction between genes and the environment also plays a role. However, seed priming does not have an effect, but irrigation is required for a duration of less than 9 days.

Table 5.4.The impact of gibberellin and salicylic acid on the photosynthesis activity (SPAD) of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles measured at anthesis in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	39.5	50.9	59.2	44.7	48.6	
	GAs	27.1	56.3	42.5	56.0	45.5	
	SA	46.0	55.1	41.3	52.3	48.7	
Alföld	Cont.	33.0	56.1	48.3	41.4	44.7	
	GAs	36.3	46.2	40.9	45.5	42.2	
	SA	41.4	56.4	45.8	42.7	46.6	
Felleg	Cont.	38.8	40.4	43.5	35.6	39.6	
	GAs	43.9	59.7	41.2	45.2	47.5	
	SA	38.9	42.6	37.2	44.3	40.8	
LSD $_{V*T*I}$		6.85				LSD $_{V*T}$	3.43
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		37.5	54.1	47.7	51.0	47.6 a	
Alföld		36.9	52.9	45.0	51.0	44.5 b	
Felleg		40.5	47.6	40.6	41.7	42.6 b	
LSD $_{V*I}$		3.96				LSD $_{V}$	1.98
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		37.1	49.1	50.3	40.6	44.3 a	
GAs		35.8	54.1	41.5	48.9	45.1 a	
SA		42.1	51.4	41.4	46.4	45.3 a	
LSD $_{T*I}$		3.96				LSD $_{T}$	N.S
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		38.3 c	51.5 a	44.4 b	45.3 b		
LSD $_{I}$		2.28					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, and T*I is the interaction between the treatments and irrigation.

Quantum yield (QY), the measurement of photosynthesis II efficiency, is equivalent to Fv / Fm in dark-adopted samples and Fv1 / Fm1 in light-adapted samples. The photosynthetic stress index did not show any significant difference in the plant's capacity to withstand drought stress in response to seed priming treatments with SA and GAs, Table B.5. 4. However, other variations exhibited varying levels of tolerance to drought stress with different wheat varieties. Specifically, the Nemrere variety showed much higher resistance to drought stress than the Felleg and Alföld types, with QY values of 0.780, 0.720, and 0.740, respectively, Table B.5. 4. This was seen in the field yield, where Nemere produced the greatest grain yield by a substantial margin. Irrigation has a significant role in alleviating the stress on photosynthesis caused by drought, Figure 5.1.

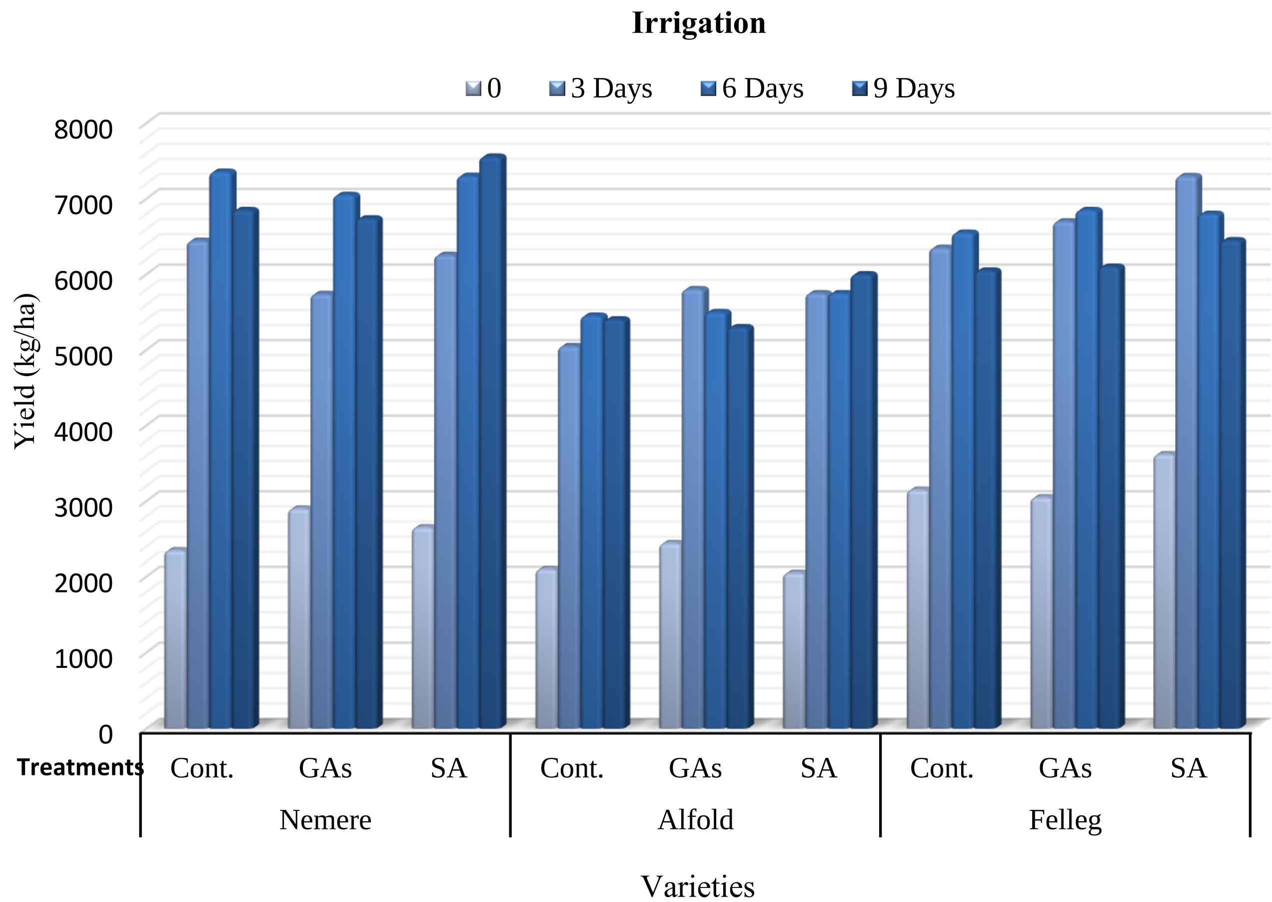

Figure 5.1. Final grain yield of wheat under different irrigation regime from different varieties and priming treatments.

3 Days is applying irrigation every three days; 6 Days is irrigation of every 6 days; 9 Days is irrigation of every 9 days; Cont is the control; GA is the gibberellin treatment; SA is the Salicylic acid treatment

Plant height is a central part of plant ecological strategy. It is strongly correlated with life span, seed mass, and time to maturity and is a major determinant of a species' ability to compete for abiotic elements. Statistics present significant differences among the wheat varieties used. Alföld showed the highest values of plant height with a mean of 84.8 cm, significantly taller than Nemere at 76.8 cm and Felleg at 77.2 cm, Table B.5. 5. Treatments of SA and GAs had no significant impact on plant height compared to the control. Irrigation significantly increases the plant height by 8.98%, 9.47%, and 8.370%, respectively, with irrigation duration of 3, 6, and 9 days, Table B.5. 5. It means irrigation has more importance than seed priming in affecting the height of the plants, although in the very earlier seedling stages the treated planted had taller seedlings.

The tiller count is an essential determinant of the final crop yield and the general well-being of the plant concerning its surrounding environment. The tillering of wheat plants may be affected by abiotic stress during the early stages of growth. The obtained data demonstrates that irrigation substantially enhances the wheat plant's capacity to produce more tillers, as compared to the control group, Table B.5. 6. Specifically, an irrigation frequency of every 6 days yielded a statistically higher number of tillers than shorter and longer irrigation durations. The number of tillers showed a substantial significant increase with irrigation. Specifically, compared to the control, the number of tillers grew significantly by 8.69%, 12.76%, and 10.75% with irrigation durations of 3, 6, and 9 days, respectively, Table B.5. 6. An irrigation frequency of 6 days with 20 mm starting from Feekes 6 is considered appropriate for wheat in the Hungarian climate. Shorter or longer durations may have adverse effects, such as water logging or water deficit, especially if the duration is too long. The tiller number of wheat plants was dramatically significantly boosted by seed priming treatments, with SA having a more pronounced impact than GAs. Using SA resulted in a 17.02% rise in plant tillers, whereas the application of GAs led to a 13.043% increase compared to the control, Table B.5. 6. The data also indicated significant variations among the tested wheat varieties. Alföld had the highest number of tillers, with a value of 5.1, followed by Nemere with 4.7, and Felleg with 4.5, with an LSD value for these comparisons of 0.2, Table B.5. 6. The results suggest that irrigation has a substantial impact on the production of plant tillers, with a duration of 6 days being the optimal period. Additionally, treating seeds with SA and GAs significantly enhances the number of tillers. Furthermore, there are variations in the capacity of different wheat varieties to generate more or fewer tillers under diverse environmental conditions and abiotic stresses.

The number of wheat spikes per unit area is one of the most important agronomic traits associated with wheat yield. As shown in the data, drought significantly affects the number of spikes produced in a unite area (m^2). Irrigation duration also has a role; a moderate duration of 6 days frequency is ideal compared to 3 or 9 days. Irrigation every 6 days increases the number of spikes per square meter by 59.11% (922.2 spike m^2) compared to the control (504.4 spike m^2). While SA has a significant positive effect on increasing the value of this trait, 766.7 spike m^2, GAs had a reverse effect, 673.9 spike m^2, compared to the control 736.1 spike m^2. Statistics present either statistical or significant variations among the wheat varieties used in their ability to produce spikes under different drought conditions. Nemere and Alföld produced significantly more spikes per unit area than Felleg. It means there are significant differences among the varieties and their interaction with the environment to withstand drought and different abiotic stresses. Hence, irrigation, especially the duration of 6 days, and SA increased the wheat spikes per unit area under the Hungarian climate, especially during drought.

The wheat yield is significantly influenced by the density of wheat spikes per unit area, making it a crucial agronomic trait and yield component. The number of spikes produced by a unit area (m^2) is considerably affected by drought, as the statistics obtained show. The irrigation frequency also has an impact; a moderate period of 6 days is considered preferable compared to 3 or 9 days. Irrigating every 6 days leads to a 59.11% increase in the number of spikes per square meter (922.2 spikes m^2) compared to the control (504.4 spikes m^2), Table B.5. 7. Although SA had a notable beneficial impact on enhancing the value of this trait, resulting in a spike of 766.7 m^2, GAs had a contrary effect, with a spike of 673.9 m^2 compared to the control's spike of 736.1 m^2 with an LSD of 21.1, Table B.5. 7. The statistics reveal significant differences in the spike production capacity of several wheat varieties when exposed to varying drought situations. Nemere and Alföld had a much higher spike density per unit area than Felleg. This indicates notable variations among the different varieties and their response to the environment regarding their ability to endure drought and other abiotic stressors. Therefore, irrigation, specifically over a period of every 6 days, together with the application of SAL, increased the number of wheat spikes per unit area in the Hungarian climate, particularly in areas experiencing drought.

The number of spikelets per spike is a definitive predictor of the eventual yield. This trait is mainly determined by hereditary factors and is influenced by the surrounding environment. Abiotic stressors significantly impact this agronomic trait. Seed priming with GAs considerably enhances the value of this trait relative to the SA and control treatments, Table B.5. 8. The value had a 2.312% rise compared to the control. Irrigation leads to a substantial increase in the number of pikelets per spike. Specifically, for irrigation durations of 3, 6, and 9 days, the growth is 30.86%, 27.12%, and 28.75%, respectively. The frequency of irrigation showed a significant difference. Irrigation every 3 days resulted in an average of 18.7 spikelets per spike, whereas irrigation every 6 and 9 days resulted in averages of 18 and 18.3 spikelets per spike, respectively, with an LSD of 0.29, Table B.5. 8. During the spikelets forming and developing stage, plants exhibit a higher need for water compared to previous phases of development. There is an apparent variance among different growing wheat varieties in their capacity to produce more or fewer spikelets, which is influenced by their genetic potential and the surrounding environment. They vary in their capacity to withstand drought stress. Alföld produces a significantly higher number of spikelets, with an average of 18.7, compared to Felleg, which has an average of 17.2. Additionally, Felleg has a significantly higher number of spikelets than Nemere, which has an average of 15.6, Table B.5. 8. To summarize, the trait is variety-dependent and greatly influenced by the abiotic stress of drought. However, using irrigation and seed priming with GAs may help alleviate the negative impact of abiotic stress on this trait.

The falling number (FN) test indirectly measures α-amylase activity in wheat flour samples to determine if they contain sprouted grain, though not continually visibly sprouted. Flour from sprouted grain is undesirable for bakers because it produces undesirable loaf characteristics. Falling numbers over 250 seconds are most suitable for the bread-baking process. In contrast, FNs above 350 seconds may indicate that the flour should be supplemented with a form of amylolytic enzyme or malted grain flour. The values 250-350 are applicable if the samples are measured in around september-october. If the samples are measured later, higher FN is produced as the long chain proteins are falling in smaller peace's. There's no measure in the favorable range. Most large-scale bakeries work with an ideal FN range of 250–280 seconds. Different values of fall numbers may be specific to unique products and processing conditions inside the plant (CAUVAIN, 2017). Seed priming did not substantially impact the FN values, with the control, SAL, and GAs having corresponding values of 386.6, 389.1, and 394.6 seconds, Table 5.5. Alföld had an FN of 352.0 seconds, whereas Felleg had an FN of 396.6 seconds, and Nemere had an FN of 421.8 seconds, with an LSD of 7.33, Table 5.5. Irrigation does not have a definitive impact on the FN. However, when applying a moderate irrigation of 20 mm of water every 9 days, the FN is considerably improved, which approaches the optimal range. This implies that the traits influenced by abiotic stress and moderate irrigation are justifiable, but seed priming treatments are not.

Table 5.5. The impact of gibberellin and salicylic acid on the falling number (seconds) of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	467.0	404.0	412.0	423.0	426.5	
	GAs	443.0	400.0	440.0	403.0	421.5	
	SA	430.0	387.0	442.0	411.0	417.5	
Alföld	Cont.	323.0	345.0	375.7	357.0	350.2	
	GAs	361.0	324.3	320.3	387.0	348.2	
	SA	344.0	331.0	383.7	371.7	357.6	
Felleg	Cont.	376.0	411.0	446.0	300.0	383.2	
	GAs	428.0	466.0	353.0	410.0	414.2	
	SA	351.0	434.0	446.0	338.0	392.2	
LSD $_{V*T*I}$		25.4				LSD $_{V*T}$	12.7
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		446.7	397.0	431.3	412.3	421.8 a	
Alföld		342.7	333.4	359.9	412.3	352.0 c	
Felleg		385.0	437.0	415.0	349.3	396.6 b	
LSD $_{V*I}$		14.67				LSD $_V$	7.33
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		388.7	386.7	411.2	360.0	386.6 a	
GAs		410.7	396.8	371.1	400.0	394.6 a	
SA		375.0	384.0	423.9	373.6	389.1 a	
LSD $_{T*I}$		14.67				LSD $_T$	N.S
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		391.4 b	389.1 b	402.1 a	377.9 c		
LSD $_I$		8.47					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, and T*I is the interaction between the treatments and irrigation.

The gluten levels in wheat flour vary significantly depending on the irrigation and seed priming treatments, affecting the plant's capacity to withstand abiotic stress. Irrigation significantly enhances the gluten content. Seed priming with GAs and SA significantly affected the wheat flour's final gluten content. Priming with GAs increased this quality trait by 4.26% and SA by 3.0%. There was a notable variance in the durations of irritation and their influence on the gluten content. Gluten content increased by 18.37%, 6.21%, and 3.74% compared to the control with the irrigation frequencies of 3, 6, and 9 days, respectively, Table 5.6. Irrigation significantly reduced the impact of drought on gluten content. In the grain-filling stage, an irrigation frequency of 20 mm every 3 days was optimal compared to other irrigation durations. The wheat plant requires more water during the grain filling than earlier stages. There are notable differences among the wheat varieties concerning these quality traits. Felleg had significantly the highest gluten content at 28.08%, followed by Nemere at 27.46%, and then Alföld at 22.02%, Table 5.6. This implies that the gluten content is determined by the interplay of genetic and environmental variables and is mainly influenced by abiotic stress. Thus, throughout the grain-filling stage, plants need increased water intake to alleviate the effects of drought stress. Failure to do so will adversely impact the gluten percentage. A slight change occurs in the gluten percentage within a month after harvest since the grain biologically changes as showed in Table B.5. 9 and Table B.5. 10.

Table 5.6. The impact of gibberellin and salicylic acid on the whole flour gluten percentage of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	22.50	25.10	22.70	10.81	20.28	
	GAs	24.30	21.40	21.30	25.20	23.05	
	SA	21.90	22.80	21.80	24.40	22.73	
Alföld	Cont.	25.70	31.07	26.90	29.23	28.23	
	GAs	22.70	28.63	28.00	26.23	26.39	
	SA	25.70	29.60	25.63	30.07	27.75	
Felleg	Cont.	25.00	31.50	29.00	23.20	27.18	
	GAs	24.30	32.50	29.90	31.50	29.55	
	SA	24.10	37.30	24.80	23.90	27.53	
LSD $_{V*T*I}$		1.34				LSD $_{V*T}$	0.67
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		22.90	23.10	21.93	20.14	22.02 c	
Alföld		24.70	29.77	26.84	20.14	27.46 b	
Felleg		24.47	33.77	27.90	26.20	28.08 a	
LSD $_{V*I}$		0.77				LSD $_{V}$	0.39
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		24.40	29.22	26.20	21.08	25.23 b	
GAs		23.77	27.51	26.40	27.64	26.33 a	
SA		23.90	29.90	24.08	26.12	26.00 a	
LSD $_{T*I}$		0.77				LSD $_{T}$	0.39
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		24.02 d	28.88 a	25.56 b	24.95 c		
LSD $_{I}$		0.45					

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, and T*I is the interaction between the treatments and irrigation.

The protein content in mature wheat grains ranges from 8% to 14%. Wheat proteins exhibit a high level of intricacy and diverse interactions among themselves, which poses challenges in their characterization. Typically, they are categorized based on their ability to dissolve. In this drought stress experiment, irrigation presents an apparent positive effect in improving the protein content of the wheat flour. When testing the whole flour using near-infrared spectroscopy (NIR), it was shown that irrigation's irrigation and frequency significantly impacted protein content. Specifically, the trait rose by 7.40%, 3.53%, and 2.56% for every 3, 6, and 9 days of irrigation, respectively, Table 5.7. It appears that irrigation is required more frequently during the grain-filling stage, either due to increased water demand for biological activity or due to more extreme abiotic conditions compared to earlier stages. In Hungary, May and June are hotter than the preceding months. Data present that seed priming have a slight a beneficial impact on the overall protein level of the flour. Nevertheless, there were notable discrepancies among the planted varieties with respect to this quality trait. Alföld had the greatest protein level at 10.76%, substantially more than Felleg at 10.45% and Nemere at 9.86%, Table 5.7. The protein content of the grains had changed after harvest for Nemere, Alföld and Felleg from 11.91%, 12.67%, and 13.02%, respectively, at the harvest day to 11.89%, 12.83%, and 13.21% a month after harvest, Table B.5. 11 and Table B.5. 12.

Table 5.7. The impact of gibberellin and salicylic acid on the whole flour protein percentage of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	9.88	10.20	9.73	9.51	9.83	
	GAs	9.41	9.71	9.74	10.48	9.84	
	SA	9.65	9.87	9.97	10.18	9.92	
Alföld	Cont.	10.19	11.39	10.79	10.99	10.84	
	GAs	10.13	10.89	11.10	10.24	10.59	
	SA	10.13	11.15	10.94	11.19	10.85	
Felleg	Cont.	10.36	11.43	11.12	9.81	10.68	
	GAs	10.10	11.29	10.24	10.41	10.51	
	SA	10.24	11.09	9.68	9.60	10.15	
LSD $_{V*T*I}$		0.35				LSD $_{V*T}$	0.18
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		9.65	9.93	9.81	10.06	9.86 c	
Alföld		10.15	11.14	10.94	10.06	10.76 a	
Felleg		10.23	11.27	10.35	9.94	10.45 b	
LSD $_{V*I}$		0.20				LSD $_V$	0.10
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		10.14	11.01	10.55	10.10	10.45 a	
GAs		9.88	10.63	10.36	10.38	10.31 b	
SA		10.01	10.70	10.20	10.32	10.31 b	
LSD $_{T*I}$		0.20				LSD $_T$	0.10
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		10.01 c	10.78 a	10.37 b	10.27 b		
LSD $_I$		0.12					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, and T*I is the interaction between the treatments and irrigation.

Data from the Zeleny test present significant differences between the irrigated and not irrigated treatments under drought stress, and irrigation increase the sedimented volume by 21.37%, Table B.5. 14. Irrigation duration is also an important in this trait where irrigation duration of every 3 days were significantly higher by 12.04% and 13.57% compared to the 6 and 9-day irrigation duration. Seed priming with GA2 and SA significantly positively affected the value of this trait where GAs had a value of 39.58%, SA with a value of 39.18%, and the control l38.25% with an LSD of 0.64. There is a significant variation among the varieties regarding the SDS-sedimentation volume with Alföld 37.66, Nemere 38.44, and Felleg 40.92, Table B.5. 14. It can be said that seed priming with GAs and irrigation, especially 20 mm irrigation every 3 days, significantly improve the SDS value and the quality of the final product.

Irrigation from different irrigation durations significantly resulted in higher flour moisture of the flour and the grain compared to the control, Table B.5. 15, Table B.5. 16, Table B.5. 17. It means irrigation is adequate in facing drought and heat stress, especially at later plant life stages.

The correlation coefficient (r) values are in, refers to the strength and the direction of each measured trait to the other at P-value ≥ 0.01 and P-value ≥ 0.05. Yield is strongly correlated at P-value ≥ 0.01 to LAI, SPAD, QY, plant height, spikes number per square meter, spikelet number, and the moisture percentage on the harvest day, Table 5.8. However, it negatively correlated to the test weight. It can be indicated that the yield's quantity and quality parameters are independent of each other or rather than opposite in general.

Based on the Hungarian environment for wheat production, it is evident that irrigation of 20 mm every 6 days is beneficial during the vegetative growth stages during a dry year, particularly during stem elongation stages (Feekes 6 to Feekes 10). This irrigation regimen is crucial for enhancing plant biomass, photosynthesis activity, and, finally yield quantity. Additionally, irrigation every 3 days during the grain-filling and stage is essential for improving quality aspects such as protein content, gluten content, and sedimentation volume. Seed priming with gibberellic acid and salicylic acid has a notable beneficial impact on enhancing plants' ability to withstand drought-induced abiotic stress. They enhanced several traits related to plant growth and crop productivity, such as the overall yield, weight of individual grains, number of plant tillers, number of spikelets per plant shoot, gluten content, and Zeleny index. The planted varieties exhibited notable differences in performance, with the newer varieties Menrot and Felleg outperforming the historic local variety Alföld in their resistance to drought stress.

Table 5.8. Correlation coefficients among seed priming and wheat abiotic stress experiment study parameters, 2023, MATE - Gödöllő.

	Final Yield	Green Yield	TGW g	TW	LAI	SPAD	QY	Plant Height	Tillers n	Spikelet n	Spikes n m2	Gluten %	FN	Gluten % *	Moisture % *	Protein %*	SSD**	Gluten% **	Moisture% **	Protein% **	Gluten ***	Moisture%***	Protein%***
Green Yield	0.97																						
TGW	0.14	0.06																					
TW	-0.32	-0.40	0.00																				
LAI	0.72	0.74	-0.12	-0.29																			
SPAD	0.44	0.41	0.20	0.02	0.37																		
QY	0.44	0.42	0.24	0.19	0.27	0.47																	
Plant Height	0.35	0.42	-0.48	0.11	0.39	0.22	0.35																
Tillers	0.21	0.21	-0.11	0.21	0.28	0.24	0.32	0.59															
Spikelet's n	0.55	0.58	-0.47	0.06	0.58	0.27	0.48	0.75	0.46														
Spikes n m2	0.62	0.63	0.12	-0.09	0.60	0.23	0.32	0.47	0.38	0.46													
Gluten %	0.25	0.37	-0.38	-0.20	0.34	0.37	0.20	0.42	0.26	0.37	0.11												
FN	0.16	0.11	0.44	-0.24	0.12	0.16	0.16	-0.27	-0.08	-0.22	0.26	0.03											
Gluten % *	0.26	0.31	-0.49	-0.10	0.40	0.25	0.30	0.33	0.13	0.50	-0.02	0.68	0.08										
Moisture % *	0.05	0.04	-0.06	0.42	-0.15	0.20	0.48	0.35	0.42	0.32	-0.13	0.30	-0.16	0.33									
Protein % *	0.09	0.15	-0.57	0.01	0.29	0.14	0.13	0.31	0.13	0.42	-0.16	0.68	0.01	0.90	0.38								
SDS *	0.11	0.12	-0.21	-0.01	0.00	0.22	0.09	0.40	0.18	0.19	0.16	0.34	0.14	0.36	0.22	0.31							
Gluten % **	0.32	0.38	-0.57	-0.07	0.46	0.34	0.16	0.36	0.12	0.50	0.09	0.73	0.01	0.81	0.26	0.81	0.40						
Moisture % **	0.34	0.37	-0.11	-0.13	0.40	0.20	0.41	0.22	0.14	0.47	0.37	0.35	0.33	0.47	0.21	0.37	0.18	0.47					
Protein % **	0.12	0.17	-0.55	-0.01	0.31	0.14	-0.01	0.28	0.12	0.39	-0.02	0.57	-0.07	0.70	0.23	0.75	0.30	0.81	0.36				
SDS**	0.22	0.27	-0.14	-0.46	0.29	-0.05	0.04	0.12	0.07	0.33	0.29	0.27	0.37	0.42	-0.06	0.33	0.23	0.30	0.66	0.46			
Moisture% ***	0.15	0.18	-0.11	0.30	0.15	0.21	0.55	0.37	0.13	0.48	0.20	0.25	0.07	0.42	0.46	0.37	0.16	0.34	0.76	0.35	0.36		
Protein % ***	0.19	0.24	-0.66	0.13	0.40	0.24	0.23	0.71	0.27	0.63	0.18	0.60	-0.14	0.73	0.36	0.71	0.53	0.75	0.38	0.67	0.27	0.45	
Gluten % ***	0.13	0.19	-0.66	-0.08	0.36	0.09	0.05	0.42	0.18	0.54	-0.04	0.48	-0.10	0.81	0.18	0.84	0.38	0.72	0.40	0.74	0.46	0.37	0.77

r ≥ 0.20 is significant at 0.05, and r ≥ 0.32 is significant at 0.01; * is the grain quality parameters measured with a NIR at the harvest day, ** is the grain quality parameters measured with a NIR a moth after harvest; *** is the flour quality parameters measured with a NIR. TKW is the thousand-grain weight; TW is the test weight; LAI is the leaf area index; QY is the quantum yield; FN in the fulling number (enzymatic activity); SDS is the SDS-sedimentation volume.

5.2 Germination Experiment

5.2.1 Temperature Sub-Experiment

5.2.1.1 Germination Duration

- Maize

This study's standard measurement point for germination evaluation was when 75% of the seeds reached a plumule length of 1 cm. In the temperature gradient experiment of 20, 25, 30, and 35 °C, which rapidly initiated germination, the seeds were determined to reach the standard measurement point the fastest, within 48 h, Figure 5.2. Temperature is critical in determining the germination duration of the seeds (SEEFELDT, KIDWELL and WALLER, 2002). The results indicate that the seeds accumulated heat units from the acquired thermal energy, and when they reached the necessary level to initiate metabolic activity, germination began at a different rate depending on the surrounding temperature condition (BOYCE, 1966). Following the temperature gradient experiment, the range from 20 to 35 °C rapidly initiated germination with no significant differences in reaching the same germination point among this range, Figure 5.2. However, moderate temperatures around 20–30 °C are necessary for a maize seed to initiate germination. The cell energy state and the activities of the enzymes changed, there was a severe reduction in protein synthesis, and the ATP content increased significantly as the temperature increased higher than this level (RILEY, 1981). Germination at 15 °C required a longer time, seven days from the start of the treatment, as confirmed by other studies (Y. J. GUAN *et al.*, 2009).

The seeds needed an extended duration of up to 34 days to reach the standard measurement point of germination at 10 °C, Figure 5.2. Maize seeds failed to germinate at 5 °C, although they were monitored for 45 days and at 40 °C. In the literature, one study concluded that the minimum germination limit for maize seed germination is 6.2 °C. The same study stated that maize seeds could not germinate at temperatures above 45 °C (SÁNCHEZ, RASMUSSEN and PORTER, 2014a). In this current study, maize seeds could not germinate even at 40 °C because they were subjected to a constant temperature. When the temperature fluctuated between the day and the night, 45 °C was the upper limit for the seed's germination. Another reason for this might be attributed to the tested variety adaptation because, in Hungary, the temperature is lower than the normal temperature in a tropical zone. The same seeds from the 5 and 40 °C treatments were tested at 20 °C, and the results showed that the germs were tied under a constant 40 °C, but only about 30% of those seeds from the 5 °C treatment germinated. The percentage difference within the range of germination between the lower and upper limits was 177.77%. The 20, 25, and 30 °C temperatures resulted in minor margin differences in germination duration and inner biological activities.

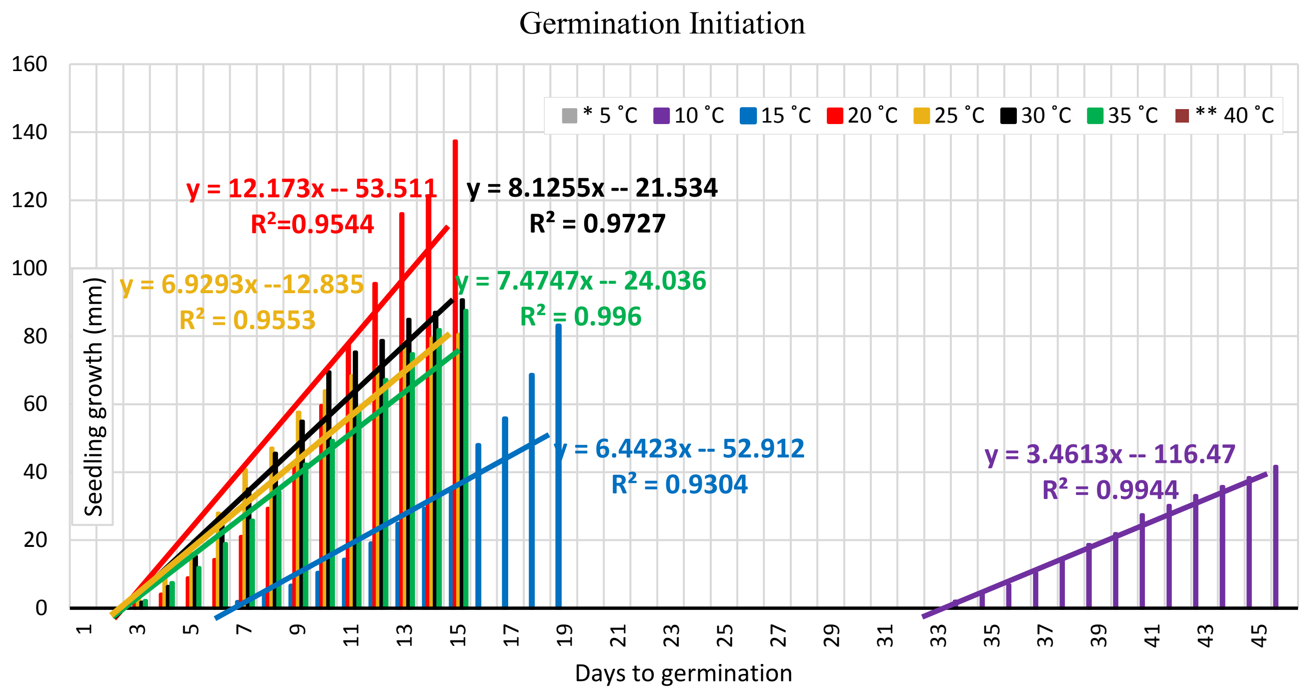

Figure 5.2. Duration from planting to germination initiation and seedling growth of maize.
The * and ** represent 5 and 40 °C (respectively), which are not presented on the graph because their values are zero (no germination).

- Wheat

Following the temperature gradient sub-experiment, the 25 to 30 °C temperature range commenced germination initiation with no significant variation in the time necessary to achieve the same germination threshold and was statistically followed by 20 °C, Figure 5.3. Seeds subjected to a temperature level of 15 °C needed more time to initiate germination. However, a moderate temperature of roughly 15–25 °C is required to commence the germination of wheat seeds. Changes in the state of the cell's energy supply and enzyme activity occurred, and protein synthesis was severely curtailed when the temperature rose over this threshold (GONG *et al.*, 2001b). At 10 °C, germination needed a more extended time, nine days from the commencement of treatment, as validated by other investigations (JIA *et al.*, 2022). To achieve the standard measurement point of germination at 5 °C, the wheat seeds required an extended time of up to 15 days, Figure 2. According to the literature, the minimum limit of germination temperature for wheat seeds is 4 °C (SCHABO *et al.*, 2020). According to the same research, wheat seeds could not initiate germination over 37 °C. Seeds can tolerate fluctuating temperatures at or near the upper limit, but under constant temperature, a lower temperature, suggested at 30 °C by this current research, is necessary to commence germination. Temperatures of the ideal range of germination, 15° to 25 °C, resulted in minor changes in germination time and internal biological activity. Although 30 °C can initiate germination rapidly, it has a reverse effect on metabolic activities in the following germination process.

Temperature is critical in regulating the length of germination duration (ZHANG *et al.*, 2021). The findings suggest that the crop seeds accumulate heat units from the thermal energy they absorb. Once they reach the required level to commence the intracellular metabolic activity, the germination process activates at a pave depending on the ambient temperature condition (HAJ SGHAIER *et al.*, 2022).

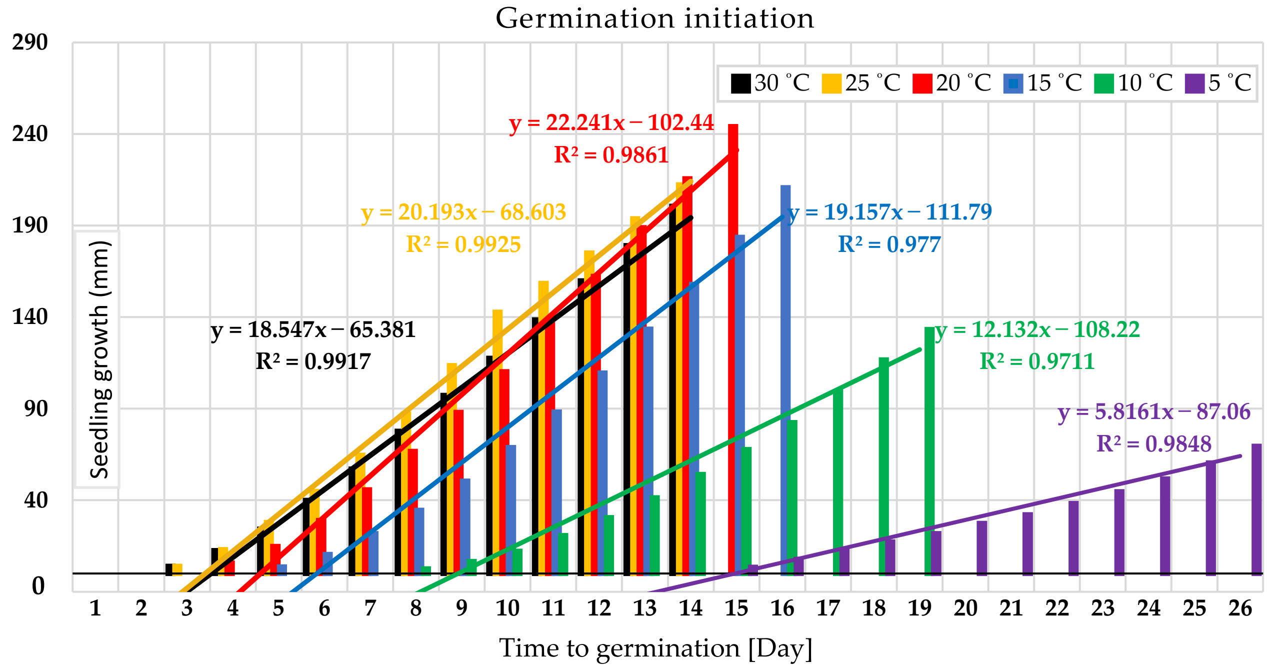

Figure 5.3. Germination duration of wheat from planting (day 1) to germination initiation and seedling development under different temperatures.

5.2.1.2 Seedling Growth

I. Maize

The best performance and the most remarkable seedling growth rate occurred at 20 °C compared to the other tested constant temperatures, Figure 5.2 and Figure 5.4. This shows that a constant temperature of 20 °C (y-value = 12.173x − 53.511) is the optimal temperature for maize seedling growth, a finding is in line with other studies that state a starting point of 23 °C for optimal growth. The results are because of the accumulation of the temperature in vitro at a constant temperature, but with fluctuating temperatures between day and night, the optimal range is slightly higher. The same pattern, but with slower growth performance, was shown at 15 °C (y-value = 6.4423x − 52.912), also attributed to the accumulation of the required temperature units for each growth stage. It is a longer duration for the same reason as seedling development at 10 °C. Almost a similar growth pattern to that of the 10 °C (y-value = 3.4613x − 116.47) treatment was shown at 35 °C (y-value = 7.4747x – 24.036); nonetheless, it was far faster, Figure 5.4; this due to the reverse impact of the high temperature on enzymes activity, protein synthesis, and chemical energy content increased and because of the formation of ROS, not because of the temperature accumulation (KHAEIM, *et al.*, 2022). Slightly similar growth development appeared at 25 and 30 °C when in the early seedling stage; they grew faster, followed by slowing growth, Figure 5.4, because different seedling growth states demand different temperature levels. This means that each stage of seedling growth requires a different temperature level. The upper germination ranges of 30 and 35 °C provide faster germination and very early seedling growth but not for the following period of seedling development. Therefore, the optimal starting point for seedling development is 20 °C with a high growth and development rate, Figure 5.4.

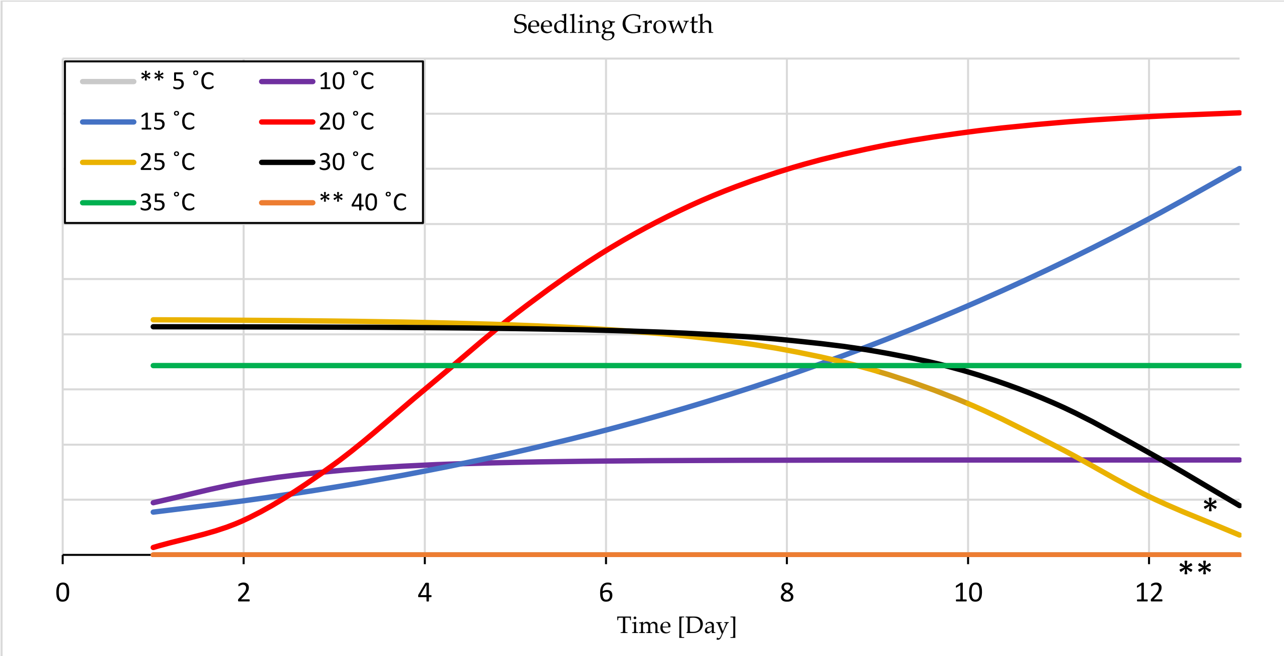

Figure 5.4. Seedling growth of maize in response to temperature.

* growth dropped down because of fungal growth at favorable temperature conditions. ** they are not shown on the graph because their value is zero (no seedling growth).

The shoot and radicle of the seedling developed similarly at and around the optimum temperature range, but their growth behavior varied as the temperature arrow crossed the optimal growth range tails in either direction, Figure B.5. 1 and Figure B.5. 2 (in the Appendix B). Under conditions where the temperature scope exceeded the optimal range, the plumule grew more rapidly than the radicle, particularly during the very early development stage, Figure B.5. 1. However, the radicle seemed to have a distinctly different pattern and temperature requirement than the Shoot since it developed better in a lower temperature than the optimal range of the whole seedling growth, particularly in the later stage, Figure B.5. 2. Shoot development and growth were the greatest at the temperature level of 20 °C and the lowest at 10 °C. The optimal shoot and radicle development temperature was 20 °C, followed by 15 °C. There was no germination at 5 and 40 °C; the Shoot and radicle growth development charts present zero values, Figure B.5. 1 and Figure B.5. 2.

II. Wheat

The experiment of the temperature gradient of 6 distinct constant temperatures, 5 °C, 10 °C, 15 °C, 20 °C, 25 °C, and 30 °C, presented that seedling growth under 20 °C gave the most outstanding performance and the most salient rate of growth Figure 5.5. Sigmoid curves, demonstrate that seedling development under 15 °C (y-value: 19.157x − 111.79, (Figure 5.3)) followed a similar pattern to that at 20 °C, but with a slightly lower growth rate. However, the seedling development under more than 25 °C had a reverse effect on seedling development, which is in line with other studies (HAJ SGHAIER *et al.*, 2022). There are discrepancies with other research that reported a broader optimal range owing day–night temperature fluctuations. However, this research presents the accumulation of the temperature in vitro at a constant temperature, which explains the narrower. For the same reason, seedling development needed a longer time with a lower growth rate. Although a nearly identical development pattern to that of the 10 °C (y-value: 12.132x − 108.22) was presented at 25° and 30 °C, nonetheless, it was far faster, Figure 5.5; it is because of the reverse impact of the high temperature on enzymes activity, protein synthesis, and biochemical energy content increased and ROS formation, not because of the temperature accumulation (TARNAWA et al,. 2023). The slightly analogous seedling development under 25° and 30 °C shows that their growth rate was rapid in the early stages but slowed in later stages. It indicates that each stage of wheat seedling development needs a different temperature. This figure illustrates that the upper germination range of 25 °C and 30 °C gives quicker germination and early seedling growth within less than five days but not for the subsequent seedling growth phase. The experiment under 5 °C showed the most negligible seedling growth and required a longer time for development, y-value: 5.8161x − 87.06, Figure 5.3. In brief, the best fitting starting point for seedling growth is 20 °C with a high development rate, Figure 5.5.

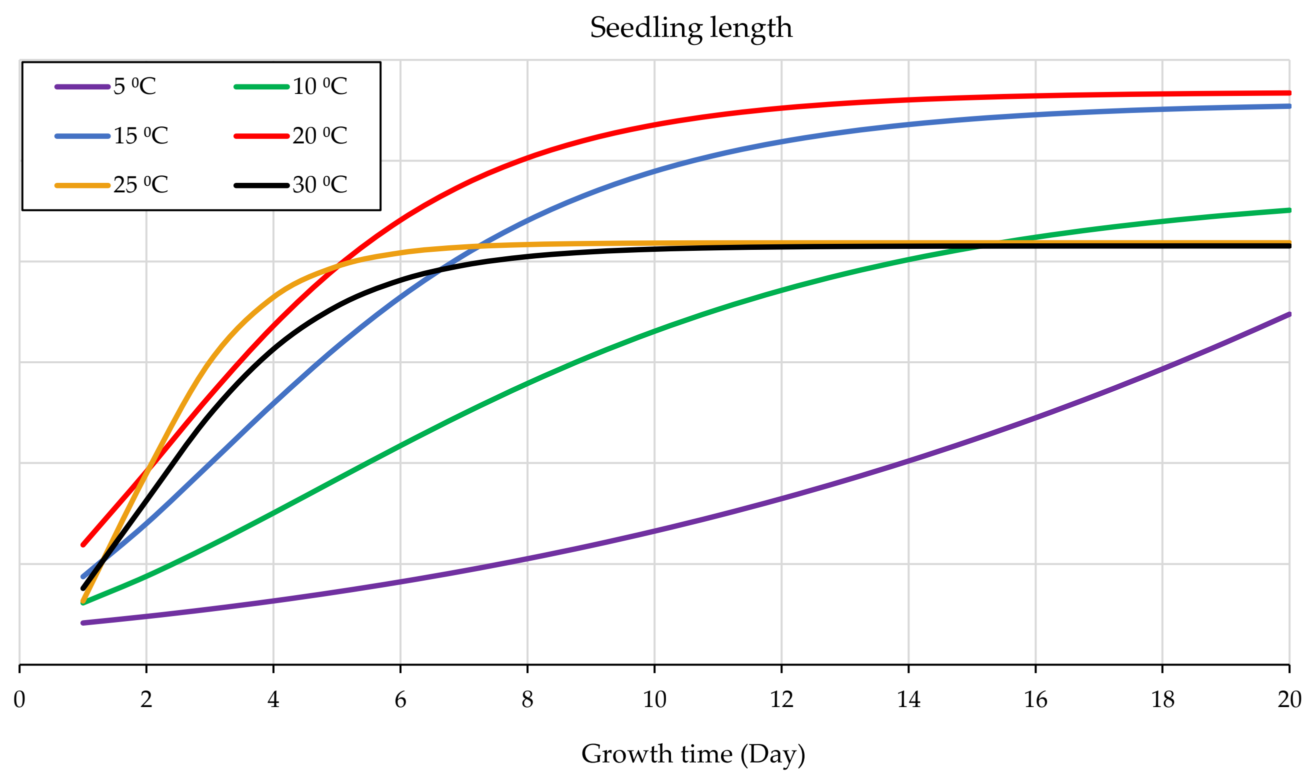

Figure 5.5 Patterns of wheat seedlings development in response to temperature-induced.

The seedling's shoots and radicles showed the same development performance at and close to the optimal range of temperature; however, their growth pattern differs when the indicator arrow of the temperature crosses the optimum limits of growth range tails, Figure B.5. 3 and Figure B.5. 4. The shoot formed and developed better, especially in the very early growth stage, than the radicle under a temperature scope higher than the optimum range, Figure B.5. 3. However, the radicle has a distinct growth pattern and need for temperature compared to the shoot because it grows better at temperatures lower than the optimum range, particularly in the later stage than the shoot, Figure B.5. 4. The highest growth and development of the shoots occurred at a temperature of 20 °C, and the least occurred at 5 °C. Therefore, the optimal temperature for the shoot and radicle development is 20 °C, followed by 15 °C. When the temperature changes, either the shoots or the radicles will be more impacted than the other. The radicle is more resistant to cold than the shoot, and vice versa; the shoot is more resistant to temperatures over the ideal threshold than the radicle(TARNAWA et al,. 2023).

5.2.2 Water Amount Sub-Experiment

I. Maize

One of the most remarkable seed quality and performance tests is the germination test, which is always linked to vigor tests, such as a seedling growth test (SINGH *et al.*, 2016; SILVA, MEDEIROS and OLIVEIRA, 2019). Water uptake and temperature analyses can provide several wheat seed quality indices regarding stress tolerance, uniformity, and germination rate. Moisture availability can critically influence seed germination (SABOURI, AZIZI and NONAVAR, 2020). Maize has germination needs comparable to those of many cereal crops (BARRERO *et al.*, 2012). Crop seeds with challenging germination requirements can be established more successfully than those with limited restrictions (SHABAN, 2013). This sub-experiment was conducted employing two water bases, one-milliliter intervals, and the percentage of the TKW at a total of 30 treatments at temperature levels of 20 and 25 °C (Table 4.1). The results in Table 3 present significant differences among the water amount potential of 0–12 ml at 20 °C for all variables, namely, the number of germinated seeds, radicle length, plumule length, total seedling length, total seedling dry weight, corrected total seedling dry weight, which were obtained by subtracting the number of non-germinated seeds, radicle dry weight, and plumule dry weight. Regarding the same water base and one-milliliter intervals from 0 to 12 ml, the same significant differences were shown for all variables at 25 °C, but with different patterns to those at 20 °C (Table B.5. 18 and Figure 5.6).

The number of germinated seeds increased sharply and significantly as the water level increased until the potential water amount was reached, followed by a slight de-crease as the water amount increased ((Table 5.9, (Table B.5. 18, Table B.5. 19, Table B.5. 20 in the appendix) and Figure 5.6 A). The same pattern was shown when applying a water amount based on the TKW with significant differences (Table 5.9 and Table B.5. 20, and Figure 5.6 B). The germination percentage at 20 °C differed slightly, with a better performance than that at 25 °C (Figure 5.6 A,B). Maize seeds can be germinated with a minimal amount of water, 0.60 ml; Table 5.9 and 5.6 represent 25% of the TKW (Table 4.1). The optimal range for germination was 0.60–5.3 ml per 9 cm Petri dish (Figure 5.6 B), representing 125–225% of the TKW (Table 4.1). In parallel, regarding the other base of water, with a 1 ml interval of water at the exact temperature of 25 °C, the optimal range for germination was similar at 1–6 ml. This means that the applied water based on the TKW is more precise for the optimization of water demand for germination (Table B.5. 18). The optimal germination range at 20 °C was 1–6 ml, which is broader than the range at 25 °C of 1–4 ml, which can be attributed to the temperature effect overlapping the water amount (Table B.5. 18 and Table B.5. 19).

Water stress plays a vital role in seedling growth. When applying the lowest amount of water, the seedling length presented the lowest mean values, and as the amount of water increased, seedling development significantly increased, Table 5.9, and in the appendix because of their size: Table B.5. 18, Table B.5. 19, Table B.5. 20, and Figure B.5. 5 and Figure B.5. 6. The optimal range of water amount for seedling growth was 3.55–7.65 ml per 9 cm Petri dish, representing 150–325% of the TKW at 20 °C, and a narrower optimal range at 25 °C ranged from 2.35 to 5.30, representing 100–225% of the TKW (Table 5.9 and Table B.5. 20). In parallel, significant seedling length development started with 2 ml of water according to the water application based on one-milliliter intervals at both temperature levels. The range of the optimal water amount at 20 °C was 2–8 ml, which is wider than the one at 25 °C of 2–4 ml (Table B.5. 18 and Table B.5. 19). This means that moisture percentage based on the TKW is more accurate and reliable. Figure 5.6 A,B, Figure B.5. 5 A,B and Figure B.5.

6 A,B present the optimal ranges for seedling development for both water supplement bases at 20 and 25 °C. Therefore, water stress significantly reduces seedlings' vigor, and seedling length increases dramatically at the starting point of the optimal range.

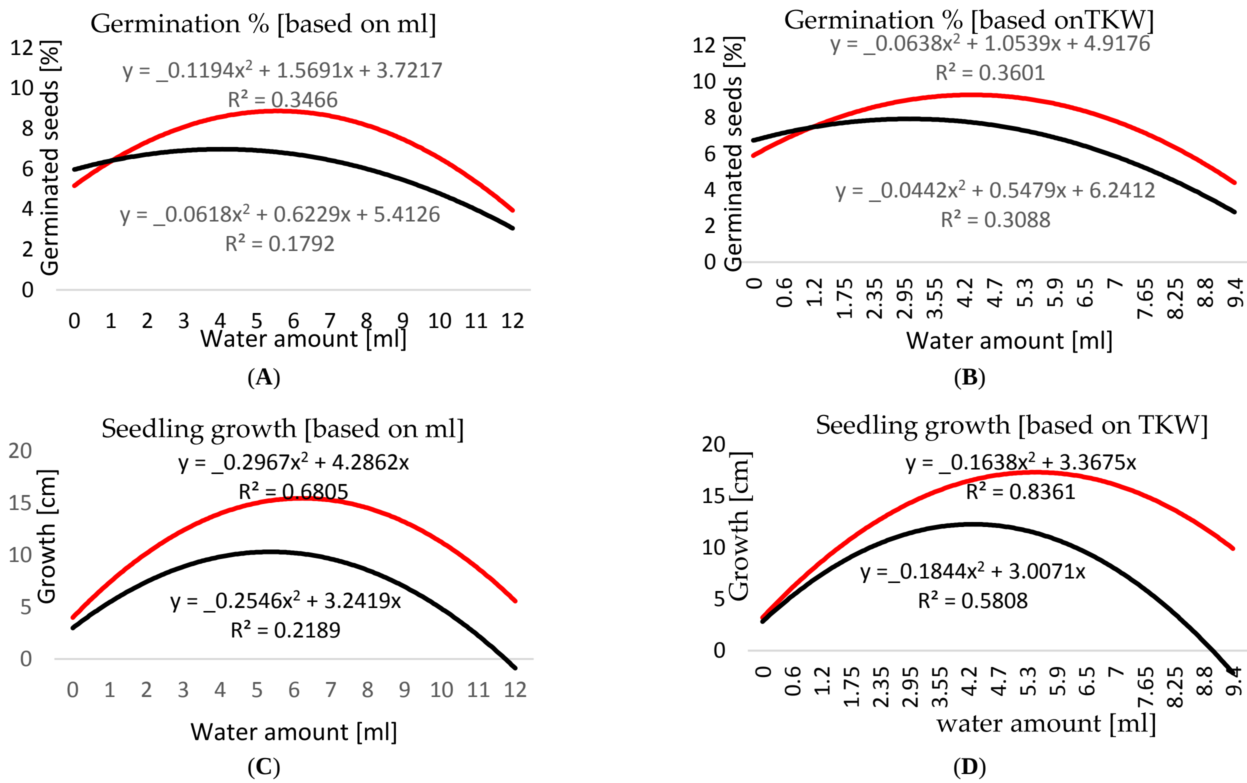

Figure 5.6. Maize seedling response to the different amounts of water at 2 temperature levels, 20 and 25 °C.

(A) Germination using different amounts of water based on 1 ml intervals (1–12). (B) Germination using different amounts of water based on percentages of TKW. (C) Seedling growth using different amounts of water based on 1 ml intervals (1–12). (D) Seedling growth using different amounts of water based on percentages of TKW.

The variance analysis revealed significant variations in the lengths of the radicle and plumule for each applied water amount. Radicle length gradually significantly in-creased as the amount of water increased (Table 5.9, Table B.5. 18, Table B.5. 19, Table B.5. 20). Thus, there is an optimal range for maize radicle growth, followed by a gradual decrease with a higher amount of water. Plumule growth and development followed a different pattern than the growth of the radicle. Therefore, it is worthwhile measuring the whole seedling; the radicle and the plumule statistically continued to be close to the optimal range as the amount of water increased than the lower amount of water (Figure B.5. 5 A,B and Figure B.5. 6 A,B). Water stress and waterlogging affect the roots more than the plumules. The plumule seemed to develop better than the root in a slightly higher amount of water, 3–10 ml, than the radicle, 1–8 ml (Table B.5. 18).

Another laboratory test is the dry weight test, which can evaluate seed vigor and seedling drought resistance. There were significant differences among the seedlings' accumulated dry matter with water availability (Table B.5. 18, Table B.5. 19, and Table B.5. 20). Dry matter accumulation occurred at the height of the optimal range of water for seedling growth to build a dry matter unit per time scale, and an increase in the water amount had no positive effect on the increase in the dry matter (Figure B.5. 5 C,D and Figure B.5. 6 C,D). When applying a higher water amount than the threshold range, the seedlings' growth and development were negatively slightly affected by the excess amount of water. This excess portion of water slowed the accumulation of dry matter in the maize seedlings. Therefore, the abiotic stresses drought and waterlogging negatively influenced dry matter accumulation. The plumule-accumulated dry matter unit required more water than a unit of root dry matter. This result is consistent with the result reported by GAO *et al.*, 2021, where the authors assessed the impact of water potential (0 and −0.2 MPa) and temperature (20, 25, and 30 °C) on the germination of *Pinus yunnanensis* seeds.

More than half of the seeds were germinated with 0.65 ml of water. Therefore, water application based on the TKW provides a better understanding of determining the limits and the optimum water requirement because seed size is essential in reaching the necessary internal seed moisture. By comparison, these results align with a study by (GAO *et al.*, 2021), reporting that "seed size has importance in predicting germination under stress conditions".

II. Wheat

Water absorption and temperature analysis can determine wheat seed quality parameters such as stress tolerance, uniformity, and germination rate. Availability of moisture reflects severe limitations on seed germination of *Triticum astivum* L (POUDEL, FINNIE AND ROSE, 2019; REDDY *et al.*, 2021; ZHU *et al.*, 2021). Therefore, seeds of the crop with stringent requirements for germination can be more effectively felicitously established than crop seeds with fewer constraints (TARNAWA et al, 2023). The water quantity experiment was carried out on two bases. Table 3 reveals significant variations among the water quantity potentials 0–12 ml for all the examined parameters: the number of non-germinated seeds, length of the radicle, length of shoot, seedling length in total, dry weight of the seedlings, seedlings' corrected dry weight that was accomplished by subtracting the non-germinated seeds, dry weight of the radicles, and dry weight of shoots.

Germination percentage increased significantly as the water quantity increased until the potential water quantity, followed by a slight decrease as the water quantity level rose due to waterlogging, as presented in Table 5.10, Figure B.5. 7 and Figure B.5. 11. A similar pattern was seen when water was applied according to the TKW with statistically significant differences, Table B.5. 21 and Figure B.5. 8. Seeds of the wheat crop can be germinated under a minimal water quantity, 0.65 ml, Table B.5. 21, which represents 75% of TKW, Table 4.1. As water is essential for germination, seeds can germinate moistures near the wilting threshold point to activate and stimulate germination metabolic processes. The wheat seeds require internal 40% moisture to germinate (KHAEIM et al,. 2022). If the interior moisture content were less than the critical moisture content limit, wheat seeds would not germinate. Under 0.65 ml, over half of the seeds germinated. Thus, water application based on the TKW enables better knowledge of the limitations and optimal water requirements since seed size is critical for attaining the 40% internal seed moisture level. These findings corroborate research conducted by HAJ SGHAIER *et al.*, 2022, stating that "seed size has importance in predicting germination under stress conditions". The optimal range for germination is 4.45–7.00 ml, Figure B.5. 8, representing 525–825% of the TKW.
The germination test, nearly always coupled with vigor tests, such as a seedling growth test, is one of the most remarkable seed quality and seedling performance tests (ELLIS, 1992; CHAKRABORTI *et al.*, 2022). There were significant differences among the seedling performance depending on supplied moisture percentages. Under a low water quantity, the seedling length presents the least mean values,

and their performance statistically significantly rose as the quantity of water increased, Table 5.10 and Table B.5. 21. The optimal range of moisture amount starts from 3.85 ml, representing 450% of TKW, Table 4. Parallel to this, significant seed length performance started under 5 ml according to the water quantity applied based on single-milliliter intervals. It implies that moisture percentages calculated using TKW are more precise, consistent, and reliable. Figure B.5. 7 and Figure B.5. 8 show that the optimal water amount range is approximately 4 to 9 ml on both water supplement bases. As a result, water stress significantly lowers seedlings' vigor; however, seedling length augmented significantly at the launching point of the optimum range.

The statistical analysis of variance revealed significant variations among the applied water quantities on each radicle length and shoot length. The radicle length progressively significantly increases as the applied water quantity increases, Table 5.10 and Table B.5. 21. There is an optimum range for wheat radicle development, which gradually decreases as the water quantity increases than the upper limit. Shoot growth followed a different pattern than the radicle. As a result, it makes sense to measure the whole seedling, Figure B.5. 7 and Figure B.5. 8. Water stresses of drought and waterlogging possess a greater impact on the radicles than the shoots.

The dry weight test is another laboratory test to determine the vigor of the seeds and drought tolerance of the seedlings. Significant differences among the amount of accumulated dry matter of the seedlings based on the availability of water, Table 5.10 and Table B.5. 21. The dry matter increased gradually as the quantity of supplied water increased over the lower limit of the optimal range. Under drought stress, the creation of dry matter is expressed chronologically by accumulating the required amount to make a unit of dry matter. More water quantity had no beneficial influence on increasing the dry matter accumulation, Figure B.5. 9 and Figure B.5. 10. Seedlings under more water supplements over the threshold range are marginally adversely impacted by surplus water compared to the required quantity. This extra water reduces the rate of dry matter accumulation in the wheat seedlings. As the data demonstrates, a shoot-accumulated dry matter unit demands more water than a unit of radicle-accumulated dry matter. This finding corroborates the one published by HAJ SGHAIER *et al.*, 2022. Water supply significantly affected the proportion of seeds germinating, the rate of seedling development, and the accumulation of dry matter: The greater the degree of hydro stress, the greater the decline in these parameters' levels. Hydrological constraints and potential ranges exist at each germination and seedling development stage, which is in line with a study by (SHABAN, 2013).

Seeds of wheat subjected to 0.65 ml of water were germinated. As a result, water application based on the TKW enables better knowledge of the limitations and optimal water requirements, as seed size is critical in achieving the required internal seed moisture. These findings corroborate research conducted by other researchers (GAO *et al.*, 2021), stating that "seed size has importance in predicting germination under stress conditions".

Table 5.9. Germination and seedling characteristic variables of *Zea mays* L. seeds respond to the water potential of the TKW base at 20 °C, MATE - Gödöllő.

[1] Water (ml)	[2] Water (TKW)	[3] Germinated Seeds	[4] Radicle (cm)	[5] Shoot (cm)	[6] Seedling (cm)	[7] Radicle DW (g)	[8] Plumule DW (g)	[9] Seedling DW (g)	[10] Corrected DW (g)
0	25%	0.00 ± 0.00 f	0.00 ± 0.00 h	0.00 ± 0.00 e	0.00 ± 0.00 h	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 g	0.00 ± 0.00 g
0.60	50%	10.0 ± 0.00 a	6.74 ± 0.92 fg	0.28 ± 0.15 e	3.51 ± 0.41 g	0.07 ± 0.01 e	0.03 ± 0.02 ef	0.10 ± 0.01 f	0.10 ± 0.01 fg
1.20	75%	10.0 ± 0.00 a	7.64 ± 0.80 defg	1.36 ± 0.15 de	4.50 ± 0.36 fg	0.15 ± 0.01 cd	0.05 ± 0.01 e	0.19 ± 0.01 e	0.19 ± 0.01 cdef
1.75	100%	9.80 ± 0.45 a	8.12 ± 0.80 cdef	2.24 ± 0.67d	5.18 ± 0.36 efg	0.18 ± 0.01 abc	0.09 ± 0.02 d	0.23 ± 0.02 cde	0.27 ± 0.01 abcd
2.35	125%	9.60 ± 0.55 a	9.36 ± 0.97 abcde	4.82 ± 1.61 c	7.09 ± 1.25 bcde	0.19 ± 0.02 abc	0.13 ± 0.03 bcd	0.32 ± 0.03 abcd	0.31 ± 0.04 ab
2.95	150%	9.00 ± 0.00 abc	8.74 ± 1.00 bcdef	5.14 ± 0.38 abc	6.94 ± 0.57 bcde	0.18 ± 0.02 abc	0.14 ± 0.00 abc	0.32 ± 0.02 abcd	0.29 ± 0.02 abc
3.55	175%	9.20 ± 0.84 ab	10.28 ± 0.87 abcde	5.94 ± 0.70 abc	8.11 ± 0.63 abcd	0.21 ± 0.04 ab	0.17 ± 0.01 a	0.38 ± 0.05 a	0.35 ± 0.05 a
4.20	200%	8.80 ± 1.30 abcd	10.30 ± 0.70 abcd	5.60 ± 0.66 abc	7.95 ± 0.64 abcd	0.22 ± 0.40 ab	0.16 ± 0.01 ab	0.38 ± 0.05 ab	0.34 ± 0.08 a
4.70	225%	9.20 ± 0.45 ab	11.40 ± 0.72 ab	6.76 ± 0.53 a	9.08 ± 0.46 ab	0.21 ± 0.02 ab	0.16 ± 0.01 ab	0.37 ± 0.02 ab	0.34 ± 0.01 a
5.30	250%	8.80 ± 1.30 abcd	12.18 ± 2.44 a	6.68 ± 1.47 ab	9.43 ± 1.89 a	0.24 ± 0.11 a	0.15 ± 0.02 abc	0.38 ± 0.12 a	0.34 ± 0.10 a
5.90	275%	7.60 ± 1.80 bcde	10.38 ± 3.50 abcd	6.76 ± 1.96 a	8.57 ± 2.65 abc	0.15 ± 0.04cd	0.14 ± 0.02 abc	0.29 ± 0.05 bcd	0.23 ± 0.10 bcde
6.50	300%	7.00 ± 2.92 de	10.24 ± 4.72 abcde	6.36 ± 2.37 abc	8.30 ± 3.53 abc	0.16 ± 0.08 bcd	0.15 ± 0.05 ab	0.31 ± 0.13 abcd	0.25 ± 0.16 abcde
7.65	325%	7.20 ± 1.92 cde	10.86 ± 4.01 abc	6.62 ± 1.36 ab	8.74 ± 2.64 abc	0.17 ± 0.07 bcd	0.17 ± 0.05 a	0.34 ± 0.11 abc	0.26 ± 0.13 abcde
8.25	350%	5.80 ± 2.95 e	6.560 ± 4.84 fg	5.02 ± 2.40 bc	5.79 ± 3.59 defg	0.12 ± 0.06 de	0.14 ± 0.06 abc	0.25 ± 0.12 de	0.17 ± 0.15 def
8.80	375%	5.80 ± 1.48 e	4.960 ± 2.51 g	4.86 ± 1.70 c	4.91 ± 2.06 efg	0.08 ± 0.04 e	0.11 ± 0.03 cd	0.19 ± 0.06 e	0.12 ± 0.06 f
9.40	400%	6.00 ± 1.58 e	7.160 ± 2.46 efg	6.20 ± 1.53 abc	6.68 ± 1.87 cdef	0.12 ± 0.03 de	0.15 ± 0.02 abc	0.27 ± 0.05 cde	0.17 ± 0.07 ef
LSD *		1.834	3.13	1.70	2.32	0.058	0.036	0.086	0.102

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; [1] the amount of applied water per 9 cm diameter Petri dish (ml); [2] percentage of water in relation to the TKW; [3] the number of non-germinated seeds in the average of the total examined seeds per treatment; [4] the mean length of the radicles of each treatment (cm); [5] the mean of the length of the plumules of each treatment (cm); [6] the mean of the length of the seedling of each treatment (cm); [7] the means of the dry weight of the radicles of each treatment (g); [8] the means of the dry weight of the plumules of each treatment (g); [9] the means of the dry weight of the seedlings of each treatment (g); [10] the mean of the corrected dry weight (g), which is the dry weight of the actual existing seedling after discarding the non-germinated ones.

Table 5.10. Parameters relating to germination and seedling characteristics of *Triticum aestivum* L. seeds respond to the application base's water potential of single-milliliter water quantity intervals, MATE - Gödöllő.

[1] Water ml	[2] Not Germinated seeds	[3] Radicles (cm)	[4] Shoots (cm)	[5] Seedlings (cm)	[6] Radicles Dry W (g)	[7] Shoots Dry W (g)	[8] Seedlings Dry W (g)	[9] Corrected Dry W (g)
0	20.0 ± 0.00 a	0.000 ± 0.00 f	0.000 ± 0.00 h	0.000 ± 0.00 f	0.000 ± 0.00 e	0.000 ± 0.00 e	0.000 ± 0.00 d	0.000 ± 0.00
1	0.40 ± 0.55 bc	10.11 ± 1.16 e	5.020 ± 1.43 g	15.13± 2.56 e	0.106 ± 0.02 d	0.112 ± 0.02 d	0.218 ± 0.05 c	0.221 ± 0.04 d
2	0.60 ± 0.55 bc	13.35 ± 1.44 d	8.950 ± 0.49 f	22.30 ± 1.14 d	0.123 ± 0.02 abc	0.123 ± 0.01 d	0.246 ± 0.03 bc	0.253 ± 0.03 c
3	0.20 ± 0.45 c	15.72 ± 1.74 abc	9.360 ± 1.96 ef	25.08 ± 3.04 c	0.133 ± 0.01 ab	0.144 ± 0.01 c	0.277 ± 0.01 ab	0.280 ± 0.02 abc
4	0.60 ± 0.89 bc	15.18 ± 0.94 bc	11.16 ± 0.55 cd	26.34 ± 1.08 bc	0.125 ± 0.01 abc	0.155 ± 0.01 bc	0.280 ± 0.02 a	0.288 ± 0.02 ab
5	0.40 ± 0.55 bc	16.26 ± 0.98 ab	10.74 ± 0.97 de	27.00 ± 1.23 abc	0.137 ± 0.01 a	0.152 ± 0.01 bc	0.289 ± 0.01 a	0.295 ± 0.01 ab
6	0.20 ± 0.45 c	16.22 ± 1.18 ab	11.48 ± 0.92 bcd	27.70 ± 0.92 ab	0.135 ± 0.01 ab	0.157 ± 0.02 abc	0.292 ± 0.08 a	0.295 ± 0.03 ab
7	0.20 ± 0.45 c	15.85 ± 1.27 ab	12.80 ± 1.17 ab	28.65 ± 1.24 ab	0.125 ± 0.02 abc	0.167 ± 0.01 ab	0.291 ± 0.01 a	0.294 ± 0.01 ab
8	0.00 ± 0.00 c	15.41 ± 1.33 abc	12.89 ± 0.83 ab	28.30 ± 2.06 ab	0.122 ± 0.02 abc	0.170 ± 0.01 ab	0.292 ± 0.02 a	0.292 ± 0.02 ab
9	0.20 ± 0.45 c	16.80 ± 0.69 a	12.60 ± 0.46 abc	29.40 ± 0.82 a	0.123 ± 0.00 abc	0.169 ± 0.02 ab	0.292 ± 0.02 a	0.295 ± 0.01 ab
10	0.60 ± 0.89 c	15.77 ± 0.92 abc	13.31± 0.88 a	29.08 ± 1.69 a	0.120 ± 0.01 bcd	0.176 ± 0.02 a	0.295 ± 0.03 a	0.304 ± 0.01 a
11	0.80 ± 0.84 bc	14.23 ± 2.09 cd	12.72 ± 2.19 ab	26.95 ± 4.01 abc	0.111 ± 0.02 cd	0.153 ± 0.01 bc	0.264 ± 0.03 ab	0.275 ± 0.03 bc
12	1.20 ± 1.30 b	15.10 ± 1.54 bc	12.47 ± 1.23 abc	27.57 ± 2.73 abc	0.105 ± 0.01 d	0.166 ± 0.02 ab	0.271 ± 0.03 ab	0.287 ± 0.02 ab
L.S.D *	0.84	1.62	1.48	2.57	0.0156	0.0204	0.2456	0.0284

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant, [1] the quantity of water application per a 9 cm Petri dish (ml), [2] the not germinated seeds number fraction of the total tested seeds, [3] the mean of each treatment's radicle lengths (cm), [4] the mean of each treatments' shoot lengths (cm), [5] the mean of each treatments' seedling lengths (cm), [6] the mean of each treatments' radicles dry weights (g), [7] the mean of each treatments' shoots dry weights (g), [8] the mean of each treatments' seedlings dry weights (g), and [9] the mean of the statistically corrected dry weight that was gained by subtracting the not germinated ones from the dry weight of the existed seedling.

5.2.3 Seed Number Sub-Experiment

I. Maize

The statistical analysis of variance indicated no significant differences among the germination percentages with different treatments and seedling densities corresponding to the aggregated values of 6, 8, 10, and 12 maize seeds per Petri dish, Table 5.11. Furthermore, there were no significant differences among the subdivisions of the aggregated values, namely, seedlings with normal plumule growth, seedlings with short plumule growth, seedlings with radicle growth only started to germinate seeds fraction, and the non-germinated seeds fraction. Therefore, since a higher seedling density than the optimum possessed a reverse effect when opening the Petri dish cover, and there were no significant differences between the four seed densities in use, it was concluded that a density of six seeds per Petri dish is better for maize germination tests in vitro.

The results address which seed numbers are essential in seedling elongation bioassays in vitro. The larger water volumes or the lower wheat seedling densities increase the quantity of phytotoxin present per seed and increase inhibition (WEIDENHAMER, MORTON and ROMEO, 1987). A seedling density higher than the optimum number negatively affects seedling growth in a Petri dish when opening the Petri dish cover. It creates exposure to water losses and, finally, seedling growth insufficiency. The statistical analysis results of variance present no significant differences between the germination percentages with different treatments and seedling densities.

Furthermore, there were no significant differences among the subdivisions of the aggregated values. Since a higher seedling density than the optimum resulted in a reverse effect when opening the Petri dish cover, and there were no significant differences between the four seed densities in use. In the case of plant breeding projects (identical seeds are sometimes in shortage), studying the optimal number of seeds necessary to use in a Petri dish experiment is essential. It assists in optimizing the usage of resources, especially for plant breeders.

Table 5.11. The germination and seedling characteristics of maize seeds respond to the number of seeds per Petri dish, MATE - Gödöllő.

[1] Seeds (n)	[2] Non-Germinated seeds (%)	[3] Started germination (%)	[4] Seedlings with radicle only (%)	[5] Seedlings with a short plumule (%)	[6] Seedlings with normal plumule (%)	[7] Aggregated value (%)
			20 °C			
6	0.133 ± 0.11	0.017 ± 0.05	0.067 ± 0.14	0.033 ± 0.11	0.750 ± 0.26	0.790 ± 0.19
8	0.188 ± 0.21	0.013 ± 0.04	0.000 ± 0.00	0.025 ± 0.08	0.787 ± 0.17	0.805 ± 0.17
10	0.090 ± 0.13	0.020 ± 0.04	0.010 ± 0.03	0.130 ± 0.22	0.780 ± 0.33	0.869 ± 0.21
12	0.192 ± 0.18	0.008 ± 0.03	0.000 ± 0.00	0.167 ± 0.25	0.558 ± 0.38	0.668 ± 0.32
LSD	* N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
			25 °C			
6	0.133 ± 0.15	0.017 ± 0.05	0.000 ± 0.00	0.033 ± 0.07	0.817 ± 0.21 a	0.840 ± 0.18
8	0.300 ± 0.13	0.013 ± 0.04	0.038 ± 0.06	0.112 ± 0.14	0.613 ± 0.26 ab	0.696 ± 0.19
10	0.290 ± 0.21	0.020 ± 0.06	0.030 ± 0.07	0.170 ± 0.28	0.490 ± 0.28 b	0.610 ± 0.21
12	0.233 ± 0.17	0.058 ± 0.09	0.008 ± 0.03	0.108 ± 0.09	0.600 ± 0.22 ab	0.678 ± 0.19
LSD	N.S.	N.S.	N.S.	N.S.	0.222	N.S.

* means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; [1] the percentage of seeds per treatment; [2] portion of the seeds that did not initiate germination; [3] seeds that started germination of the total examined seeds per treatment; [4] percentage of germinated seeds with only radicles after ten days of incubation; [5] percentage of seedlings with short plumules (shorter than approximately 4 cm) after ten days of incubation; [6] percentage of seedlings with normal plumule length after ten days of incubation; [7] the aggregated value following Equation (2) of the four categorized groups: number of non-germinated seeds, germination with the only radicle, seedling with a short plumule, and normal seedling.

II. Wheat

The ANOVA revealed no significant differences among germination percentages of the seedling densities corresponding to the aggregated values of 15, 20, and 25 seeds of wheat in a Petri dish, Table 5.12. In addition, the subsets of the aggregated values presented no significant variations: seedlings with normal radicles, seedlings with short shoots, seedlings with only radicles, and the portion non-germinated seeds. Therefore, because increasing seedling density beyond the optimal has an opposite impact by the opening of Petri dishes lids, Figure B.5. 12, and there were no significant variations among used densities, 15 seeds per Petri dish are more appropriate than higher densities for wheat germination experiments in vitro.

The data demonstrate that seed numbers are a critical factor in seedling growth bio-assays in vitro. Increased water volumes or denser wheat seedlings increase the amount of phytotoxin contained in each seed, hence increasing inhibition (GONG *et al.*, 2001a; HAJ SGHAIER *et al.*, 2022). Greater than optimal seeding density has a detrimental effect on seedling development in Petri dishes and the opening of Petri dish lids. They are exposed to water loss, which has a detrimental effect on seedling development. Results presented no significant differences among different seeds and seedling densities of 15, 20, and 25 in a Petri dish for the measured traits, Table 5.12. Since high seedling density has an opposite impact by the opening of Petri dish lids and there were no significant variations among used densities, 15 seeds per Petri dish are more appropriate than higher densities for wheat germination experiments in vitro. In plant breeding initiatives (identical breed seeds are sometimes scarce), it is critical to determine the ideal number of seeds to use in a Petri dish experiment. It is beneficial in resource optimization, particularly for plant breeders.

Table 5.12. Parameters relating to germination and seedling characteristics of *Triticum aestivum* L. seeds respond to the number of seeds per Petri dish, MATE - Gödöllő.

[1] Seeds n	[2] Not Germinated Seeds %	[3] Seedlings with Radicle Only %	[4] Seedlings with A Short Shoots %	[5] Seedlings with Normal Shoots %	[6] Aggregated Value %
15	0.0267 ± 0.047	0.0000 ± 0.000	0.0000 ± 0.000	0.9733 ± 0.047	0.9733 ± 0.047
20	0.0400 ± 0.046	0.0000 ± 0.000	0.0000 ± 0.000	0.9600 ± 0.046	0.9600 ± 0.046
25	0.0280 ± 0.027	0.0040 ± 0.013	0.0000 ± 0.000	0.9640 ± 0.030	0.9653 ± 0.028
L.S.D	* NS	NS	NS	NS	NS

* Indicates non-significant variations in (column) among means ($p < 0.05$), following L.S.D, [1] the number of seeds as treatment, [2] the not germinated seeds percentage of the total tested seeds, [3] percentage of seeds germinate that have only radicles, [4] percentage of seedlings that have short shoots (shorter than 4 cm). [5] Percentage of seedlings that have normal shoots length, and [6] the aggregated value of the four classified groups as determined by Equation (2): number of not germinated seeds, seedlings that have only radicle, seedlings that have a short shoot, and normal seedling length.

5.2.4 Antifungal Experiment

This study section presents the experiment conducted to find a specific technique to prevent fungal growth in Petri dishes. At higher temperatures, fungal growth increases compared to lower temperatures. This fungal growth affects the measurements of study parameters. Although the treatment prevented fungal growth, the antifungal, Amistar Xtra, negatively affected seedling growth, Figure 5.7. The maize seeds grown in a media containing Hypo showed a positive effect, stimulating germination and reducing fungal growth, but no significant effect on seedling growth compared to the control. Figure 5.8 presents a reverse relationship between the fungicide concentration and seedling growth and development when applied to the growth media. The lowest antifungal concentration, 10 ppm, contributed to better seedling growth, but less than the control. Figure 5.9 presents the effect of two different techniques, priming with fungi sterilizer solution and applying antifungal, used to prevent fungal growth. The seed priming technique showed a significantly much better effect on seedling growth than the other one.

Fungal growth increased as the temperature increased, even in vitro (ALDARS-GARCÍA *et al.*, 2018). This fungal growth affects the measurements of study parameters by negatively impacting plumules and radicles. This study was partly designed to find a specific technique to prevent fungal growth in vitro. Although the antifungal, Amistar Xtra, prevented fungal growth, it negatively affected seedling growth. It harms the cell's osmotic pressure and the water uptake by the seeds. Therefore, the germination percentages and seedling development were highly affected as the antifungal concentration increased in the growth media when applied to it. Although Hypo presented the positive effect of stimulating germination and reducing fungal growth, it showed no significance in seedling growth compared to the control, which was slightly lower. The impact of the two different techniques, priming with fungi sterilizer solution and applying antifungal, used to prevent fungal growth was noticeable. The literature regarding antifungal activity on seed germination states that antifungal inhibits and damages hyphae in vitro (KRISHNAN, VELRAMAR and VELU, 2019). It damages DNA and protein and reduces the GSH content of the fungus. Therefore, antifungals prevent maize seed germination problems and mycotoxicosis on maize kernels (KRISHNAN, VELRAMAR and VELU, 2019). The seed priming technique shows a significantly much better effect on seedling growth than adding the antifungal to the growth media. It can be stated that sterilizing seeds with a minimum antifungal, less than 1000 ppm, can reduce fungal growth in vitro.

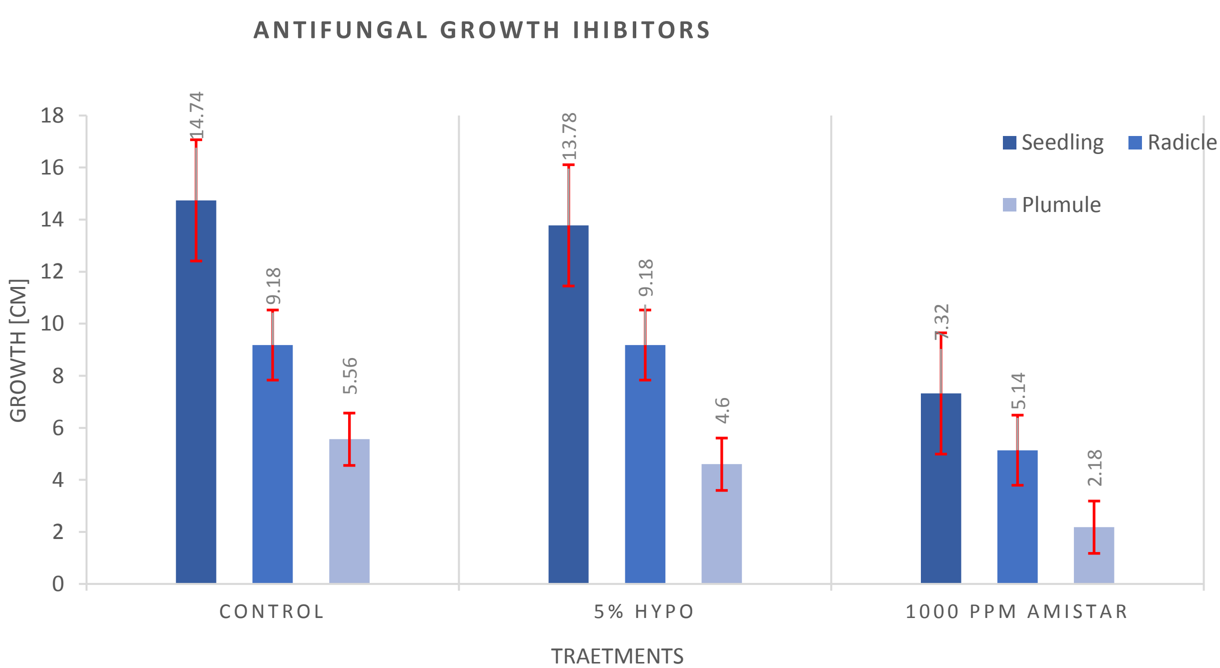

Figure 5.7. Seedling, radicle, and plumule performance using antifungal and Hypo priming. LSD value is 3.56.

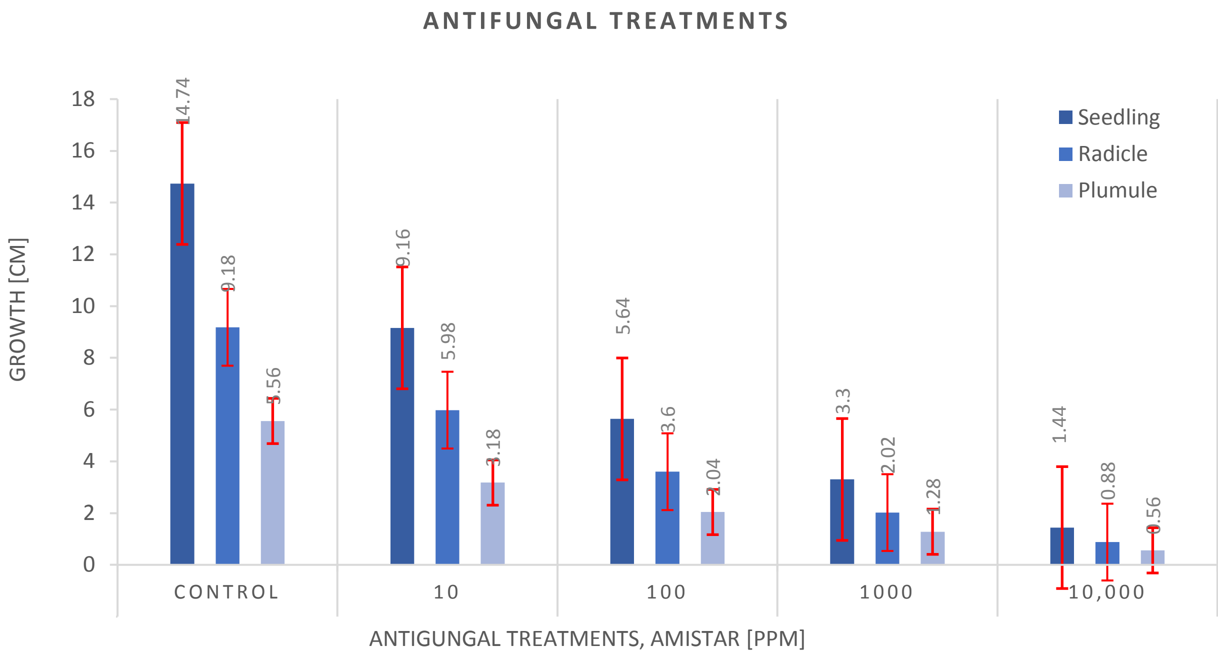

Figure 5.8. Seedling, radicle, and plumule performance using different concentrations of antifungal growth media. LSD value is 2.64.

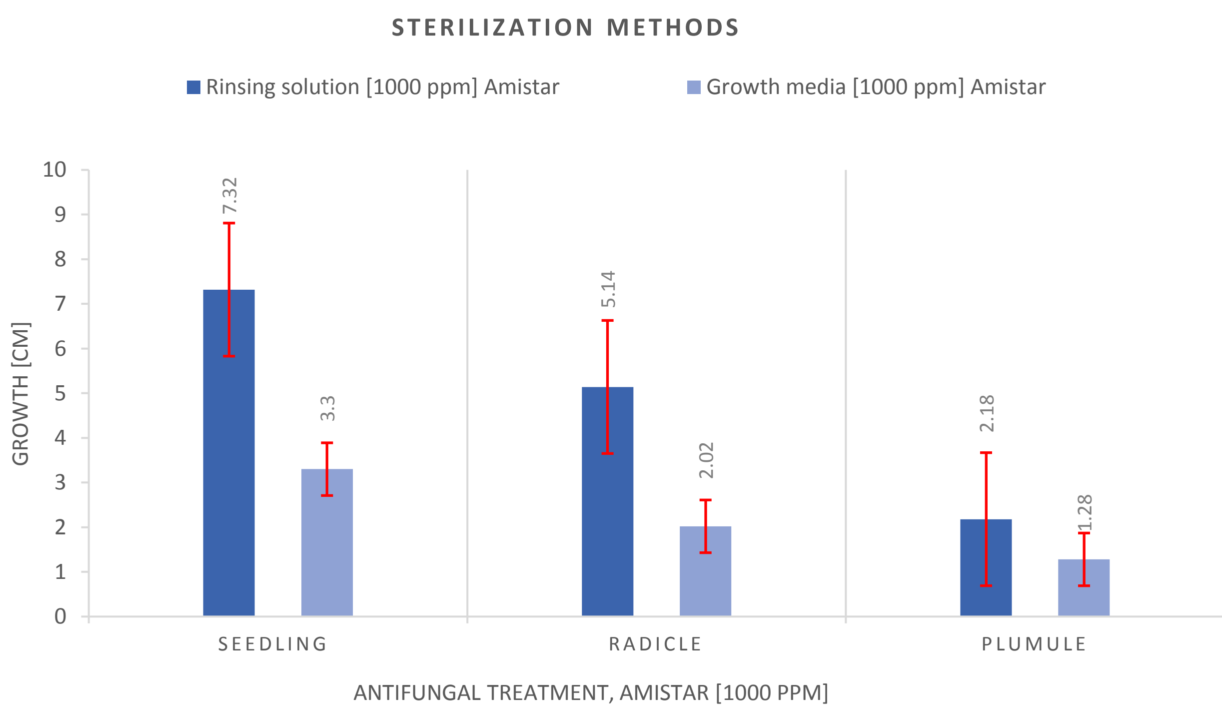

Figure 5.9. Seedling, radicle, and plumule performance using 2 fungal prevention techniques (seeds were primed with sterilizer solution and antifungal media). LSD value is 1.66.

5.3 Effective Microorganisms Experiment

5.3.1 2021-2022

The primary aim of this part of the study was to evaluate the interaction of microorganisms, nitrogen fertilizer (particularly ammonium nitrate, NH_4NO_3), and irrigation in wheat plants, intending to mitigate the impacts of abiotic stressors. The evaluation was undertaken to examine the effects of these factors on both the quantity and quality of yield. Microbes can potentially mitigate the impacts of abiotic stressors by synthesizing growth-promoting chemicals, such as phytohormones. Moreover, microorganisms can enhance plant nutrient absorption, particularly in soils lacking in nutrients, through the processes of fixing atmospheric nitrogen and solubilizing mineral minerals. The microorganisms were utilized in various environments of irrigated and non-irrigated field trials, in conjunction with different nitrogen applications, to investigate their impact on promoting plant growth, development, and productivity. To achieve this objective, three distinct wheat varieties, namely Alföld, Nemere, and Menrot, were used in various irrigation systems. Additionally, the application of effective microorganisms, in conjunction with nitrogen application, was implemented.

The increasing scarcity of irrigation water threatens global winter wheat production and food security (ZENG *et al.*, 2023). Wheat is a major world food crop; irrigation has been pivotal in enhancing its sustainable production. The findings of the current investigation revealed a statistically significant positive linear correlation between irrigation (20 mm of water after heading weekly) and production of wheat, Table 5.13 and Figure 5.10. On average, in overall treatments, the irrigated wheat field produced a significantly higher grain yield by 35.45%, 3091 kg/ha, than the non-irrigated one, 2160 kg/ha. This finding aligns with previous research showing a significant increase in wheat productivity using irrigation, particularly in regions characterized by dry and semi-arid climates (POURMEHDI and KHEIRALIPOUR, 2023; ZENG *et al.*, 2023). There were significant variations among the treatments: the combination of EM + N resulted in the highest grain yield, 3125 kg/ha, which is significantly higher than other treatments. Nitrogen treatment led to a statistically significant increase in grain production, with a mean value of 2861 kg/ha. The EM treatment resulted in significantly higher grain yields by 11.11% of 2384 kg/ha than the control 2133 kg/ha, respectively. This implies that effective microorganisms play a role in improving plant performance and countering abiotic stresses, particularly drought stress. The result shows an interaction between the EM and the nitrogen application. Separately or in combination, it helps plant strength at different levels, ultimately resulting in increased resistance to the surroundings to the abiotic stresses. This finding is corroborated by a study in which researchers used EM on wheat crops, eventually demonstrating significant enhancements in growth promotion and yield augmentation. (HU and QI, 2013).

Genetic environment (G*E) interaction among wheat varieties presents apparent variations. Some varieties, Menrot and Nemere yielded significantly greater values of 2938 kg/ha and 2899 kg/ha than Alföld 2041 kg/ha as an average across the irrigation system and treatments, Table 5.13. The relationship between genotype and environment was evident in the Alföld variety, as shown by a significant increase in yield of 1261 kg/ha with irrigation. This implies that local variety has the potential to achieve higher yields within various ranges when environmental conditions align with the needs of the varieties or when specific treatments are used to alleviate the adverse impacts of environmental pressures. This point is supported by other research regarding the environment meeting genetics requirements (GERARD *et al.*, 2020).

Table 5.13. Yield production kg/ha of *Triticum aestivum* L under drought stress and different treatments of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non-Irrigated	Menrot	1550	2033	3300	3050	2483	
	Nemere	1750	2175	3600	2767	2573	
	Alföld	1298	1433	1483	1483	1424	
Irrigated	Menrot	3050	3350	3650	3517	3392	
	Nemere	2650	3767	3800	3683	3475	
	Alföld	2500	2517	2950	2667	2658	
LSD_{I*V*T}		369.6				LSD_{I*V}	206
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non-Irrigated		1532	1880	2794	2433	2160 b	
Irrigated		2733	2889	3455	3289	3091 a	
LSD_{I*T}		228.2				LSD_I	180.8
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		2300	2691	3475	3283	2938 a	
Nemere		2200	2487	3683	3225	2899 a	
Alföld		1899	1975	2216	2075	2041 b	
LSD_{V*T}		255.7				LSD_V	127.9
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		2133 d	2384 c	3125 a	2861 b		
LSD_T		147.6					

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

The measurement of seed size is often referred to as Thousand Kernel Weight (TKW). Understanding this particular attribute of seeds is crucial for making informed choices about seeding management, crop establishment, and, ultimately, the potential yield. A seed batch characterized by a greater seed size has an increased thousand kernel weight. A seed batch with seeds of smaller size has a reduced TKW. This trait exhibits variability based on several factors, primarily the variety. This research demonstrates that no statistically significant changes are seen in the context of irrigation, Table B.5. 22. The weight of 45.41 g was observed in the irrigated field compared to the weight of 44.62 g in the non-irrigated field, 1.75% higher. Nevertheless, there are notable variations in the levels of TWK across the study treatments. The combination of EM + N yielded the most statistically significant results, with a mean of 45.64 g. This result significantly differed from the mean of the EM treatment alone, 45.1 g, the mean of the N treatment, 44.83 g, and the control, 44.49 g. The least significant difference (LSD) value for these comparisons was 0.757. There were notable variations seen across the different varieties. Nemere exhibited the highest thousand kernel weight TKW value of 48.65 g, followed by Menrot with a TKW of 46.89 g and Alföld with a TKW of 39.51 g. These differences were statistically significant, as shown by the LSD value 0.656, Table B.5. 22. In brief, significant interactions were observed between treatments and varieties, indicating that the effects of treatments varied depending on the specific variety. However, no significant interactions were found between varieties and irrigation and between treatments and irrigation.

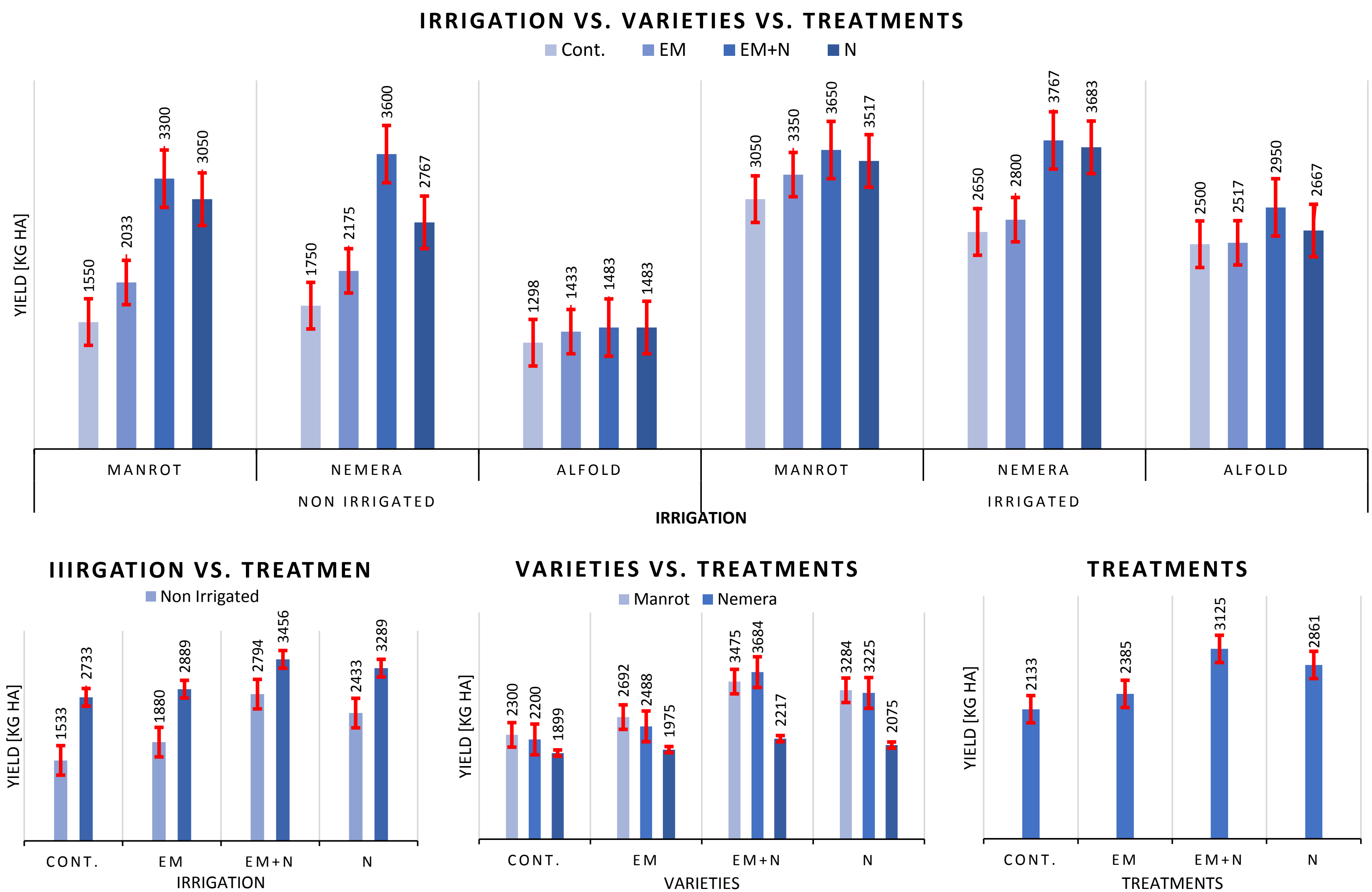

Figure 5.10. Yield production kg/ha under drought stress and different treatments of different varieties of *Triticum aestivum* L.

Hectolitre mass (HLM), also referred to in some countries as bushel-, specific- test-, or hectoliter weight, is the weight of a standard volume of grain (i.e., 1 hl = 100 l) and is a measure of the bulk density and soundness of grain (MANLEY *et al.*, 2009). The aforementioned standard has a historical significance in wheat grading, functioning as a comprehensive reference for evaluating a confluence of traits. HLM is an essential indicator of the physical quality of wheat and has long been recognized as an indicator of the flour yield of wheat (MANLEY *et al.*, 2009; NUTTALL *et al.*, 2017).

In this research, irrigation decreases the value of HLM slightly significantly by 0.52% of 79.345 kg/hl, than the not irrigated field, 79.764 kg/hl with LSD of 0.268, Table B.5. 23. This means the irrigated field resulted in bigger grains. While no statistically significant differences were observed among the treatments, a significant interaction was observed between the treatment and the varieties. The variety Alföld exhibited the highest mean value of 80.492 kg/hl, followed by Menrot with a mean value of 79.947 kg/hl and Nemere with a mean value of 78.225 kg/hl. These differences were statistically significant, with a least significant difference (LSD) value of 0.3769. According to Table B.5. 23, there is a dual interaction between irrigation and varieties. In brief, HLM is significantly influenced to a moderate extent by irrigation and, to a considerable extent, by the different types. The application of nitrogen, effective microorganisms, and their amalgamation do not have any discernible influence on the HLM values. This indicates that this triat's expression is influenced by genetic variables and various environmental conditions, including the presence of drought and high temperatures.

The contemporary grain industry necessitates heightened standards in terms of both quality and safety. To guarantee that the grain adheres to industry standards and is deemed suitable for consumption, it is necessary to subject it to thorough and stringent testing procedures and investigate the effects of the treatments and abiotic stresses on it.

The wheat quality laboratory of small grains conducts various analyses on wheat grain and/or flour. The functioning of wheat is influenced by the amount of protein present in flour, which may vary (LE BOURGOT *et al.*, 2023). Irrigation had a statistically but insignificant effect on the grain protein content, Table 5.14. The mean value of protein content in the irrigated plots across treatments and varieties was 11.90% for the irrigated field and 11.92% in the stressed field. There were no significant differences in the protein values among the varieties. Alföld had somewhat elevated values of 12.13%, surpassing those of Nemere and Menrot at 11.82% and 11.79%, respectively.

However, there were significant variations among the study treatments. The application of nitrogen has a significant impact on the protein content. The application of N alone resulted in a substantially higher value of 13.96%, while the combination of N and EM yielded a value of 12.60%, both of which were significantly greater than the values obtained with the EM itself at 10.68% and the control group 11.28%, Table 5.14. This finding is in accord with previous research since the amino acids that form the foundation of proteins are derived from the nucleotide base N (SUN *et al.*, 2023).

Table 5.14. Whole flour protein content (%) under drought stress and different treatments and of *Triticum aestivum* L measure with NIR of 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non-Irrigated	Menrot	11.9	9.517	12.65	12	11.517	
	Nemere	10.57	9.98	14.833	12.827	12.053	
	Alföld	8.88	13.88	12.833	13.2	12.198	
Irrigated	Menrot	10.35	12.193	11.557	14.17	12.068	
	Nemere	12.5	9.007	12.717	12.143	11.592	
	Alföld	13.5	9.503	11.017	14.24	12.065	
LSD $_{I*V*T}$		1.1133				LSD $_{I*V}$	0.5324
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non-Irrigated		10.45	11.126	13.439	12.676	11.922 a	
Irrigated		12.117	10.234	11.763	13.518	11.908 a	
LSD $_{I*T}$		0.6226				LSD $_I$	0.354 $^{N.S}$
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		11.125	10.855	12.103	13.085	11.792 a	
Nemere		11.535	9.493	13.775	12.485	11.822 a	
Alföld		11.19	11.692	11.925	13.72	12.132 a	
LSD $_{V*T}$		0.8018				LSD $_V$	0.400 $^{N.S}$
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		11.283 b	10.68 c	12.601 a	13.097 a		
LSD $_T$		0.4629					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Wet gluten is acquired by the process of washing a flour sample with a sodium chloride solution, resulting in the removal of starch and other soluble constituents, leaving behind the gluten component alone. The experimental procedure entails the creation of a dough mixture followed by removing starch and water-soluble constituents, such as water-extractable arabinoxylans, sugars, and water-soluble proteins, from the dough. The residual material obtained after the washing technique, which is characterized by its wet and stretchy nature, is mainly composed of water-insoluble proteins (gliadins and glutenins), accounting for about 85% of the total protein content (LIU *et al.*, 2022). The quantity of this substance serves as an indicator of the amount of gluten present. The highest value of wet gluten can reach up to 45% (LI *et al.*, 2024a). In the present research, it was observed that the application of irrigation resulted in a notable elevation in the gluten content, with a value of 33.35%, as opposed to the drought-stressed field, which exhibited a gluten value of 27.66%, Table 5.15. Nitrogen significantly affects the gluten value 34.76% compared to the other treatments.

The EM has no impact as compared to the control. There is no substantial variation in the gluten content value across the used different wheat varieties across treatments. There is a dual interaction between the irrigation and the varieties; for example, the gluten level on Menrot increased significantly from 25.51% to 35.32%, Table 5.15. This finding indicates that irrigation and nitrogen application significantly impact the gluten content level in wheat flour.

Table 5.15. Gluten content (%) under drought stress and different treatments and of *Triticum aestivum* L measured by gluten wash machine of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)**				**I * V**	
		Cont.	EM	EM+N	N		
Non-Irrigated	Menrot	21.5	19.97	29.47	31.1	25.51	
	Nemere	25.25	22	33.12	31.58	27.99	
	Alföld	20.75	34.4	34.22	28.52	29.47	
Irrigated	Menrot	31.65	32.9	34.77	41.97	35.32	
	Nemere	37.8	26.5	36.9	35.23	34.11	
	Alföld	28.5	24.27	29.57	40.18	30.63	
LSD $_{I*V*T}$		3.15				LSD $_{I*V}$	2.127
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non-Irrigated		22.5	25.46	32.27	30.4	27.66 b	
Irrigated		32.65	27.89	33.74	39.13	33.35 a	
LSD $_{I*T}$		2.234				LSD $_{I}$	2.097
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		26.58	26.43	32.12	36.53	30.42 a	
Nemere		31.52	24.25	35.01	33.41	31.05 a	
Alföld		24.62	29.33	31.89	34.35	30.04 a	
LSD $_{V*T}$		2.022				LSD $_{V}$	1.011 $^{N.S}$
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		27.58 c	26.67 c	33.01 b	34.76 a		
LSD $_{T}$		1.167					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

The falling number (FN) test indirectly measures α-amylase activity in wheat flour samples to determine if they contain sprouted grain, though not continually visibly sprouted. FN was within the range of the ideal level with the irrigation 366.9 but was over the range with the stresses field 398.7, Table 5.16. There was a significant interaction between the irrigation and the varieties where the irrigation pushed the FN value toward the ideal range; for example, the stresses field of Nemere has an FN value of 420.2, and the irrigated field has a value of 355.2. There were significant variations among the varieties across the irrigation and the treatments. Nitrogen and effective microorganisms presented no significant impact on the FNs, Table 5.16. It can be concluded that drought stress negatively affects the α-amylase activity in wheat flour, and irrigation significantly improves its value to meet the required range for bakeries, while the used treatments present no impact.

Table 5.16. Falling number values (time per second) under drought stress and different treatments for *Triticum aestivum* L flour of 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non-Irrigated	Menrot	440.5	363.2	418.5	376.7	399.7	
	Nemere	441	392.5	441.8	405.3	420.2	
	Alföld	360.5	405.8	344.3	394.2	376.2	
Irrigated	Menrot	375.5	377.5	382.7	384.8	380.1	
	Nemere	370	337.2	373.5	340.2	355.2	
	Alföld	356	362.7	375.8	366.7	365.3	
LSD_{I*V*T}		40.37				LSD_{I*V}	23.26
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non-Irrigated		414	387.2	401.6	392.1	398.7 a	
Irrigated		367.2	359.1	377.3	363.9	366.9 b	
LSD_{I*T}		25.50				LSD_{I}	21.05
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		408	370.3	400.6	380.8	389.9 a	
Nemere		405.5	364.8	407.7	372.8	387.7 a	
Alföld		358.2	384.2	360.1	380.4	370.8 b	
LSD_{V*T}		27.64 N.S				LSD_{V}	13.82
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		390.6 a	373.1 a	389.4 a	378.0 a		
LSD_{T}		15.96 N.S					

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

The quantitative and qualitative composition of protein components undergoes continuous changes throughout the ripening process of wheat grain, leading to the formation of gluten and alterations in its physical characteristics. The primary protein constituents of gluten, namely gliadin and glutenin, undergo formation inside grains throughout their early stages of development (LI *et al.*, 2024a). The buildup of milk maturity progresses progressively from its initial stage. During the last stage of the maturation process, known as the full ripening phase, the gluten content becomes excessive, resulting in less cohesiveness and reduced ability to retain moisture. The grain's gliadin content rises as it further ripens, with the creation of gliadin representing the concluding phase of protein synthesis (GUO *et al.*, 2021). The intermolecular connections between amino acids are reinforced, establishing stable protein macromolecular structures during the first stages of waxy maturity (GUO *et al.*, 2021). Additionally, the extensibility of gluten undergoes augmentation.

The changes in the protein and gluten continue after harvesting, Table B.5. 26Table B.5. 27. Therefore, part of this study follows the changes in the protein, gluten, sedimented materials, and moisture at three post-harvest points: harvest day grain measurement, grain measurement after a month of the harvest day, and whole flour measurements. Table B.5. 29 and Table B.5. 30 present the change in the gluten content. The SDS values for increases from the harvest days to a month after harvest from 42.19 ml and 43.54 ml Table B.5. 25, respectfully for the irrigated and not irrigated field, to 56.25 ml and 46.12 ml, Table B.5. 24. These values were measured with the same NIR device. Protein percentage changes from 13.46%, Table B.5. 27, of the whole grain at the harvest day to 11.90% of the whole flour a month after harvest, Table 5.14. Gluten content changed within the storage month after harvest from 30.77%, Table B.5. 27, for the whole grain of the irrigated field to 34.23%, Table B.5. 28, for the whole flour and to 33.35%, Table 5.15, for the white flour measured with gluten wash machine. The summer of 2022 was super dry, and the grain moisture measured with NIR on the day of harvest was 8.91%, Table B.5. 33, increased to 10.60%, Table B.5. 32, for the whole grain a month after harvest, and to 11.022, Table B.5. 31, for the whole flour. These parameters present the biochemical changes in the wheat grains starting from the day of harvest to a month after to give enough time for the materials inside the grain to continue forming.

The measured parameters are correlated either positively or negatively, statistically or significantly as seen in table of correlation Table 5.17 and its probability in Table B.5. 53. Yield is significantly correlated positively with TKW 0.46 and significantly negatively with protein -0.24, Table 5.17, Figure 5.11, and Figure 5.13. The direction and the strength or the relationship between the yield as a response to TKW were measured with the equation (yield kg/ha=1817 + 57.67 TKW g), Figure 5.11. Yield correlates statistically negatively with the other measure parameters, such as gluten content, Figure 5.12. Gluten content correlates significantly positively with protein 0.86, moisture 0.56, and SDS 0.87.

This experiment in the planting year of 2021-2022 of applying N, EM, and their combination along with the control in irrigated and not irrigated fields provided innovative and unique insights into addressing abiotic stressors in agriculture, especially drought. Irrigation has a significant positive impact on wheat yield quantity and quality. On average, the in-crop use of EM + N + irrigation demonstrates a significant enhancement in crop production and improvements in several quality indicators. The use of EM applications has been seen to provide beneficial outcomes in enhancing the resilience of crops against the adverse effects of drought and heat conditions, although to varying extents. The in-crop application of EM has not been used by any researcher so far, and this discovery is significantly adding to the existing scientific information of the knowledge body of science.

Table 5.17. Correlation coefficients among the study parameters of EM application and wheat abiotic stress experiment of 2021-2022, MATE - Gödöllő.

						Whole flour test (NIR)			Whole grain test a month after harvest (NIR)				Whole grain test at harvest (NIR)		
	Traits	Yield	TKW	Test weight	Falling_No	Gluten (Gluten Wash)	Moisture_1	Protein_1	Gluten_1	Gluten_2	Moisture_2	Protein_2	Z_Index_1	Gluten_3	Moisture_3	Protein_3
	TKW	0.46*														
	Test weight	-0.14	-0.54*													
	Falling_No	0.11	0.24	-0.06												
	Gluten_wash	-0.01	0.21	0.06	0.03											
Flour test	Moisture_1	-0.11	0.03	0.18	-0.22	0.56*										
	Protein_1	-0.09	0.13	-0.02	0.26*	0.68*	0.29*									
	Gluten_1	-0.04	0.11	0.20	0.11	0.84*	0.64*	0.80*								
Grain test a After	Gluten_2	-0.07	0.16	0.09	0.11	0.91*	0.51*	0.71*	0.86*							
	Moisture_2	-0.31*	0.17	0.02	-0.11	0.63*	0.57*	0.43*	0.55*	0.56*						
	Protein_2	-0.02	0.09	0.14	0.12	0.86*	0.49*	0.72*	0.83*	0.96*	0.44*					
	Z_Index_1	0.00	0.13	0.11	0.10	0.87*	0.50*	0.70*	0.82*	0.95*	0.48*	0.97*				
Grain test at harvest	Gluten_3	-0.19	-0.02	-0.01	0.06	0.43*	0.41*	0.28*	0.39*	0.43*	0.32*	0.37*	0.38*			
	Moisture_3	-0.28*	-0.28*	-0.30*	-0.08	-0.11	-0.13	0.02	-0.17	-0.10	-0.16	-0.15	-0.17	-0.03		
	Protein_3	-0.24*	0.03	0.02	0.05	0.46*	0.36*	0.41*	0.44*	0.47*	0.34*	0.44*	0.40*	0.89*	-0.10	
	Z_Index_2	-0.11	0.01	-0.14	0.05	0.24	0.26	0.28	0.22	0.26	0.12	0.24*	0.21	0.75*	0.10	0.80*

* the correlation coefficient is significant at the probability level of 0.05, -1 is the flour quality parameters, -2 is the grain quality parameters measured a single month after harvest, and -3 is the grain quality parameters measured at the harvest day.

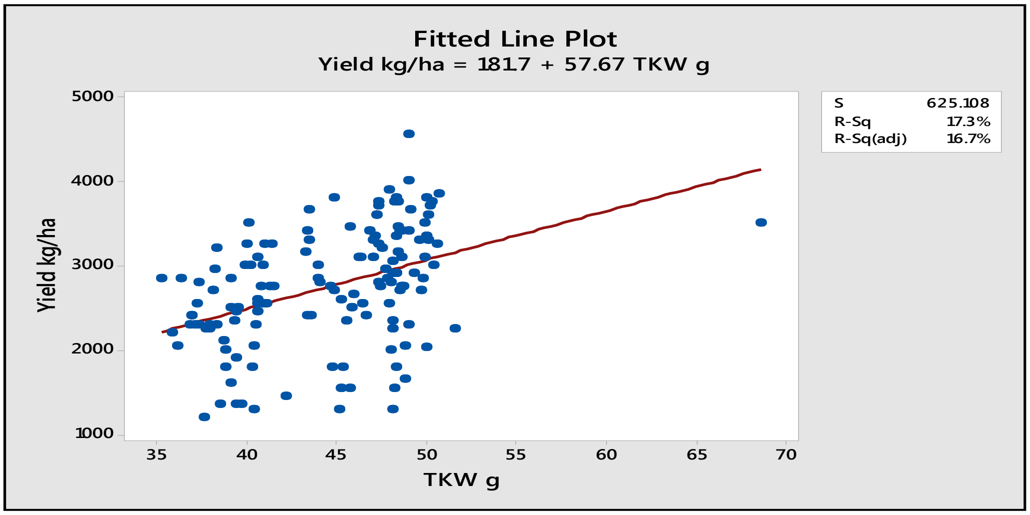

Figure 5.11. Yield response to TKW as an indicator for wheat grain production.

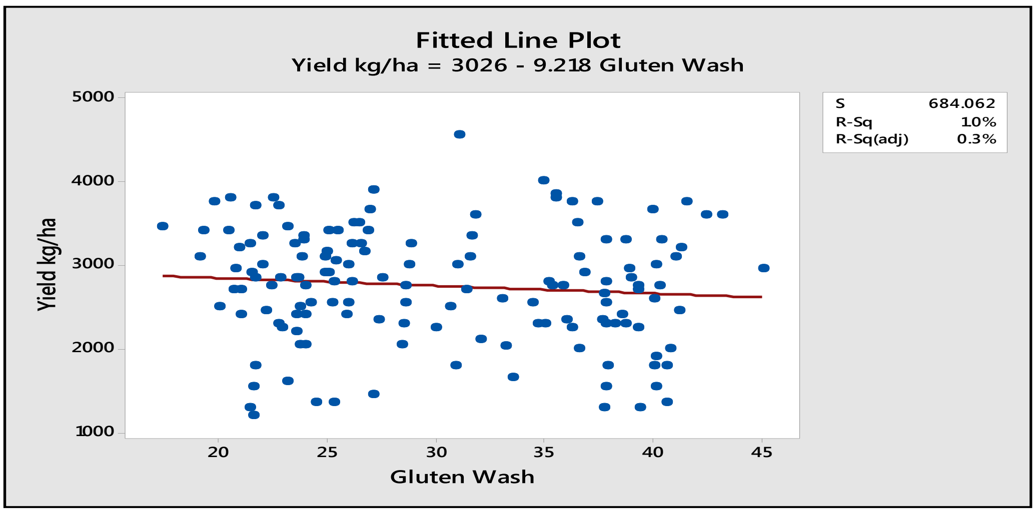

Figure 5.12. Yield response to gluten content as an indicator for grain production.

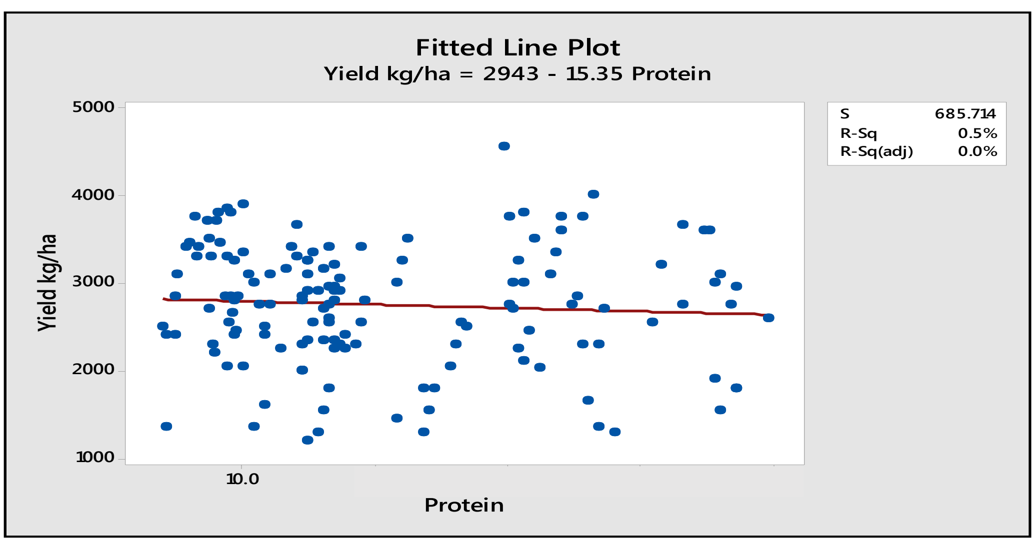

Figure 5.13. Yield response to protein content as an indicator for grain production.

5.3.2 2022-2023

Throughout the subsequent agricultural cycle, 2022 - 2023, the proposed plan underwent a process of development, updating, and modification. The present study incorporated the application of nitrogen doses. A total of six nitrogen doses, namely 0, 40, 80, 120, 160, and 200 kg/ha, were employed as an active agent of NH_4NO_3 to the what crop of Felleg variety. The primary focus of the initial season was the investigation of the impact of drought on yield and quality parameters, specifically in relation to the application of N and EM. The second year of the study was dedicated to examining drought conditions, varying nitrogen doses, and the application of EM on various vegetative parameters and yield and quality parameters.

Statistics indicate that the use of effective microorganisms (EM) has a significant impact on wheat productivity. The grain production was improved by 25.05% after applying the EM twice, at F3 and F10, Table 5.18. However, based on the data, it seems that the second application time, EM at F10, was more successful in increasing field output than a single application time at F3 since there was a significant difference. The EM plays a crucial function in aiding the plant's resilience against moisture deficiency. However, as there is no evidence of their impact on the grain yield when applied solely at F3, it may be attributed to the need for the EM treatment for a soil temperature of about 17°C at the time of application. The temperature optimization may be achieved during the latter stages of the plant's life, namely in April in Hungary. The temperature at the moment of application may have a significant impact on the microorganisms themselves, whether it is low or high.

Table 5.18. Yield production (kg/ha) of *Triticum aestivum* L under drought stress and different treatments of effective microorganisms and nitrogen treatments in 2023, MATE - Gödöllő.

Nitrogen Treatments kg/ha	EM Treatment			Mean N*	
	0 EM	EM at F3	EM at F3 and F10		
0	3533	2417	4467	3472 ± 1402 c	
40	3417	3350	5233	4000 ± 1069 c	
80	4617	4550	5633	4933 ± 800 b	
120	4800	5417	6550	5589 ± 872 ab	
160	5250	5200	6400	5617 ± 751 a	
200	5683	5683	6833	6067 ± 631 a	
LSD $_{T*N}$	N.S			LSD $_N$	680.7
Mean T	4550 ± 1140 b	4436 ± 1258 b	5853 ± 1062 a		
LSD $_T$	481.3				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the nonapplication of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 are two application times at Feekes 3 and 10 growth stages, and N is the nitrogen application (NH_4NO_3).

Available data demonstrates that using nitrogen (N) dramatically enhances the ultimate grain yield. It seems that when the levels of N increased, there was a corresponding rise in grain yield. The grain yield increased by 14.13%, 34.76%, 46.72%, 47.19%, and 54.40% compared to the control after adding nitrogen at rates of 40, 80, 120, 160, and 200 kg/ha, Table 5.18. This refers to the contribution of N application to the plant's overall health and its capacity to withstand abiotic stresses in the plant's environment. Ultimately, this leads to an improvement in grain output. There is a notable interaction between the use of N and EM applications regarding grain production. The maximum grain yield of

6800 kg/ha was achieved when using EM at F3 and F10, together with a nitrogen application rate of 200 kg/ha. The value exhibits a significant increase compared to the control group with 0EM and 0N, since it only yields 3533 kg/ha, Table 5.18. This data aligns with the green yield data presented in Table B.5. 34. Data regarding the effect of the treatments, EM and N, present only statistical but not significant effects on the TKW and the test weight, Table B.5. 35 and Table B.5. 36.

The application of effective microorganisms did not influence the plant leaf area; however, the N treatment significantly impacted it, Table 5.19. The application of nitrogen at quantities above 120 kg/ha significantly increased the size of the wheat canopy. Nevertheless, a reduced rate of N treatment had a considerable impact on the leaf area compared to the control, albeit it was not as substantial as the higher rates. The leaf area had an increase of 83.87%, 85.10%, and 85.10% compared to the control with the 120, 160, and 200 kg/ha N, Table 5.19. A high-quality extensive canopy increases photosynthetic surface and productivity, producing higher crop output. Data in Table B.5. 37 present that although there is no significant increase in the rate of the photosynthesis activity, there is a statistical increase with both treatments and levels. Table B.5. 38 present the photosynthesis II under the abiotic stress and the study treatment, which had an role in mitigating its reverse impact.

Table 5.19. Leaf area of *Triticum aestivum* L grown under drought stress and different treatments of effective microorganisms and nitrogen treatments measured at anthesis in 2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	1.75	1.13	1.18	1.35 ± 0.54 c	
40	1.67	1.7	2.47	1.95 ± 0.66 bc	
80	2.42	2.33	2.74	2.50 ± 0.63 b	
120	3.68	2.93	3.30	3.30 ± 0.46 a	
160	3.39	2.85	3.80	3.35 ± 0.93 a	
200	3.54	2.75	3.30	3.20 ± 0.67 a	
LSD T*N	N.S			LSD N	0.633
Mean T	2.74 ± 1.05 a	2.28 ± 0.83 b	2.8 ± 1.05 a		
LSD T	0.448				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the nonapplication of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

The number of tillers per plant is crucial in wheat production since each tiller ultimately bears a head, thus contributing to the overall grain output. Before this development stage of wheat plant, it is crucial to stimulate the plant to promote the production of more tillers. It may also be achieved by mitigating the impact of abiotic stressors that surround the plants. The application of nitrogen leads to a considerable significant increase in the number of tillers per plant. Based on the results, using N level at 120 to 200 kg/ha significantly enhances the tiller count, Table 5.20. During this stage of life in the Hungarian environment, plants have relatively low levels of moisture stress, but the dry season occurs at a later time. However, the presence of N seems to stimulate the plant to enhance its physical structure following its genetic potential in response to the surrounding environment. Applying 200 kg/ha results in a 47.058% increase in plant tillers compared to the control, Table 5.20. Therefore, providing N before the plant's tillering stage is essential.

The spike density per square meter shows a substantial rise with 80 kg/ha N and greater quantities, Table B.5. 39. However, this trait was not affected by the EM treatments. Nitrogen is essential for the plant to enhance the expression of this agronomic trait, particularly in the presence of abiotic stressors. For instance, the spike density per square meter shows a 38.35% increase when 120 kg/ha N is applied, compared to the control, Table B.5. 39.

Table 5.20. Number of tillers per plant of *Triticum aestivum* L grown under drought stress and different treatments of effective microorganisms and nitrogen treatments in 2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	2.5	2.3	3.1	2.6 ± 0.51 d	
40	2.6	2.4	3.5	2.8 ± 0.63 d	
80	3.3	3.5	3.7	3.5 ± 0.40 c	
120	3.7	4.1	4.1	4.0 ± 0.38 ab	
160	3.1	3.4	4.1	3.6 ± 0.56 bc	
200	4.4	3.6	4.5	4.2 ± 0.76 a	
LSD T*N	N.S			LSD N	0.43
Mean T	3.3 ± 0.72 b	3.2 ± 0.84 b	3.8 ± 0.65 a		
LSD T	0.3				

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the nonapplication of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

The number of spikelets per spike was significantly affected by applying EM and N treatments, Table 5.21. While there was a little discrepancy in the administration of EM once during the F3 development stage, substantial differences were seen when administering the EM treatment at the F3 and F10 growth stages. This treatment resulted in a 6.84% increase in the number of spikelets per spike compared to the control, Table 5.21. The second application of EM helps enhance this agronomic attribute and ultimately contributes to the yield. Additionally, using EM during this growth stage helps plants withstand abiotic stresses and improves their overall performance. This trait significantly rose when the nitrogen application exceeded 80 kg/ha. For example, applying 120 kg of nitrogen per hectare enhances the number of spikelets per pike by 24.63%, Table 5.21. It can be inferred that using EM in F3 and F10, together with an N treatment of at least 80 kg/ha, is essential for mitigating abiotic stressors and enhancing the number of spikelets per spike, ultimately leading to a considerable improvement in crop production.

The data indicate that neither treatment impacted the time it took for the plants to go from planting to heading, Table B.5. 40. It means the environmental factor is more effective in influencing this trait than the treatments.

Using effective microorganism treatments twice at F3 and F10 significantly influenced plant height. Table 5.22 demonstrates a substantial 3.94% increase in plant height compared to the control. This treatment enhances the plant's ability to endure drought-induced stress that occurs throughout the latter phases of plant development, namely beginning from the booting stage. However, administering a single time of EM treatment at F3 does not have any substantial influence on this particular trait. While farmers may not favor higher wheat plants, their height indicates the plants' response to treatments and overall health. While applying a minimal quantity of 40 kg/ha of N resulted in a statistical rise in plant height, 80 kg/ha or more of N led to a significant increase in its values. For instance, applying a rate of 200 kg per hectare resulted in a 21.73% increase in plant height, Table 5.22. Based on the findings, it can be inferred that in Hungarian cultivation conditions, the application of EM in F3 and F6, along with a substantial amount of N application ranging from 120 to 200 kg/ha, is necessary to effectively combat abiotic stresses and cultivate high-quality plants that possess strong resistance to such pressures, particularly drought.

Table 5.21. Number of spikelets per spike of *Triticum aestivum* L grown under drought stress and different treatments of effective microorganisms and nitrogen treatments in 2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	11.5	11.3	13.3	12.1 ± 1.79 c	
40	12.7	13.0	14.9	13.5 ± 1.48 b	
80	15.3	14.5	15.8	15.2 ± 1.05 a	
120	15.4	15.3	15.7	15.5 ± 1.23 a	
160	15.2	14.3	15.3	14.9 ± 0.87 a	
200	14.5	15.5	15.7	15.2 ± 0.78 a	
LSD T*N	N.S			LSD N	1.18
Mean T	14.1 ± 1.83 b	14.0 ± 1.87 b	15.1 ± 1.23 a		
LSD T	0.84				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the nonapplication of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table 5.22. The height of the plant (cm) of *Triticum aestivum* L grown under drought stress and different treatments of effective microorganisms and nitrogen treatments in 2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	65.6	57.7	73.7	65.6 ± 8.76 c	
40	75.4	71.2	80.6	75.7 ± 5.69 b	
80	78.7	75.3	81.9	78.6 ± 3.45 ab	
120	80.4	80.7	81.7	80.9 ± 1.54 a	
160	80.7	78.1	81.7	80.1 ± 2.95 a	
200	82.1	81	81.7	81.6 ± 2.41 a	
LSD_{T*N}	N.S			LSD_N	3.66
Mean T	77.1 ± 6.81 b	74.0 ± 8.60 c	80.2 ± 4.42 a		
LSD_T	2.59				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the nonapplication of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

The experimental treatment also had an impact on the yield quality parameters. The application of beneficial microorganisms significantly enhanced the plant's capacity to endure abiotic stresses during grain filling, improving the ultimate crop's quality, as seen in Table 5.23. Implementing the EM treatment at F3 and F10 results in a substantial 3.35% increase in the overall protein content of the flour, as compared to the control. Nevertheless, administering a single-time EM treatment had no impact on wheat quality. This outcome is expected, considering the treatment was administered at the F3 stage. It may be said that using effective microorganisms around the time the grains are being filled might enhance the quality of wheat flour, particularly in terms of its protein content.

Furthermore, empirical evidence indicates a positive correlation between the quantity of nitrogen administered and the protein content. However, according to the findings, a minimum nitrogen quantity of 120 kg per hectare is required to enhance and augment the protein content. As the quantity of nitrogen increases up to 200 kg/ha, there is a gradual rise in the protein %. The protein content improved by 7.41%, 10.78%, and 11.51% when the quantity of applied nitrogen fertilizer increased from 120 to 160 and 200 kg per hectare, respectively, compared to the control. When measuring the protein content of the whole grain on the day of harvest and a month after the harvest, increases in protein percentage were observed due to the continued biochemical process of protein formation within the first month after harvest, Table B.5. 41 and Table B.5. 42.

Moreover the effect of N treatments was more apparent when looking at the whole grain protein than the whole grain protein. Measuring the protein content on harvest day indicates that N application of 160 and 200 kg/ha had the most significant influence on its percentage, followed by 120 kg/ha, with a significant reduction. The protein percentages during the first month's storage increased by 3.04%, for example, for those with 120 kg/ha N. Hence, the administration of 160- 200 kg/ha of nitrogen and effective microorganisms during growth stages F3 and F10 enhances the plant's resilience to abiotic stressors and improves its capacity to produce better quality grains and wheat flour with greater protein content.

Table 5.23. Whole flour protein (%) of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments in 2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	9.51	9.62	10.08	9.74 ± 0.44 c	
40	9.76	9.78	10.26	9.93 ± 0.43 c	
80	10.15	9.95	10.3	10.13 ± 0.42 bc	
120	10.39	10.08	11.01	10.49 ± 0.57 ab	
160	10.93	10.48	11.14	10.85 ± 0.42 a	
200	10.92	10.93	10.95	10.93 ± 0.55 a	
LSD T*N	N.S			LSD N	0.448
Mean T	10.27 ± 0.71 b	10.14 ± 0.57 b	10.62 ± 0.56 a		
LSD T	0.316				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the nonapplication of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

The other quality parameter is the content of the gluten. Nitrogen application increases the percentage of the gluten, while the EM application presents no effect, Table B.5. 43. Evidence from the data indicates a positive correlation between the quantity of nitrogen administered and the proportion of gluten. For instance, the gluten percentage in the white flour measured with the gluten wash machine rose by 24.19% when 200 kg/ha N was applied, compared to the control. While the application of EM at F3 and F10 did not provide any significant effects, a statistical impact was still seen. Specifically, the overall gluten content of the flour rose from 25.5% to 26.54%, Table B.5. 43.

Measuring the gluten content of the whole flour indicates a more specific indication regarding the most useful N level affecting the gluten percentages. It shows that 160 and 200 kg/ha N application significantly improved the whole flour quality, Table B.5. 44. It means this level of N is needed to mitigate the effect of the abiotic stresses and improve the flour quality. In the same way, measuring the grain gluten content specified these two N levels to be the most effective, Table B.5. 45 and Table B.5. 46. When comparing the gluten content of grains at the time of harvest, Table B.5. 45, and one month later, Table B.5. 46, there is an observed rise in the percentage of gluten throughout the storage period. This is attributed to ongoing biochemical processes and protein formation during the first month following harvest. It can be concluded that to overcome the drought stress and obtain a good quality yield, 160-200 kg/ha N is needed, and EM application at F3 and F10 slightly influences the plant's ability to produce a better-quality yield.

Different values of fall numbers may be specific to unique products and processing conditions inside the plant (CAUVAIN, 2017). Data show that EM application does not affect enzymatic activity. However, N seems to have a great impact, Table B.5. 47. N application of 120 kg/ha and more increases the FN more than the optimal level. However, N application of 80 kg/ha resulted in an enzymatic activity within the optimal 363.6 seconds, Table B.5. 47. Moreover, a lower N application resulted in an even lower FN value.

Data from the SDS-sedimentation volume test (Zeleny test) present significant differences when applying N compared to the control. The most significant rise in the SDS-sedimentation volume test was made with 160 and 200 kg/ha N application, respectively, 46.4 and 48.2 ml, Table B.5. 48, when measured on the harvest day. Regarding the EM effect on the SDS value, it made only a slight statistical influence, increasing it, Table B.5. 48 and Table B.5. 49. There were no notable variations among the treatments regarding moisture content one month after harvest, both in the flour and in the grain, Table B.5. 50 and Table B.5. 52. However, there are significant variations in the moisture content with the EM and N treatments measured on the day of harvest, Table B.5. 51. Applying EM at both F3 and F10 growth stages led to a substantial reduction in grain moisture, with a measured value of 1.45% compared to the control group. Similarly, applying N at a rate of 200 kg/ha resulted in a considerably significantly reduced grain moisture percentage of 2.18%, Table B.5. 51. Yield is significantly correlation with the vegetative growth traits and had a slight reverse correlation with the quality parameters, Table 5.24.

Based on this experiment, it can be concluded that applying EM twice at F3 and F10 has a very advantageous impact on significantly increasing the yield by 25.05% and improving the yield quality, particularly the protein content, by 3.35%. The application of EM mainly contributes to production by raising the number of tillers per plant by 14.08% and the number of spikelets per spike by 6.84%, resulting in an overall increase in yield. Applying nitrogen at 160-200 kg per hectare significantly increases all vegetative and yield metrics. Respectively, grain yield had a significant increase of 47.19% and 54.40%, leaf area by 85.10% and 85.10%, plant tillers by 32.25% and 47.05%, spikelets number per spike by 20.740% and 22.71%, plant height by 19.90% and 21.73%, and protein content by 10.78% and 11.51%. These statements may be summarized as follows: they result in the development of a more robust and resilient plant capable of enduring abiotic stressors and producing under drought.

Table 5.24. Correlation coefficients among the study parameters of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments, MATE - Gödöllő.

	Final Yield	Green Yield	TGW	TW	LAI	SPAD	QY	Tillers n	Spikes n m2	Spikelets n	Heading date	Plant height	FN	Gluten%	Moisture% *	Protein% *	Gluten% *	Gluten% **	Moisture% **	Protein% **	SDS **	Gluten% ***	Moisture% ***	Protein% ***
Green Yield	0.96																							
TGW	-0.38	-0.32																						
TW	-0.34	-0.42	0.28																					
LAI	0.73	0.74	-0.29	-0.35																				
SPAD	0.16	0.16	-0.09	-0.07	0.03																			
QY	0.21	0.22	-0.06	-0.11	0.03	-0.13																		
Tillers n	0.79	0.82	-0.18	-0.33	0.68	0.18	0.03																	
Spikes n m2	0.35	0.42	-0.15	-0.38	0.47	-0.19	-0.04	0.32																
Spikelets n	0.78	0.80	-0.20	-0.31	0.59	0.04	0.09	0.68	0.33															
Heading Date	0.51	0.48	-0.26	0.00	0.38	-0.04	-0.05	0.44	0.27	0.54														
Plant Height	0.83	0.85	-0.25	-0.41	0.73	0.12	0.13	0.73	0.39	0.77	0.44													
FN	0.53	0.55	-0.21	-0.32	0.36	0.07	-0.03	0.47	0.09	0.47	0.15	0.43												
Gluten %	0.73	0.73	-0.49	-0.46	0.64	0.11	0.06	0.61	0.32	0.56	0.40	0.58	0.57											
Moisture% *	-0.16	-0.14	0.38	-0.22	-0.05	-0.08	-0.05	-0.02	-0.01	-0.08	-0.28	-0.06	0.14	-0.06										
Protein% *	0.64	0.71	-0.32	-0.42	0.59	0.16	0.03	0.62	0.37	0.51	0.26	0.57	0.45	0.74	-0.10									
Gluten% *	0.68	0.70	-0.38	-0.48	0.60	0.12	0.12	0.58	0.28	0.51	0.28	0.54	0.54	0.86	-0.09	0.76								
Gluten% **	0.73	0.73	-0.42	-0.37	0.72	0.11	0.02	0.65	0.31	0.58	0.35	0.66	0.59	0.82	-0.12	0.73	0.79							
Moisture% **	-0.52	-0.54	0.25	0.16	-0.44	-0.11	-0.23	-0.34	0.03	-0.36	-0.16	-0.56	-0.26	-0.44	0.16	-0.37	-0.44	-0.46						
Protein% **	0.73	0.73	-0.45	-0.40	0.68	0.03	0.07	0.61	0.27	0.58	0.34	0.61	0.58	0.86	-0.11	0.77	0.83	0.92	-0.52					
SDS **	0.74	0.74	-0.39	-0.40	0.64	0.10	0.03	0.67	0.31	0.63	0.34	0.69	0.63	0.84	-0.03	0.77	0.78	0.90	-0.42	0.92				
Gluten% ***	0.73	0.73	-0.49	-0.44	0.69	0.04	0.07	0.61	0.32	0.57	0.32	0.59	0.63	0.89	-0.04	0.78	0.80	0.89	-0.46	0.95	0.91			
Moisture% ***	0.18	0.24	0.16	0.12	0.13	-0.16	0.17	0.18	0.18	0.11	0.05	0.27	0.07	0.07	0.05	0.12	-0.02	-0.01	-0.31	0.08	0.10	0.07		
Protein% ***	0.55	0.55	-0.41	-0.37	0.64	0.08	0.01	0.50	0.32	0.39	0.18	0.51	0.54	0.75	0.00	0.59	0.66	0.90	-0.41	0.79	0.76	0.85	-0.10	
SDS ***	0.69	0.69	-0.34	-0.19	0.64	0.02	0.08	0.56	0.32	0.58	0.37	0.61	0.48	0.66	-0.15	0.75	0.64	0.77	-0.39	0.79	0.81	0.81	0.24	0.58

$r \geq 0.27$ is significant at 0.05, and $r \leq 0.35$ is significant at 0.01; * is the quality parameters of the whole flour, ** is the quality parameters measured with an NIR at the harvest day, *** is the quality parameters measured with a NIR a moth after harvest; TKW is the thousand-grain weight; TW is the test weight; LAI is the leaf area index; QY is the quantum yield; FN in the fulling number (enzymic activity); SDS is the SDS-sedimentation volume.

5.4 In-Crop N-Splitting-Timing Experiment

This experiment aimed to assess the in-crop nitrogen uptake, assimilation, and mobilization in wheat plants subjected to abiotic stress conditions. The comparison of morphological and quality parameters across different nitrogen application rates and timings enables the identification of the optimal nitrogen application strategy in the context of both drought and irrigation conditions. Furthermore, the outcomes of this study can provide valuable insights into crop management strategies, specifically pertaining to the application rates, timing, and division of nitrogen fertilizers. These strategies aim to enhance nitrogen use efficiency (NUE) and counteract the adverse impact of abiotic stress on crop productivity.

The statistical study reveals a robust positive impact of N-splitting on wheat grain yield, namely at the critical development stages of F3, F6, and F10, Table 5.25. When splitting and applying the identical nitrogen N dosage of 160 kg/ha into three doses (F3=53.33, F6=53.33, and F10=53.33) kg/ha, Table 4.2, there is a substantial increase in the ultimate grain yield by 5.20% compared to using just two doses (F6=80 and F10=80) kg/ha. This gain is also statistically significant compared to applying the total quantity of nitrogen 160 kg/ha in F3 by 2.45%, Table 5.25. This means that nitrogen management is crucial in enhancing plant vigor and resilience to abiotic stressors. Furthermore, it implies that the wheat plant must be improved before the growth stages, which will have a greater impact on the yield components. This can be achieved by enhancing the plan to increase the number of plant tillers, spiks, spikelets, and, ultimately, grain filling. The success of this enhancement process relies on the genetic capacity of the plant and its interaction with the environment, mainly because yield is a quantitative trait. It is well known that the physiological component of yield is determined by the multiplication of the number of tillers, the number of spikelets per spike, and the grain filling (TKW), Eq. V.

Data shows that irrigation greatly enhances the plant's capacity to withstand the adverse impact of drought-induced abiotic stress, resulting in a 12.573% increase in ultimate grain production. This improvement was seen across several N-splitting treatments and different wheat varieties, with the yield rising from 6216 kg/ha in the non-irrigated field to 7050 kg/ha in the irrigated area, Table 5.25. Therefore, these findings suggest that irrigation is beneficial to be applied in a dry year in a Hungarian environment starting from Feeks 6, with a water amount of 20 mm, every week during the dry periods is characterized by low rain fall, Table 5.25 and Table B.5. 54.

The cultivated wheat varieties exhibit substantial variation in their sensitivity to drought, N application, and irrigation and their genetic capacity to endure stressors. Statistics indicate that Nemere variety achieved a much higher grain yield than Felleg by 20.17% and 35.26% compared to Alföld, Table 5.25. Despite notable variations among contemporary wheat varieties, they exhibit superior resistance to drought stress compared to the older Alföld variety, which yielded a mere 5536 kg/ha across all treatments.

The best management compilation of this experiment in terms of gain yield resulted in 8433 kg/ha when using the wheat variety of Nemere, splitting the same amount of N in three dosages, and irrigating with 20 mm water starting from Feeks 6 every week during the dry periods is characterized by low rainfall. Therefore, to mitigate the effect of abiotic stresses, especially drought, this experiment suggests using modern-produced varieties along with a good strategy of N application by splitting it into doses and irrigating the plant when needed, especially in the critical growth stages.

Table 5.25. Yield production (kg/ha) of *Triticum aestivum* L under drought stress and different treatments of irrigation and N-splitting in various growth stages in 2023, MATE - Gödöllő.

Varieties	Irrigation (I)	Fertilization (F)			V * I
		F3	F3 + F6	F3 + F6 + F10	
Alföld	Irrigated	4817	6983	5833	5878
	Not	5867	4333	5383	5194
Felleg	Irrigated	6800	6867	6817	6828
	Not	6208	5817	6233	6086
Nemere	Irrigated	8150	8750	8433	8444
	Not	7983	6000	8117	7367
LSD_{V*I*F}		556.1			LSD_V N.S

V * F

Varieties	F3	F3 + F6	F3 + F6 + F10	Variety means
Alföld	5342	5658	5608	5536 ± 1198 c
Felleg	6504	6342	6525	6457 ± 1025 b
Nemere	8067	7375	8275	7906 ± 531 a
LSD_{V*F}	393.2			LSD_V 227

I * F

Irrigation	F3	F3 + F6	F3 + F6 + F10	Irrigation means
Irrigated	6589	7533	7028	7050 ± 1400 a
Not Irrigated	6686	5383	6578	6216 ± 1210 b
LSD_{I*F}	321			LSD_I 185.4

F

Fertilization	F3	F3 + F6	F3 + F6 + F10
Mean fertilization	6638 ± 1352 ab	6458 ± 1552 b	6803 ± 1220 a
LSD_F	227		

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at the growth stage of Feekes3, F3+F6 the total amount of N-seplited in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were seplited into three portions 53.3 for each growth stages.

Nemere has significantly the greatest TKW, 41.61 g, followed by Felleg, 36.28, which is significantly higher than Alföld, 34.68 g, with an LSD of 2.28, Table B.5. 55. Concerning TKW, there was a statistical interaction seen between the varieties and the fertilizer treatments, as well as between the irrigation and the fertilizer treatments. However, these interactions were not found to be significant. This implies that the expression of this trait is more influenced by genetic factors when all other abiotic factors are held constant. The hectoliter weight is a metric unit used to measure the volume of wheat. Cereals with elevated hectoliter weights have greater density and weight, generally correlated with higher protein content. While no notable differences were seen across the different growing wheat varieties and irrigation regimes, the test weight exhibited a substantial variance due to N-splitting. Splitting the N into three doses resulted in the lowest value of 75.98 $kghl^{-1}$, statistically different from the value of 76.13 $kghl^{-1}$ obtained with a single dosage application. However, splitting the N into two doses greatly increased the value to 77.90 $kghl^{-1}$, which was the highest, Table B.5. 56. The third dose did not impact this measurement, whereas a greater dosage during the second application had the most significant effect by enhancing the plant's vegetation, thus influencing the test weight.

Tillers play a crucial role in the growth and development of the wheat plant. The density of plants influences the grain yield, the number of tillers per plant, the number of grains per tiller, and the weight of each grain. Hence, tillering is essential for productivity. The data show no significant impact on the resulting tiller number when dividing the N dosage. It indicates that administering the whole quantity of N, half of it, or one-third of it just before the tillering stage aiming to improve tillering has an equivalent impact, Table 5.26. It indicates that applying minimal nitrogen is sufficient to stimulate wheat plants to generate their potential number of tillers. It is a beneficial strategy that is both cost-effective and involves reserving the remaining nutrients for use during later development phases. Irrigation has no discernible impact on the quantity of tillers produced. This phenomenon may be related to the specific time of the year when the tillering stage coincides with a rainy wet period in Hungary, followed by a dry period in subsequent phases. However, there were noticeable significant variations among the cultivated wheat varsities. Alföld had the highest number of tillers, with an average of 4.26 tillers per plant, substantially more than Felleg's average of 3.81 tillers and statistically higher than Nemere's average of 4.03 tillers, Table 5.26. It may be inferred that N-Splitting is a successful application strategy since lowering the quantity applied does not decrease the number of tillers compared to the treatment with the total amount. However, no significant differences were seen regarding the trait of plant height Table B.5. 58.

Table 5.26. Tillers number per plant of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N-splitting in various growth stages in 2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I
		F3	F3 + F6	F3 + F6 + F10	
Alföld	Irrigated	4.13	4.20	4.20	4.18
	Not	4.00	4.13	4.87	4.33
Felleg	Irrigated	3.87	3.47	3.53	3.62
	Not	4.40	4.20	3.40	4.00
Nemere	Irrigated	4.00	3.80	3.87	3.89
	Not	4.47	3.93	4.13	4.18
LSD_{V*I*F}		N.S			LSD_{V*I} N.
V * F					
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety means
Alföld		4.07	4.17	4.53	4.26 ± 0.50 a
Felleg		4.13	3.83	3.47	3.81 ± 0.55 b
Nemere		4.23	3.87	4.00	4.03 ± 0.52 ab
LSD_{V*F}		N.S			LSD_V 0.35
I * F					
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation means
Irrigated		4.00	3.82	3.87	3.90 ± 0.45
Not Irrigated		4.29	4.09	4.13	4.17 ± 0.61
LSD_{I*F}		N.S			LSD_I N.
F					
Fertilization		F3	F3 + F6	F3 + F6 + F10	
Mean fertilization		4.14 ± 0.40	3.96 ± 0.56	4.00 ±0.66	
LSD_F		0.35			

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at the growth stage of Feekes3, F3+F6 the total amount of N seplited in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 for each growth stages.

Considering the same perspective, and since each tiller ultimately produces one head, Table B.5. 57 (in the appendix B)shows no significant disparities in the overall quantity of N application, 1067 spikes per square meter, compared to the N-splitting in three separate applications, 1007 spikes per square meter, with an LSD of 136.1, Table B.5. 57. This confirms the study finding that supplying nutrients to the plant throughout its whole life cycle is more advantageous than supplying the total amount in a single time. However, there is a notable variation across the different varieties, which is expected due to their genetic potential and ability to generate varying numbers of plant tillers in response to the surrounding abiotic and environmental conditions.

The other component of the yield equation is the grain number produced per spike. Drought stress significantly affects the number of spikelets in each spike throughout their formation and production, as seen in Table 5.27. The irrigated plots yielded a significantly higher number of spikelets per spike, with a 12.114% increase compared to the non-irrigated area. Therefore, an irrigation need of 20 mm weekly is necessary for irrigation during this specific life stage since it is usually associated with a dry period of the year in Hungary. While there were no notable differences among the N-splitting applications, the N-splitting application in three doses yielded a higher number of spikelets per spike, namely 17.80. This was followed by the two-time N application with 17.40, and lastly the single-time N application with 17.30. Applying a minimal quantity of nitrogen before this development stage is advantageous since it stimulates the plant to generate more spikelets, ultimately leading to an increase in yield.

Table 5.27. Spikelets per a spike (n) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N-splitting in various growth stages in 2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3 + F6 + F10		
Alföld	Irrigated	21.60	20.40	21.00	21.00	
	Not	17.40	17.93	18.80	18.04	
Felleg	Irrigated	18.07	17.60	17.27	17.64	
	Not	16.07	16.40	16.07	16.18	
Nemere	Irrigated	18.80	17.07	15.27	17.04	
	Not	14.87	15.00	15.40	15.09	
LSD_{V*I*F}		N.S			LSD_{V*I}	0.68
V * F						
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety means	
Alföld		19.50	19.17	19.90	19.52 ± 1.81 a	
Felleg		17.07	17.00	16.67	16.91 ± 1.62 b	
Nemere		16.83	16.03	15.33	16.07 ± 0.85 c	
LSD_{V*F}		0.83			LSD_V	0.48
I * F						
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation means	
Irrigated		19.49	18.36	17.84	18.56 ± 2.12 a	
Not Irrigated		16.11	16.44	16.76	16.44 ± 1.41 b	
LSD_{I*F}		0.68			LSD_I	0.39
F						
Fertilization		F3	F3 + F6	F3 + F6 + F10		
Mean fertilization		17.30 ± 2.31	17.40 ± 1.80	17.80 ± 2.19		
LSD_F		N.S				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at the growth stage of Feekes3, F3+F6 the total amount of N seplited in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 for each growth stages.

The plant height was considerably impacted by drought stress; however, irrigation increased the plant height by 2.15%. The irrigated field had an average plant height of 89.2 cm, whereas the non-irrigated area had an average height of 87.3 cm, Table B.5. 59 (in the appendix). Administering the whole quantity of N once at the F3 stage increased plant height compared to dividing the dose. Nevertheless, possessing a greater value is not considered advantageous. However, it does indicate the plant's ability to withstand abiotic stress throughout the vegetative stage. Nonetheless, it lacks any correlation with both the yield and the quality.

The leaf area index (LAI) quantifies the leaf materials in a canopy. It is the ratio of one side leaf per unit ground area. Periodically, yearly cultivated plants and cultivated areas might exhibit notable fluctuations in the LAI. The measure is valuable for characterizing canopy development and production's regional and temporal patterns. Examining this trait is essential for understanding the influence of canopy size on total crop production, regardless of the presence or absence of abiotic stress. This traverses a broader canopy, designed to enhance the productivity of photosynthesis. The study findings indicate that drought stress had a considerable significant detrimental impact on the LAI at the anthesis stage, Table B.5. 59. The irrigated field had a 10.552% increase in canopy compared to the non-irrigated area. Drought significantly impairs the photosynthetic capacity, thereby affecting its output. The application of N fertilizer as a single dose at the F3 growth stage had the most significant impact on enhancing LAI. It leads to the development of a larger canopy, increased surface coverage, and greater photosynthetic activity compared to splitting the same amount of N fertilizer and applying it at different growth stages. Applying nitrogen during the late phases of plant growth is unlikely to impact the plant's physical size. However, it may enhance photosynthesis output quality by increasing photosynthetic units' activity while their number remains constant in the late stages. Planted wheat varieties exhibit significant variations in their capacity to generate varying amounts of leaf canopy under drought and heat stress conditions. Among them, Felleg demonstrated the most superior performance, Table B.5. 59.

The SPAD is a widely used device that quantifies the chlorophyll levels in leaves. It is often used to determine the most suitable time and amount of fertilizer application to enhance crop productivity. The measurement reveals substantial disparities across the cultivated wheat cultivars. For instance, the data indicates that Nemere had a chlorophyll concentration at the anthesis stage that was 14.6716% more than Felleg, Table B.5. 60. This refers to the superior capacity of this wheat variety to withstand abiotic stressors compared to others.

Quantum yield (QY) is a metric used to quantify the efficiency of photosynthesis II. The photosynthetic stress index showed significant variations in the plant's ability to endure drought stress concerning N-splitting treatments. The obtained data indicates that dividing the application of nitrogen into portions and applying them at wheat growth stages of F3, F6, and F10 leads to a substantial increase in plant growth and resistance to abiotic stresses, as compared to applying the total quantity of N all at once or in two applications, Table B.5. 61. When three portions of N application were used, the photosynthetic II efficiency improved significantly to 0.800, compared to using two portions and applying them over time, which resulted in an efficiency of 0.788, and using a single-time application, which resulted in an efficiency of 0.774, Table B.5. 61. This suggests that N-splitting is a very successful strategy for fertilization since it enhances photosynthesis and helps plants cope with abiotic stressors, particularly drought. Furthermore, various wheat varieties have shown diverse degrees of resistance to drought stress. Nemrere variety exhibited much greater tolerance to drought stress than the Felleg and Alföld varieties, at the anthesis stage as indicated by QY values of 0.808, 0.790, and 0.764, respectively.

The gluten content of the whole flour, as evaluated by the gluten wash machine, exhibits substantial variation across different fertilization application strategies and irrigation regimes. Splitting the application of nitrogen into three timings, F3, F6, and F10, resulted in significantly higher gluten percentages of 33.52% compared to when nitrogen was solely administered in F3, which resulted in a gluten percentage of 30.54%, or when it was applied in two portions in F6 and F10, resulting in a gluten percentage of 31.77%. The increase in gluten percentage was 9.30% and 5.36%, respectively. Applying N before grain filling enhances the quality of the final product. Irrigation positively affects the improvement of wheat quality metrics. The gluten content had a 4.539% rise as a result of irrigation in comparison to the area that was not irrigated. The gluten content was measured 4 times in two different times, once for the whole grain on the harvest day with NIR, another time one month after the harvest day for the whole grain NIR, the third time measured for the whole flour with NIR, and the fourth time with gluten wash machine to investigate the biochemical changes occur into the grain after harvest. It is clear that the gluten formation continued, and its percentage increased after harvest, Table 5.28, Table B.5. 62, Table B.5. 63, and Table B.5. 64. Hence, the administration of N and irrigation during the latter stages of the crop's life cycle have a notable impact on gluten production, leading to a substantial increase in its percentage. Proper storage and moisture management post-harvest are crucial for maximizing the ongoing protein and gluten formation.

Table 5.28. Whole flour gluten content (%) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N-splitting in various growth stages in 2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3 + F6 + F10		
Alföld	Irrigated	31.55	34.80	34.29	33.55	
	Not	29.00	30.86	32.76	30.88	
Felleg	Irrigated	33.99	32.00	34.87	33.62	
	Not	28.52	30.93	34.71	31.39	
Nemere	Irrigated	30.59	31.10	33.51	31.73	
	Not	29.58	30.94	30.89	30.50	
LSD_{V*I*F}		N.S			LSD_{V*I}	1.70
V * F						
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety means	
Alföld		30.28	32.83	33.53	32.21 ± 2.64	
Felleg		31.25	31.47	34.79	32.50 ± 2.14	
Nemere		30.09	31.02	32.25	31.12 ± 2.59	
LSD_{V*F}		N.S			LSD_V	N.S
I * F						
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation means	
Irrigated		32.04	32.58	33.38	32.67 ± 2.01 a	
Not Irrigated		29.04	30.97	33.66	31.22 ± 2.74 b	
LSD_{I*F}		1.70			LSD_I	0.98
F						
Fertilization		F3	F3 + F6	F3 + F6 + F10		
Mean fertilization		30.54 ± 2.60 c	31.77 ± 1.95 b	33.52 ± 2.01 a		
LSD_F		1.20				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at the growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 for each growth stages.

The characterization of wheat proteins is challenging due to their complex and varied interactions with one other, resulting in a high degree of complexity. Generally, they are classified according to their solubility. The investigation demonstrates that the process of N-splitting, together with precise timing and irrigation, has a significant favorable impact on enhancing the protein content of wheat flour. The nitrogen splitting strategy is an effective method to raise the protein content and ultimately improve wheat quality. Dividing the nitrogen administration into three equal doses results in a substantial increase of 3.14% in protein content compared to applying the complete quantity of nitrogen at a single time point, F3, and by 5.69% greater than splitting the nitrogen application into two time times, F3 and F6, Table 5.29. This suggests that applying nitrogen during the latter stages of development might be beneficial for directing it toward the grain, boosting the amino acids that serve as building blocks for proteins. Similar findings were seen when assessing the protein content of the whole grain. The protein content of F3, F6, and F10 was 15.29%, which was considerably greater than the protein content of F3 and F6, 14.22%, and the protein content of F3 alone, 14.20%, as shown in Table B.5. 66. Protein synthesis and modifications in wheat grains persist for up to one month after harvest. This experiment examined the alterations and observed a 2.44% increase in the percentage of whole grain. The percentage rose from 14.92 to 15.29 with three timings, from 14.4 to 14.22 with two timings, and from 14.7 to 14.20 with a single timing of N application, Table B.5. 65 and Table B.5. 66.

Evidence indicates that irrigation substantially affected the protein content of the whole grain, resulting in a 1.74% increase, Table B.5. 65. Irrigation is essential for mitigating the abiotic stress caused by drought and enhancing the quality of wheat flour, mainly when applied during the grain filling stage, to improve nitrogen use efficiency. This is especially important in Hungary, where there is a low precipitation rate during this period. During the grain-filling stage, irrigation is needed more often, either because there is a higher demand for water due to biological activity or because the abiotic conditions are more harsh than in previous stages. In Hungary, the months of May and June have higher temperatures than the earlier months. However, there were significant differences among the planted varieties concerning this particular trait. Alföld and Felleg had the highest protein content in whole flour, with 12.14% and 12.18%, respectively, compared to Nemere, at 11.3%, Table 5.29.

The findings of this experiment indicate that N-splitting three times is a more efficient method for boosting the protein content of the grain and the final wheat flour. This strategy is also beneficial in mitigating the impact of abiotic stress, particularly drought. Irrigation is necessary to effectively address the drought and enhance water quality, particularly concerning protein content. It is typical for the wheat variety Nemere to have the greatest grain yield but the lowest protein content compared to the other used wheat varieties, Alföld and Felleg.

The falling number (FN) test indirectly measures α-amylase activity in wheat flour samples to determine if they contain sprouted grain, though not continually visibly sprouted. Flour from sprouted grain is undesirable for bakers because it produces undesirable loaf characteristics. Falling numbers over 250 seconds are most suitable for the bread-baking process. In contrast, FNs above 350 seconds may indicate that the flour should be supplemented with a form of amylolytic enzyme or malted grain flour. Most large-scale bakeries work with an ideal FN range of 250–280 seconds. Different values of fall numbers may be specific to unique products and processing conditions inside the plant (Cauvain, 2017). N-splitting seems to have a statistical reverse effect on the falling number value where three times application increased the value to 423.4 seconds from 412.2 seconds with a single time N application, Table B.5. 67. Irrigation also negatively increases the falling number value over the optimal level, and there is a significant effect on the wheat varieties since they have different abilities to withstand abiotic stresses. This implies that the traits influenced by abiotic stress and moderate irrigation are justifiable, but N-splitting treatments are somewhat preferable.

Table 5.29. Whole flour protein content (%) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N-splitting in various growth stages in 2023, MATE - Gödöllő.

Varieties	Irrigation	Fertilization (F)			V * I	
		F3	F3 + F6	F3 + F6 + F10		
Alföld	Irrigated	12.35	11.95	12.16	12.15	
	Not	11.83	11.91	12.65	12.13	
Felleg	Irrigated	12.65	11.90	12.78	12.44	
	Not	11.86	11.32	12.56	11.91	
Nemere	Irrigated	11.32	11.36	11.67	11.45	
	Not	11.34	11.10	11.81	11.42	
LSD_{V*I*F}		N.S			LSD_{V*I}	N.S
V * F						
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety means	
Alföld		12.09	11.93	12.41	12.14 ± 0.44 a	
Felleg		12.26	11.61	12.67	12.18 ± 0.44 a	
Nemere		11.33	11.23	11.74	11.43 ± 0.62 b	
LSD_{V*F}		N.S			LSD_V	0.27
I * F						
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation means	
Irrigated		12.11	11.74	12.20	12.02 ± 0.63	
Not Irrigated		11.68	11.44	12.34	11.82 ± 0.58	
LSD_{I*F}		N.S			LSD_I	N.S
F						
Fertilization		F3	F3 + F6	F3 + F6 + F10		
Mean fertilization		11.89 ± 0.60 b	11.59±0.44 c	12.27 ± 0.58 a		
LSD_F		0.27				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at the growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 for each growth stages.

The Zeleny Index is a chemical measure used in breeding and rapid analysis to forecast the comprehensive baking quality of wheat. The determination is based on either the ground kernel or the flour and may vary from 0 to 80. Wheat with a Zeleny Index below 20 is often considered inappropriate for baking. Data from the SDS-sedimentation volume test (Zeleny test) present significant differences between the irrigated and not irrigated treatments under drought stress, and irrigation increases the sedimented volume by 10.390%, Table B.5. 69. There is a significant variation among the varieties regarding the SDS-sedimentation volume when measured at the harvest day with Alföld 50.54 ml, Nemere 44.30 ml, and Felleg 48.25 ml, with an LSD of 4.39, Table B.5. 68. Nevertheless, the substantial differences among the various types decreased with storage time due to internal biochemical changes in the grain, Table B.5. 68 and Table B.5. 69. Nitrogen splitting does not have a substantial influence on the value of this parameter. It can be inferred that drought stress substantially impacts the SDS value. To alleviate this stress and enhance the SDS value, irrigation is necessary. Ultimately, this will improve the quality of wheat flour.

Data present no significant variation among the N treatments and the varieties regarding the flour and grain moisture percentages, Table B.5. 70, Table B.5. 71, and Table B.5. 72. However, the moisture changed from the day of harvest to a month after harvest during storage.

Table 5.30 of the correlation coefficient and their probability in Table B.5. 73 demonstrate a robust positive correlation among the ultimate grain production and the following variables: TKW, LAI, SPAD, SDS, and spikes number per square meter. Nevertheless, negative correlations were observed between the ultimate grain yield and the moisture, protein, gluten, and plant height. These correlations are logical since it is often seen that increasing the quantity parameters tends to have an impact on the quality parameter. A greater value of TKW suggests that the plants performed well in coping with abiotic stress during grain filling and that the applied treatments were successful. The good impact of the N-splitting treatments and irrigation had a beneficial influence on the variability of growth indices, such as the leaf area index and photosynthetic activity, resulting in increased crop output. TKW negatively correlates with tiller count per plant, spike count, and spikelet count per spike. The quality metrics, such as the protein and gluten percentages, correlate with one another.

This study is crucial for addressing the management strategy of nitrogen usage, application and timing, and irrigation to mitigate the abiotic stresses caused by drought and heat. The plant growth, grain yield, and wheat quality parameters were significantly enhanced by implementing a nitrogen splitting strategy, which involved dividing the nitrogen into three portions and applying them during critical growth stages that directly influenced the final yield. These growth stages include tillering (Feekes 3), stem elongation and canopy development (Feekes 6), and spikelet formation followed by grain filling (Feekes 10). The results demonstrated a superior outcome when the same total quantity of N was applied compared to applying it all at once in F3 or dividing it across F3 and F6. The grain production, protein content, gluten content, and number of spikelets per spike showed a significant rise.

Nevertheless, some traits, such as plant height and leaf area index, were significantly diminished due to splitting nitrogen doses. This outcome is comprehensible since these parameters need a complete initial N dosage to achieve higher values. Hence, this strategy is efficacious in alleviating the effects of drought stress and enhancing nitrogen use efficiency. Providing a substantial amount of nitrogen during the grain-filling stage would further improve the quality of wheat grains and flour. In the Hungarian environment, irrigation of 20 mm weekly is beneficial during the dry period, typically during the booting, shooting, and grain-filling phases when there is little to no precipitation. There was a notable disparity among the cultivated wheat varieties in their resistance to drought and heat conditions, with newer produced varieties, such as Nemere, exhibiting more resistance than the older variety, Alföld. However, the variety that exhibits a larger grain yield is associated with a lower protein percentage, and vice versa.

Table 5.30. Correlation coefficients among the study parameters of N-splitting and wheat abiotic stress experiment, MATE - Gödöllő.

	Final Yield	GreenYield	TKW	TW	LAI	SPAD	QY	Tillers n	Spikes n m2	Spikelets n	PH	FN	Gluten%	Moisture% *	Protein% *	Gluten% *	Gluten% **	Moisture% **	Protein% **	SDS **	Gluten% ***	Moisture% ***	Protein% ***
Green Yield	0.94																						
TKW	0.39	0.35																					
TW	-0.19	-0.16	0.03																				
LAI	0.30	0.29	-0.18	-0.28																			
SPAD	0.09	0.05	-0.08	-0.16	-0.13																		
QY	0.19	0.03	0.14	-0.27	-0.12	0.10																	
Tillers n	-0.13	-0.15	-0.02	-0.03	-0.07	0.12	-0.03																
Spikes n m2	0.28	0.25	-0.07	-0.22	0.47	-0.27	0.04	-0.12															
Spikelets n	-0.35	-0.34	-0.40	0.08	0.03	0.01	0.09	0.16	-0.24														
Plant Height	-0.28	-0.26	-0.44	-0.02	0.18	0.16	-0.03	0.32	-0.33	0.69													
FN	-0.02	-0.06	0.35	-0.12	-0.39	0.26	0.05	-0.02	-0.11	-0.40	-0.26												
Gluten %	0.01	0.05	-0.05	-0.08	0.05	0.20	0.19	-0.12	0.05	0.30	0.02	-0.08											
Moisture% *	-0.51	-0.47	-0.09	-0.20	-0.28	0.15	-0.11	0.31	-0.30	0.07	0.17	0.22	-0.04										
Protein% *	-0.28	-0.23	-0.34	-0.22	0.39	-0.02	-0.10	-0.10	0.13	0.34	0.25	-0.20	0.46	0.16									
Gluten% *	-0.29	-0.25	-0.32	0.15	0.20	-0.27	-0.06	-0.16	0.08	0.51	0.26	-0.46	0.35	-0.03	0.55								
Gluten% **	-0.24	-0.22	-0.26	-0.13	0.18	0.03	0.16	-0.07	0.10	0.46	0.19	-0.26	0.64	-0.03	0.73	0.61							
Moisture% **	-0.37	-0.36	0.01	-0.17	-0.26	0.16	-0.19	0.07	-0.18	-0.47	-0.22	0.50	-0.27	0.57	-0.06	-0.30	-0.26						
Protein% **	-0.41	-0.37	-0.36	-0.15	0.15	0.00	0.09	-0.06	0.03	0.48	0.29	-0.23	0.55	0.12	0.79	0.72	0.94	-0.12					
SDS **	-0.40	-0.34	-0.25	0.02	-0.17	0.10	-0.10	-0.09	-0.21	0.16	0.18	0.09	0.25	0.15	0.39	0.36	0.41	0.16	0.51				
Gluten% ***	-0.10	-0.10	-0.12	-0.32	0.23	0.11	0.16	-0.25	0.13	0.31	0.10	-0.03	0.59	-0.06	0.66	0.46	0.83	-0.13	0.80	0.35			
Moisture% ***	-0.37	-0.32	0.06	-0.13	-0.26	0.29	-0.14	0.17	-0.21	-0.15	-0.06	0.32	-0.04	0.74	0.05	-0.06	-0.03	0.58	0.07	0.14	-0.02		
Protein% ***	-0.15	-0.14	-0.17	-0.39	0.20	0.14	0.17	-0.13	0.07	0.27	0.16	0.02	0.61	0.10	0.64	0.37	0.75	-0.04	0.76	0.33	0.90	0.09	
SDS ***	0.16	0.14	-0.11	0.01	0.22	0.07	0.03	-0.14	-0.04	0.41	0.26	-0.17	0.11	-0.25	0.11	0.19	0.21	-0.42	0.14	-0.01	0.38	-0.21	0.31

r= 0.27 - 0.34 is significant at 0.05, and r ≥ 0.35 is significant at 0.01; * is the grain quality parameters measured with an NIR at the harvest day, ** is the grain quality parameters measured with an NIR a month after harvest; *** is the flour quality parameters measured with an NIR a month after harvest; TKW is the thousand kernel weight; TW is the test weight; LAI is the leaf area index; QY is the quantum yield; FN in the fulling number (enzymic activity); SDS is the SDS-sedimentation volume.

5.5 Nitrogen Doses- Wheat Quality- Abiotic-Stresses Experiment

The primary aim of this research was to evaluate the processes involved in nitrogen uptake, absorption, and mobilization throughout the latter stages of development in wheat plants (specifically, beyond Feekes 10), particularly when exposed to adverse climatic conditions. Examining plant morphology and yield quality parameters under varying nitrogen administration rates enables the determination of the most effective nitrogen application dose in addressing abiotic stress factors. In addition, the findings of this study possess the capacity to significantly enhance our understanding of crop management tactics, particularly concerning determining the optimal dosage of nitrogen fertilizers. The main objective of applying these fertilizer rates is to improve nitrogen usage efficiency (NUE) and mitigate the adverse effects of abiotic stress on agricultural output. The field trials were done amidst the severe drought and extreme climatic conditions in Hungary in season from 2022.

The data obtained indicate the presence of statistically significant differences among the N treatments of 0, 40, 80, 120, 160, and 200 kg/ha of N active agent, using NH_4NO_3. However, these differences are not apparent in a coherent fashion, Table 5.31. It seems that applying nitrogen fertilizer in late growth stages on the heading stage and after has no positive effect on grain yield quantity of wheat under extreme drought and heat stresses. That it is, higher N application rates 120, 160, and 200 kg/ha of N active agent present statistically no increase in the yield; nevertheless, lower to non-N applications present a better performance in terms of yield quantity, for example, 80 kg/ha N, present significantly higher yield 3350 kg/ha than more considerable N application rate, for example, 200 kg/ha N, 2950 kg/ha, Table 5.31. It suggests that high nitrogen dosage increases the negative pressure on the crop. This study provides evidence that administering fertilizers during the latter stages of the crop's life cycle, particularly under drought and heat stress conditions, has a detrimental impact on the overall yield amount.

It seems logical since the genetic, physiological yield component equation relies on the value of each component, as the following Eq. V:

Eq. V $$\text{GP Yield} = \text{Spikes n} \times \text{grain n per a spike} \times \text{TKW}$$

Where: GP is the genetical, physiological interaction

Maximizing the mathematical value of each of these three components is necessary to obtain the highest possible yield. Nevertheless, regardless of the nitrogen treatment rates, whether applied before or during grain filling, it does not significantly increase the gross yield value. Furthermore, the use of nitrogen fertilizer only during the late development stage, particularly under conditions of drought and heat stressors, would not provide any beneficial effects on crop productivity. This is due to the plant's limited capacity to absorb nitrogen effectively without adequate water availability. Based on existing literature, plants need more water for efficient use of nitrogen during their reproductive development stages compared to the vegetative phases (WUHAIB, 2013).

The Harvest Index (HI) is a metric that quantifies the proportion of grain yield concerning the total dry matter of the shoot. It serves as an indicator of the effectiveness of reproductive processes in plants. The determination of HI is contingent upon the interplay of genotypes (G), environment (E), and crop management (M) as in the following equation (PORKER et al., 2020):

Eq. VI $$HI = G \times E \times M$$

The historical advancements in genetic yield enhancements in wheat may be mainly attributed to the augmentation of harvest index (HI) via breeding efforts. The significance of environmental elements in the context of management impact is underscored by the inclusion of the seasonal pattern of water supplies and the occurrence of severe temperatures during crop reproductive development.

The study's findings indicate that effective management strategies in the face of abiotic stresses can enhance the harvest index (HI) value and increase crop yield. One such approach involves the application of nitrogen (N) fertilizers not only during the reproductive stage of plant life cycles but also during critical growth stages such as tillering (Feekes 3) and stem elongation (Feekes 6).

Data show that yield positively responds to the TKW, and 80 kg/ha N seemed more efficient to be applied at later growth stages under drought stresses than at high application rates. This particular rate led to the attainment of the most significant yield and the highest thousand-kernel weight (TKW) simultaneously, Table 5.31. Figure 5.15 presents the grain yield response to TKW, which the yield increased as the values of the TKW increased, and the grain yield increased as a response.

The NH_4NO_3 application, specifically at Feekes 10, was utilized to examine the impact of nitrogen application on crop yield and yield quality. Several post-harvest parameters were evaluated for the effects of the treatments and abiotic conditions used. A preliminary assessment was conducted on the day of harvest using near-infrared spectroscopy (NIR). Subsequently, the grain yield that was obtained underwent a storage period of one month prior to the commencement of quality assessments. The allocated time frame was designated to facilitate the occurrence of sufficient material composition and seed formation processes. Subsequently, a series of examinations pertaining to quality were carried out roughly one month subsequent to the harvest. The evaluations encompassed various parameters, such as hectoliter weight, Zeleny index, gluten content determined through the utilization of a gluten wash device, falling number, NIR whole flour tests for quantifying moisture, protein, and gluten levels, as well as NIR whole grain testing for both whole grain samples to ascertain the respective NIR indexes.

The indirect measures of α-amylase activity, FN, present that higher levels of N application significantly elevate the FN values higher than the desirable range, above 350 seconds, Table 5.31. There were no significant differences among N application ranges from 0 till 80 kg/ha N, where 0, 80, and 120 resulted in α-amylase activity within or very close to the desirable ranges for bread-baking, 355.7, 364.3, and 356.3 seconds, Table 5.31. However, a higher N application rate resulted in higher unsuitable FN values were 120, 160, and 200 kg/ha N values were at 390.3, 389.5, and 392.0 seconds, insignificant among them, Table 5.31. Since this FN test of wheat flour determines if it contains sprouted grain, though not continually visibly sprouted, flour from sprouted grain is undesirable for bakers because it produces undesirable loaf characteristics. The higher N application levels had a reverse impact regarding this point. However, FNs above 350 seconds may indicate that the flour should be supplemented with a form of amylolytic enzyme or malted grain flour. Most large-scale bakeries work with an ideal FN range of 250–280 seconds. Different values of fall numbers may be specific to unique products and processing conditions inside the plant (Cauvain, 2017). It can be concluded that high levels of N application, above 120 kg/ha N, negatively affect the α-amylase activity in wheat flour, and lower N levels than this limit resulted in FNs values meeting the required range for bakeries.

Wet gluten is acquired after removing the dough's starch and water-soluble constituents, such as water-extractable arabinoxylans, sugars, and water-soluble proteins. The quantity of this substance serves as an indicator of the amount of gluten present. The highest value of wet gluten can reach up to 45% (Li et al., 2024b). In this part of the study, the highest N application presents the most significant value of gluten content. Nitrogen application at 200 kg/ha resulted in 33.65% statistical but insignificant differences compared to the N application of 120 and 160 kg/ha, respectively, 32.08% and 29.88%, Table 5.31. However, gluten content at these N application levels was significantly higher than lower levels of 40 and 80 kg/ha, with 24.95% and 28.53% values. The control had the least significant gluten content values compared to all N application levels, 20.25%, Table 5.31. Therefore, N significantly impacts gluten content; the higher the N applied level, the more the gluten content in wheat flour.

The wheat quality laboratory of small grains conducts various analyses on wheat grain and/or flour. The functioning of wheat is influenced by the amount of protein present in flour, which may vary (Le Bourgot et al., 2023). The finding presents that the higher levels of N application resulted in the most significant value of protein content. Nitrogen application at 200, 160, and 120 kg/ha resulted in 12.22, 12.81, and 11.54% respectively, Table 5.31. However, protein content at these N application levels was significantly higher than lower levels of 40 and 80 kg/ha, with 9.96 and 10.58% values, respectively. The control had the least significant values of protein content than all levels of N treatments, 8.30%, Table 5.31. It can be stated that N application significantly influences protein content, and the higher N applied level between 120 and 200 kg/ha is appropriate, with more statistically preferable results from 160-200 kg/ha for increasing protein content.

Data from the SDS-sedimentation volume test present significant differences among the N-level treatments under drought stress. The highest level of N application, 200 kg/ha, resulted in the most significant value of sediment volume resulting from the acidification of a suspension of wheat flour, 64.50 ml, Table 5.31. There were statistical but insignificant differences regarding the sediment volume between this N level and 160 and 120 kg/ha, respectively, 58.23 and 57.20 ml. However, SDS volume at these N application levels under drought stress was significantly higher than the control and the lower levels of 40 and 80 kg/ha, respectively, 28.20, 41.87, and 51.07 ml, Table 5.31. Therefore, N significantly impacts gluten content, and the higher the N applied level, the more the gluten content in wheat flour. This finding is consistent with other studies where N application increases the SDS volume (Acar and Koksel, 2023). In brief, N-treatment adding nitrogen at levels above 120 kg/ha, with more preferable 200 kg/ha, had significant favorable impacts on enhancing SDS values ultimately, wheat quality.

The changes in the protein and gluten composting continue subsequent to the harvest. Therefore, part of this study follows the changes in the protein, gluten, sedimented materials, and moisture at three post-harvest points: harvest day grain measurement and grain measurement after a month of the harvest day. The results from Table 5.32 present an increase in the protein and gluten contents of the grains. Protein values, for example, for the N treatments of 0, 40, 80, 120, 160, and 200 increased respectively from 9.17 to 10.8, 11.23 to 11.50, 14.30 to 13.43, 13.17 to 14.34, 14.90 to 15.00, and 14.54 to 16.03%. These parameters present the biochemical changes in the wheat grains starting from the day of harvest to a month after to give enough time for the materials inside the grain to continue forming. However, the SDS volume values decreased during this duration, Table 5.32. The moisture was increased during this time duration according to the data, which refers to the dry season, and the grain was below the required moisture level at harvest because of the extreme dry season.

Table 5.33 along with Figure 5.15, Figure 5.16, and Figure 5.17 present that yield was positively correlated with the TKW, HLM, and moisture but negatively correlated with protein, gluten, and SDS. This is logical and consistent with studies by other researchers (Balla et al., 2011; Eser et al., 2020; Le Bourgot et al., 2023; Nuttall et al., 2017; Plant et al., 1981; Tomaz et al., 2021). However, regardless of yield, TKW, and HLM, the quality parameters, including protein, gluten, and SDS, were significantly correlated positively.

This study provides evidence that administering fertilizers during the latter stages of the crop's life cycle, particularly under drought and heat stress conditions, has a detrimental impact on the overall yield amount. The finding of this study suggests that management under abiotic stresses can improve the value of HI and obtain a higher yield, for example, by applying N fertilizers not only at the reproductive stage of the plant life cycles but also at the vegetative growth stages such as tillering stage Feekes 3 and also stem elongation stage Feekes 6. Moderate N application at this stage during abiotic stresses also increases the grain quality, including the protein and the gluten contents. However, a high rate of N application increases extreme abiotic stresses (drought stress) on wheat plants and negatively impacts the yield quantity.

Table 5.31. Parameters relating to the production and quality of *Triticum aestivum* L. responding to different levels of nitrogen application under drought and heat stresses in 2021-2022, MATE - Gödöllő.

[0]N Level	[1]Yield (kg/ha^{-1})	[2]TKW (g)	[3]HLM ($kghl^{-1}$)	[4]FN (seconds)	[5]Gluten (%)	[6]Protein (%)	[7]Moisture (%)	[8]SDS (ml)
0	3133 ab	46.87 b	78.95 c	355.7 b	20.25 d	8.30 d	11.0 a	28.20 d
40	3067 b	47.58 b	80.07 b	364.3 b	24.95 c	9.96 c	11.0 a	41.87 c
80	3350 a	49.42 a	81.23 a	356.3 b	28.53 bc	10.58 bc	10.8 a	51.07 b
120	2967 b	47.59 b	80.22 b	390.3 a	32.08 ab	11.54 ab	11.1 a	57.20 ab
160	2945 b	46.79 b	77.60 d	389.5 a	29.88 ab	12.81 a	11.0 a	58.23 ab
200	2950 b	47.27 b	80.82 ab	392.0 a	33.65 a	12.22 a	10.9 a	64.50 a
LSD *	272.7	1.047	0.784	11.09	3.794	1.522	N.S.	7.462

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; [0] nitrogen levels applied as a kilogram of active agent N per hectare; [1] grain yield measured as kilogram per hectare (kg/ha^{-1}); [2] thousand kernel weight measured with seed counter machine and weight (g); [3] Hectolitre mass (test weight) measured as kilogram per hectoliter ($kghl^{-1}$); [4] falling number (α-amylase activity) measured per time (second); [5] gluten percentage of the white flour measured by gluten wash machine; [6] protein content of the whole flour measured with NIR (%); [7] moisture level of the whole flour measured with NIR (%); [8] sedimentation volume (Zeleny Test) of the whole grain measured with NIR (ml).

Table 5.32. Postharvest biochemical changes in some parameters in the grain of *Triticum aestivum* L. resulted from different nitrogen application levels under drought and heat stresses in 2021-2022 measured with an NIR, MATE - Gödöllő.

[0]N Level	On the harvest day				A month after the harvest day			
	Protein (%)	**Gluten** (%)	**[1]SDS** (ml)	**Moisture** (%)	**Protein** (%)	**Gluten** (%)	**[1]SDS** (ml)	**Moisture** (%)
0	10.08 e	21.33 e	31.10 b	8.0 a	9.17 e	22.2 d	28.20 d	10.9 a
40	11.50 d	24.43 d	31.40 b	7.9 a	11.23 d	24.0 d	41.87 c	10.8 a
80	13.43 c	33.33 b	42.40 ab	7.9 a	14.30 bc	28.3 c	51.07 b	10.5 a
120	14.43 bc	30.20 c	45.33 a	8.3 a	13.17 cd	31.5 bc	57.20 ab	10.8 a
160	15.00 b	29.77 ab	47.57 a	8.1 a	14.90 ab	33.9 ab	58.23 ab	10.8 a
200	16.03 a	31.23 a	51.87 a	8.1 a	14.54 a	36.5 a	64.50 a	10.6 a
LSD *	1.021	2.919	12.81	N.S.	1.334	3.779	7.462	N.S.

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; [0] nitrogen levels applied as a kilogram of active agent N per hectare; [1] sedimentation volume (Zeleny Test) of the whole grain measured with NIR (ml).

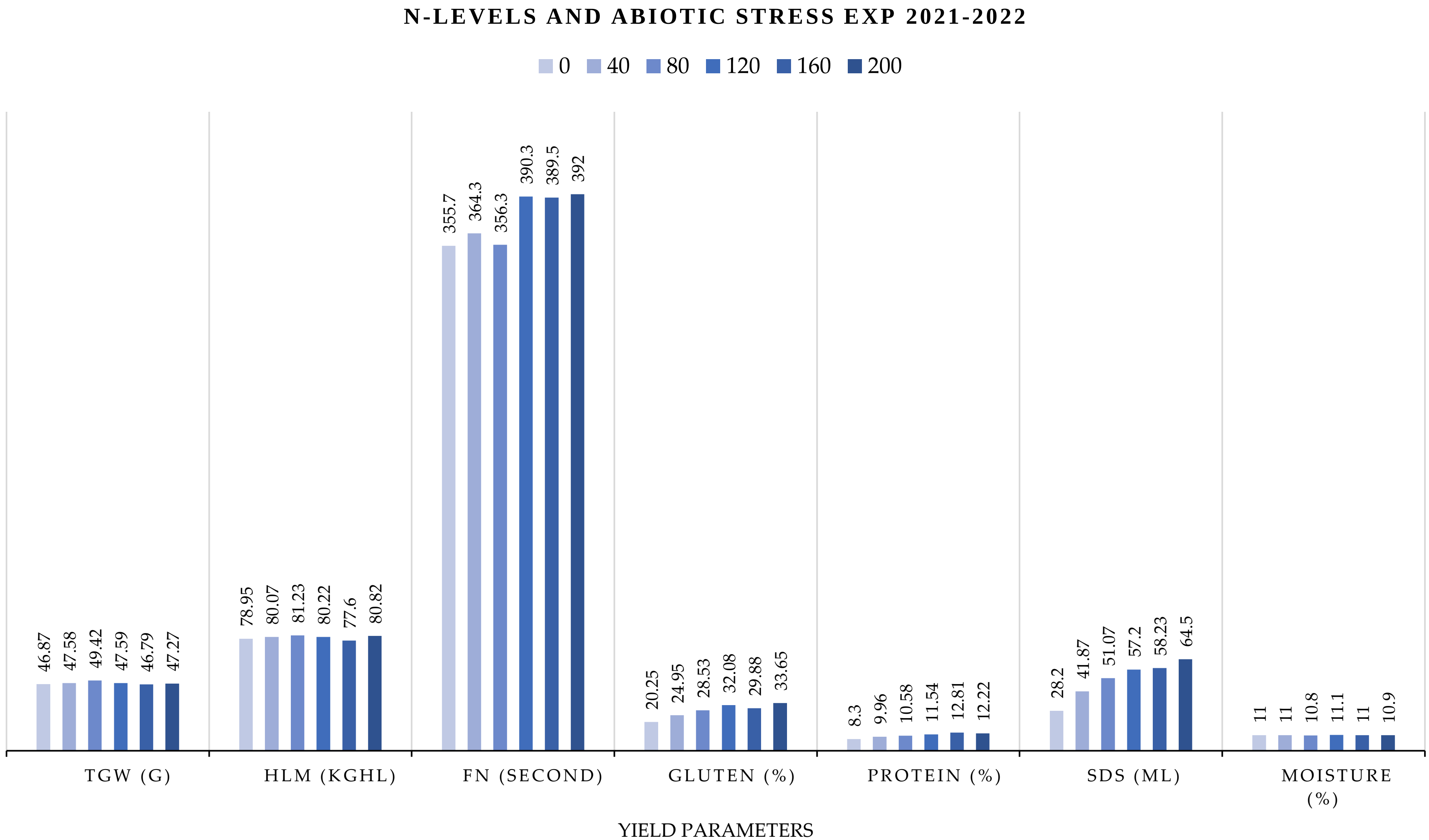

Figure 5.14. Parameters relating to the production and quality of *Triticum aestivum* L. responding to different levels of nitrogen application under drought and heat stresses in 2021-2022.

TKW is the -thousand-grain weight measured with seed counter machine and weight (g); HLM is the Hectolitre mass (test weight) measured as kilogram per hectoliter (kg/hl); FN is the falling number (α-amylase activity) measured per time (second); gluten percentage of the white flour measured by gluten wash machine; protein content of the whole flour measured with NIR (%); moisture level of the whole flour measured with NIR (%); SDS is the sedimentation volume (Zeleny Test) of the whole grain measured with NIR (ml).

Table 5.33. Correlation coefficients among the study parameters of the wheat experiment at different levels on nitrogen application under drought and heat stresses in 2021-2022, MATE - Gödöllő.

							Whole flour test (NIR)			Whole grain test a month after harvest (NIR)				Whole grain test at harvest (NIR)		
	Traits	Yield	TKW	Test weight	Falling_No	Gluten (Gluten Wash)	Moisture_1	Protein_1	Gluten_1	Gluten_2	Moisture_2	Protein_2	Z_Index_1	Gluten_3	Moisture_3	Protein_3
	TKW	0.46														
	Test weight	0.31	0.54*													
	Falling_No	-0.73*	-0.37	-0.13												
	Gluten_wash	-0.53*	0.10	0.32	0.75*											
Flour test	Moisture_1	-0.23	-0.30	-0.03	0.26	0.09										
	Protein_1	-0.58*	0.07	-0.07	0.78*	0.80*	-0.10									
	Gluten_1	-0.52*	0.10	0.19	0.75*	0.94*	0.06	0.87*								
Grain test a After storage	Gluten_2	-0.59*	0.04	0.14	0.78*	0.95*	0.02	0.90*	0.95							
	Moisture_2	-0.13	-0.41	-0.31	0.05	-0.32	0.58*	-0.17	-0.29	-0.35						
	Protein_2	-0.59*	0.01	0.12	0.79*	0.94*	0.02	0.89*	0.94*	1.00*	-0.33					
	Z_Index_1	-0.56*	0.10	0.23	0.77*	0.96*	0.03	0.90*	0.95*	0.99*	-0.31	0.98*				
Grain test at harvest	Gluten_3	-0.61*	-0.02	0.15	0.78*	0.94*	0.03	0.83*	0.91*	0.98*	-0.38	0.97*	0.97*			
	Moisture_3	-0.66*	-0.19	0.07	0.37	0.36	0.34	0.29	0.32	0.33	0.31	0.33	0.32	0.34		
	Protein_3	-0.62*	-0.03	0.15	0.76*	0.93*	0.02	0.83*	0.91*	0.97*	-0.39	0.97*	0.96*	1.00*	0.34	
	Z_Index_2	-0.41	0.04	0.18	0.69*	0.79*	0.05	0.71*	0.72*	0.82*	-0.34	0.80*	0.81*	0.83*	0.35	0.80*

* the correlation coefficient is significant at the probability level of 0.05, -1 is the flour quality parameters, -2 is the grain quality parameters measured a single month after harvest, and -3 is the grain quality parameters measured at the harvest.

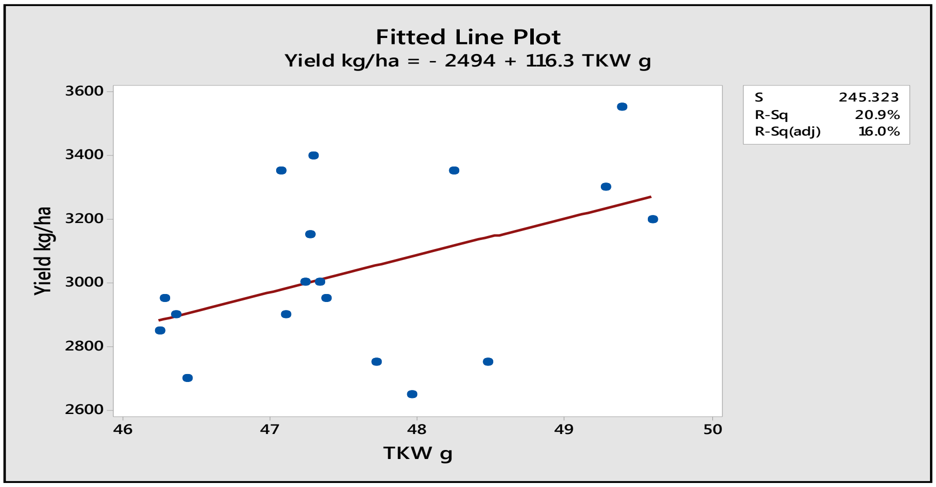

Figure 5.15. The effect of TKW on wheat grain production.

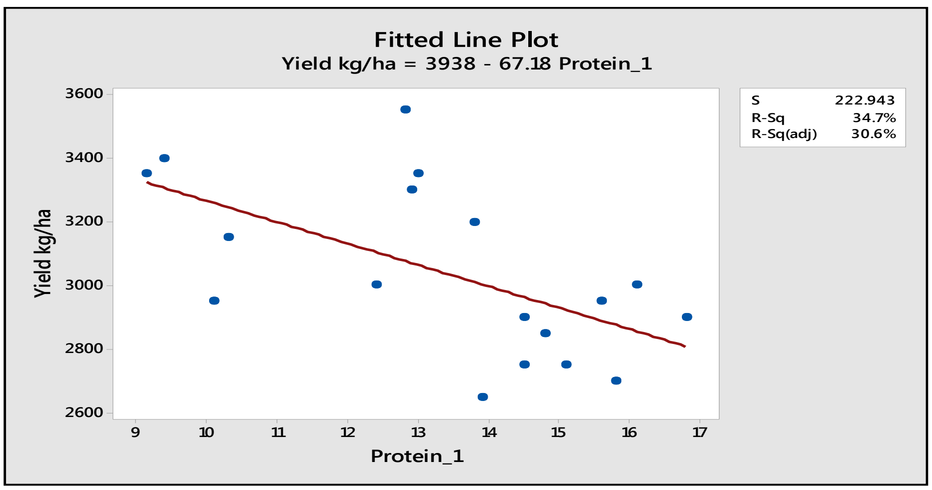

Figure 5.16. Yield response to protein content as an indicator for grain production.

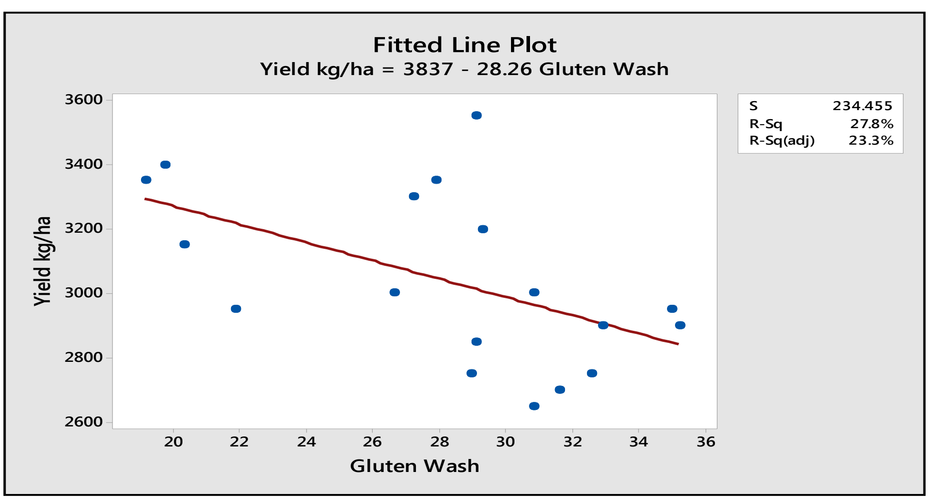

Figure 5.17. Yield response to gluten content as an indicator for grain production.

5.6 Maize Field Experiment

The primary objective of this experiment is to provide a comprehensive analysis of the impact of abiotic stress on the growth and development of maize while also exploring strategies to improve the resilience of these crops under stressful environmental conditions. The field trial was conducted during the summer growing season of 2022 and subsequently replicated on a larger scale during the summer growing season of 2023. In both years, the experimental treatments consisted of separate applications of nitrogen from different sources, namely organic and conventional, at a rate of 160 kg/ha in 2022. The study was developed in the following year, 2023, and fertilizer doses were introduced as a factor. The applied rates of N doses from both sources were 80, 160, 240, and 320 kg/ha active agents. Also, effective microorganisms were applied individually and combined with the aforementioned nitrogen sources.

In Hungary, the year 2022 saw severe aridity, while the following year, 2023, exhibited average precipitation levels. An almost negligible harvest was achieved in the year 2022. Nevertheless, a substantial yield was accomplished in 2023. Despite the early implementation of irrigation in the irrigated field on a weekly basis, there were no significant differences in kernel production compared to the non-irrigated area, Table 5.34. Nevertheless, there was a statistical increase with irrigation by 8.39%. The data revealed a notable interaction between the irrigation and the treatments. Irrespective of the nitrogen source used, it led to a substantial increase in the kernel yield compared to the control. This is due to nitrogen's role as a vital macronutrient for plant activity and serves as a fundamental constituent of amino acids, which constitute the basic units of plant proteins and enzymes. Proteins are the structural components of plants, whereas enzymes enable a wide range of metabolic processes in plants. Nitrogen is also a chlorophyll molecule component, allowing the plant to capture sunlight energy by photosynthesis, driving plant growth and maize kernel yield. Table 5.34 shows a significant difference between the N sources, namely the chemical and organic sources. Applying NH_4NO_3 at a rate of 160 kg per hectare resulted in a kernel yield of 16838 kg per hectare, whereas the organic source yielded 8458 kg per hectare, with a percentage difference of 66.25%.

Nevertheless, no significant variations were seen between the nitrogen sources when greater levels of nitrogen application, namely 240 and 320 kg/ha, were used. This implies that more organic-based applications are required to achieve a higher crop yield. This can be attributed to the gradual release of nitrogen and the rate at which organic matter decomposes, which can be influenced by various factors such as moisture, temperature, and types of microorganisms present.

The use of efficient microorganisms led to a substantial increase of 67.44% in maize kernel output, reaching 9773 kg/ha, compared to the control group, which yielded 4844 kg/ha, Table 5.34. Using EM treatments in conjunction with OM fertilizer demonstrates a significant statistical improvement in kernel production compared to its combination with chemical fertilizer. Nevertheless, the simultaneous use of EM and fertilizer does not substantially impact maize kernels' production in irrigated and non-irrigated areas. This implies that EM treatment might somewhat mitigate plant stress when used alone, but other factors, such as the presence of fertilizers, may overshadow its impact.

Based on the data, it can be inferred that irrigation does not significantly affect kernel production in Hungary during an average precipitation year. However, applying EM (effective microorganisms) can slightly enhance the yield compared to the control group. Furthermore, the chemical nitrogen source

NH_4NO_3 has a greater influence on the yield than the organic source but using a high amount of OM can show a better performance.

Table 5.34. Kernel yield (kg/ha) of *Zea mays* L. responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

Kernel Yield kg/ha						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	16251	17425	16838	±	821	a
160 O.M.	9205	7710	8458	±	3540	ab
240 NH_4NO_3	15543	14773	15158	±	3732	abc
240 O.M.	9774	8098	8936	±	2611	bcd
320 NH_4NO_3	15694	17862	16778	±	1725	bcd
320 O.M.	6220	8223	7222	±	2714	bcd
80 NH_4NO_3	14719	10937	12828	±	5246	bcd
80 O.M.	7508	3323	5415	±	4020	bcd
CONT.	7642	4844	6243	±	3574	bcd
EM	11990	9773	10881	±	4857	bcd
EM + 160 NH_4NO_3	10918	10749	10834	±	1730	bcd
EM + 160 O.M.	7344	7825	7585	±	1165	bcd
EM + 240 NH_4NO_3	10394	11462	10928	±	1646	bcd
EM + 240 O.M.	5849	5492	5670	±	1991	bcd
EM + 320 NH_4NO_3	11898	13262	12580	±	1376	bcd
EM + 320 O.M.	8629	6349	7489	±	3149	bcd
EM + 80 NH_4NO_3	12590	42716	27653	±	38347	cd
EM + 80 O.M.	7842	5841	6841	±	1623	d
LSD $_{Trt*Irrig}$.	15711.3		LSD	11109.2		
Irrigation means	10556 ± 3918	11481 ± 13984				
LSD_{Irrig}.	N.S					

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

The chemical fertilizer has a very beneficial effect on the production of cobs, including both the kernels and the empty cob, Table B.5. 74. This effect is seen across all treatments, including those combining chemical fertilizer with EM, as shown in Table B.5. 74. Ammonium nitrate at varying levels of use resulted in considerably greater crop output compared to the control; the varied levels were observed in terms of organic matter, EM itself, and the combination of N with the EM. For instance, the application of 160 NH_4NO_3 treatment led to a yield of 19583 kg/ha, while the control yielded 10966 kg/ha, which increased by 56.41%, Table B.5. 74. The combination treatment of EM + NH_4NO_3 seems detrimental to the plant root's ability to absorb nitrogen from the chemical source, unlike the organic material source of nitrogen. The use of irrigation did not have a meaningful effect on the yield of cobs in Hungary despite a statistical improvement being seen.

The empty cobs (corn cobs without the kernels) present an apparent effect of the treatments. The N application was superior from a different source than all other treatments. The superiority of NH_4NO_3

was evident over the OM. For example, 160 kg/ha of ammonium nitrate resulted in empty cobs of 2709 kg/ha compared to 160 kg/ha of the OM 1461 kg/ha, with an increase of 59.85%, Table B.5. 75. N treatments of different sources of 160 Kg/ha significantly yielded higher empty cobs weight. This concerns the function of nitrogen in the formation of the plant structure.

Increased cob length correlates with higher grain production, resulting in greater yield. The nitrogen administration significantly increased the number of kernels per column in a corn cob, independent of the nitrogen source, Table B.5. 76. nitrogen treatments at 160 and 240 kg/ha led to a considerably more significant number of grains per column than all other treatments, including the control, the EM, and the combination of N and EM at various levels. This suggests that the presence of nitrogen improves the genetic capacity to increase the number of kernels per cob due to the interplay between the environment, nitrogen availability, and genetics. The quantity of kernels per row on a cob is crucial for determining the yield. Across the various treatment modalities used in this trial, no statistically significant differences were seen in this trait, Table B.5. 77. Nevertheless, irrigation is crucial in dramatically increasing the number of kernels per row on a cob. This is related to the alleviation of stress caused by irrigation. N application increased the cobs number per plant, Table B.5. 78. There was a positive correlation among the presence of ammonium nitrate and organic matter and an increased number of cobs per plant. Based on the findings, it can be concluded that EM does not contribute to an increase in the number of cobs per plant. In a typical year, when there is sufficient rainfall in Hungary, irrigation does not increase the quantity of cobs per plant.

Measurements of photosynthetic activity were carried out after randomly selecting 4 maize plants from each plot. The photosynthetic activity of each plant was evaluated by measuring both the lower and top leaves, as well as 3 leaves from the center of the plant. The data indicates that the photosynthetic activity experiences a substantial rise in the presence of nitrogen, as seen in based on the 2-year interaction, Table B.5. 78 it can be concluded that NH_4NO_3 and NH_4NO_3 + EM had the most impact on raising the SPAD value. Following closely in third place is the application of organic matter. NH_4NO_3 + EM and OM have considerably more significant effects than the control group. This indicates that the treatments significantly reduce the impact of drought stress at various levels, as shown in Table 5.16. The ideal range for N application is between 160 to 240 kg/ha, independent of the source of N. NH_4NO_3 is preferred over the organic matter within this range, Table 5.35, Table 5.36, and Table 5.37. The nitrogen administration from various sources increased this trait, mainly when an adequate quantity was administered, as shown in 2023, Table 5.35. Applying 160 kilograms per hectare and higher NH_4NO_3 or OM significantly increased the SPAD value by 80.27% and 5.39%, respectively. However, the application of 80 kg/ha resulted in a marginal enhancement in photosynthetic activity, which is considered inadequate in terms of fertilizer dosage. The chemical supply of nitrogen enhances the rate of photosynthetic activity to a substantially greater extent than organic matter, as shown by the results from Table 5.36 of the 2022 study. This can be explained by the abundant presence of available nitrogen in the soil surrounding the roots of the corn plant, compared to the nitrogen released from organic matter, which low rate released. The availability of nitrogen from OM depends on various factors such as the decomposition rate, soil temperature, the presence and activity of decomposing microorganisms, and the moisture content.

In 2023, the EM treatment alone showed much more significant performance than the combined application with N fertilizers, as shown in Table 5.35. Using EM resulted in a substantial rise in the SPAD value compared to the control. In 2022, which has much lower precipitation than in 2023, EM demonstrates superior effectiveness in enhancing photosynthesis compared to the control group in each individual year.

Table 5.35. Photosynthesis activity refereed as a SPAD value of *Zea mays* L. responding to different treatment applications under drought stress measured at the tasselling growth stage (VT) in 2023, MATE - Gödöllő.

SPAD				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
160 NH_4NO_3	93.1	67.5	80.3 ± 34.7	a
160 O.M.	36.8	35.7	36.2 ± 9.7	a
240 NH_4NO_3	86.7	98.3	92.5 ± 6.9	ab
240 O.M.	42.0	40.3	41.2 ± 10.2	abc
320 NH_4NO_3	83.3	104.6	93.9 ± 13.9	abc
320 O.M.	41.3	36.8	39.1 ± 9.6	bcd
80 NH_4NO_3	69.2	74.0	71.6 ± 16.4	bcde
80 O.M.	30.3	31.3	30.8 ± 6.8	cdef
CONT.	34.0	34.7	34.3 ± 1.6	defg
EM	33.8	35.3	34.5 ± 2.1	defgh
EM + 160 NH_4NO_3	73.2	62.0	67.6 ± 9.4	efghi
EM + 160 O.M.	68.0	38.6	53.3 ± 22.9	fghi
EM + 240 NH_4NO_3	77.0	74.3	75.7 ± 5.9	fghi
EM + 240 O.M.	59.0	40.2	49.6 ± 18.5	fghi
EM + 320 NH_4NO_3	78.3	71.0	74.7 ± 23.1	ghi
EM + 320 O.M.	66.0	42.7	54.3 ± 20.1	ghi
EM + 80 NH_4NO_3	61.7	55.7	58.7 ± 16.1	hi
EM + 80 O.M.	52.9	33.7	43.3 ± 16.0	i
LSD $_{Trt*Irrig}$.	24.5		LSD $_{Trt}$	19.9
Irrigation mean	60.4 ± 21.9 a	54.3 ± 27.0 b		
LSD$_{Irrig}$.	5.0			

* Different lowercase letters (column) present significant differences between the means (p < 0.05), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means (p < 0.05), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table 5.36. Photosynthesis activity refereed as a SPAD value of *Zea mays* L. responding to different treatments under drought stress at the tasselling growth stage (VT) in 2022, MATE - Gödöllő.

SPAD				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
CONT	16.23	15.73	15.98 ± 1.94 d	
EM	13.73	21.8	17.77 ± 4.73 c	
NH_4NO_3	18.2	25.4	21.8 ± 415 a	
O.M	17.6	21.67	19.63 ± 2.31 b	
EM + NH_4NO_3	13.43	26.77	20.1 ± 7.32 b	
EM + O.M.	8.8	26.53	17.67 ± 9.77 c	
LSD $_{Trt*Irrig}$.	2.521		LSD $_{Trt}$	1.596
Irrigation means	14.67± 3.40 b	22.98± 4.20 a		
LSD$_{Irrig}$.	1.23			

* Different lowercase letters (column) present significant differences between the means (p < 0.05), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means (p < 0.05), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Based on the 2-year interaction, it can be concluded that NH_4NO_3 and NH_4NO_3 + EM had the most impact on raising the SPAD value by 52.19% and 67.88%, respectively, Table 5.37. Following closely in third place is the application of organic matter. NH_4NO_3 + EM and OM have considerably larger effects than the control group. This indicates that the treatments significantly reduce the impact of drought stress at various levels, as shown in Table 5.37. The ideal range for N application is between 160 to 240 kg/ha, independent of the source of N. NH_4NO_3 is preferred over organic matter within this range.

Table 5.37. Photosynthesis activity at the anthesis stage refereed as a SPAD value of *Zea mays* L. responding to different treatment applications under drought stress measured at the tasseling growth stage (VT) in 2022 and 2023, MATE - Gödöllő.

SPAD					
Year (Y)	Treatments (T)	Irrigation (I)		Y * T	
		No-Irrigation	Irrigation		
2022	Cont.	16.2	15.7	16.0	
	EM	13.7	21.8	17.8	
	NH_4NO_3	13.4	26.8	20.1	
	O.M.	8.8	26.5	17.7	
	EM + NH_4NO_3	18.2	25.4	21.8	
	EM + O.M.	17.6	21.7	19.6	
2023	Cont.	34.0	34.7	34.3	
	EM	33.8	35.3	34.5	
	NH_4NO_3	78.2	53.7	65.9	
	O.M.	63.0	46.9	54.9	
	EM + NH_4NO_3	93.1	67.5	80.3	
	EM + O.M.	36.8	35.7	36.2	
LSD_{Y*T*I}		N.S		LSD_{Y*T}	16.59
Y * I					
Year		No-Irrigation	Irrigation		
2022		14.7	23.0	18.8 ± 5.65 b	
2023		56.5	45.6	51.1 ± 24.5 a	
LSD_{Y*I}		7.96		LSD_Y	10.09
T * I					
Treatments		No-Irrigation	Irrigation		
Cont.		25.1	25.2	25.2 ± 9.7 c	
EM		23.8	28.5	26.2 ± 9.4 c	
NH_4NO_3		45.8	40.2	43 ± 26.1 ab	
O.M.		35.9	36.7	36.3 ± 25.1 bc	
EM + NH_4NO_3		55.7	46.5	51.1 ± 38.6 a	
EM + O.M.		27.2	28.7	27.9 ±10.9 c	
LSD_{T*I}		N.S		LSD_T	12.36
I					
Irrigation		No-Irrigation	Irrigation		
Irrigation means		35.6 ± 27.80 a	34.3 ± 19.8 a		
LSD_I		N.S			

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

The leaf area index (LAI) quantifies the leaf materials in a canopy. It is the ratio of one side leaf per unit ground area. Seasonally, annual crops and croplands can show significant variations in the LAI. It is a useful metric for describing spatial and temporal canopy growth and productivity patterns.

Studying this trait is crucial for comprehending the impact of canopy size on the overall yield, both in the presence and absence of abiotic stress. This passes through a wider canopy, intended to provide a greater yield of photosynthesis. In a year with normal precipitation in Hungary, 2023, when there was slight drought stress, no significant differences were made. The treatments showed only statistical variations in LAI values among maize plots of different levels of ammonium nitrate, organic matter, effective microorganisms, and their combinations. Simultaneously, irrigation yielded statistically similar results, although a rise in the LAI value in 2023 was not significant. In 2022, during a year characterized by severe drought stress, the application of N treatments at a rate of 160 kg/ha from various sources, alone or together with the use of EM, led to a considerably greater leaf area index in both the irrigated and non-irrigated fields, Table B.5. 79. NH_4NO_3 increased the leaf area by 27.23%, and the OM increased it by 66.66%. Nitrogen may mitigate drought stress to a certain extent. The use of EM has a comparable beneficial impact on enhancing the canopy and mitigating the effects of drought stress in a dry year, significantly increasing its value by 44.72%. In 2022, irrigation greatly increased the canopy area by 60.49% within the year compared to 2023, where irrigation only slightly increased its value. This indicates that irrigation may assist plants in overcoming drought and heat stress when precipitation levels are below the Hungarian normal year, Table B.5. 80. No significant change was seen in the number of leaves per plant among the data collected from both years and various treatments, Table B.5. 81.

Table 5.38. Plant leaf area index (m^2) of *Zea mays* L. responding to different treatment applications under drought stress measured at the tasseling growth stage (VT) in 2023, MATE - Gödöllő.

LEAF AREA INDEX						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	2.14	2.27	2.21	±	0.22	a
160 O.M.	1.35	1.47	1.41	±	0.27	a
240 NH_4NO_3	2.36	2.80	2.58	±	0.32	a
240 O.M.	1.56	1.36	1.46	±	0.19	a
320 NH_4NO_3	2.13	2.54	2.34	±	61.10	a
320 O.M.	1.66	1.30	1.48	±	0.29	a
80 NH_4NO_3	2.10	2.13	2.11	±	0.25	a
80 O.M.	1.52	1.63	1.57	±	0.21	a
CONT.	1.35	1.58	1.46	±	0.20	a
EM	1.66	1.90	1.78	±	0.27	a
EM + 160 NH_4NO_3	1.64	1.50	1.57	±	0.43	a
EM + 160 O.M.	1.27	1.52	1.40	±	0.29	a
EM + 240 NH_4NO_3	1.55	1.72	1.64	±	0.32	a
EM + 240 O.M.	1.46	1.34	1.40	±	0.23	a
EM + 320 NH_4NO_3	1.62	1.82	1.72	±	0.29	a
EM + 320 O.M.	1.30	1.75	1.52	±	0.46	a
EM + 80 NH_4NO_3	1.23	1.68	1.46	±	0.42	a
EM + 80 O.M.	1.50	1.42	1.46	±	0.21	a
$LSD_{Trt*Irrig.}$	0.49		LSD_{Trt}	N.S		
Irrigation means	4.41 ± 2.47	1.76 ± 0.51				
$LSD_{Irrig.}$	N.S					

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

The results demonstrate that drought stress significantly impacts plant height, Table 5.39, Table B.5. 82, and Table B.5. 83. The use of irrigation resulted in a substantial rise in plant height by 6.78%, with an average of 237.8 cm, as opposed to the non-irrigated field, which had an average height of 222.2 cm in the year 2023, Table 5.39. The plant height in 2022 in the irrigated field was 140.1 cm, which is significantly higher by 5.12% than the non-irrigated field, 133.1 cm, Table B.5. 82. During the two years, the act of irrigating resulted in a noticeable and substantial growth in plant height, increasing from 179.8 cm to 186.7 cm, Table B.5. 83. Precipitation and climate have a significant effect by 50.71% on the plant height, which was 136.6 cm in 2022, which was a dry year, compared to 229.4 cm in 2023, Table B.5. 83. Applying ammonium nitrate and organic matter at 160 and 240 kg/ha resulted in the observed plant height, Table 5.39. In 2023, the use of EM had no discernible impact on the height of plants, Table 5.39. In 2022, similar findings were seen, indicating that the use of EM did not have a beneficial effect on plant height, Table B.5. 82. In brief, irrigation dramatically improves the plant height, especially in a dry year. N from different sources improves the ability of plants to face drought and heat stress to a certain level when N's optimal range is 160 to 240 kg/ha, and more N application has a reverse impact. EM application has no role in helping plants improve their plant height under drought and heat stress.

Table 5.39. Plant height of *Zea mays* L. responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

PLANT HEIGHT cm						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	263.3	276.7	270.0	±	8.9	a
160 O.M.	223.3	230.0	226.7	±	8.2	ab
240 NH_4NO_3	260.0	273.3	266.7	±	10.3	ab
240 O.M.	160.0	236.7	198.3	±	87.5	abc
320 NH_4NO_3	263.3	270.0	266.7	±	5.2	bcd
320 O.M.	223.3	223.3	223.3	±	5.2	bcd
80 NH_4NO_3	250.0	273.3	261.7	±	13.3	cde
80 O.M.	216.7	230.0	223.3	±	10.3	def
CONT.	200.0	210.0	205.0	±	8.4	def
EM	206.7	216.7	211.7	±	11.7	def
EM + 160 NH_4NO_3	233.3	233.3	233.3	±	12.1	def
EM + 160 O.M.	226.7	233.3	230.0	±	6.3	def
EM + 240 NH_4NO_3	226.7	223.3	225.0	±	10.5	def
EM + 240 O.M.	223.3	216.7	220.0	±	6.3	def
EM + 320 NH_4NO_3	233.3	236.7	235.0	±	10.5	def
EM + 320 O.M.	223.3	230.0	226.7	±	12.1	def
EM + 80 NH_4NO_3	150.0	236.7	193.3	±	85.9	ef
EM + 80 O.M.	216.7	230.0	223.3	±	10.3	f
$LSD_{Trt*Irrig.}$	46.6		LSD_{Trt}	34.1		
Irrigation means	222.2 ± 44.3 b	237.8 ± 21.9 a				
$LSD_{Irrig.}$	11.0					

* Different lowercase letters (column) present significant differences between the means (p < 0.05), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means (p < 0.05), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Measuring stem diameter is widely used to evaluate plant development and its associated economic and ecological advantages. It mainly pertains to the accumulation of plant materials and the vigor of plant development. During periods of stress, this metric is likely to be influenced due to the existence of a direct correlation among stem diameter and other growth characteristics. The stem diameter seems to provide a practical measure of the overall leaf area of a plant during its rapid development phase, particularly for plants that present apical dominance. Typically, this association follows an exponential pattern; however, maize showed a linear response. Data show that applying N and EM significantly increases the value of stem diameter. Ammonium nitrate application resulted in the highest significant increase in the strait by 50%, which made 1.55 cm and the control 0.93 cm in 2022, Table B.5. 84. Statistically but not significantly followed by the application of EM that had means values of 1,45 cm and the combined EM+NH_4NO_3 1.32 cm. the application of organic matter made a statistical but not significant increase compared to the control with a value of 1.18 with an increase in percentage by 23.69% difference. However, the combined treatment of EM+OM resulted in a significant increase in the stem diameter with a value of 1.43 cm, Table B.5. 84. These results mean that the available nitrogen source, ammonium nitrate, increases plant growth more than the slow-release N source from the organic matter, which can affect the decomposition process by several factors, mainly moisture availability. It also means that the application of EM has a role in contributing to plant bodybuilding, which might be due to stress mitigation. Irrigation has a positive effect in 2022 by increasing the plant stem diameter by 25.28%, with the value in the non-irrigated field at 1.14 cm and in the irrigated area at 1.47 cm, Table B.5. 84.

Maize oil is a derivative of enterprises that produce maize flour and starch. The fatty acid profile of maize oil is characterized by a substantially elevated proportion of linoleic acid, ranging from 58% to 62%. The primary triacylglycerol molecules in maize oil are LLL 25%, LLO 22%, LLP 15%, OOL 11%, and PLO 10%. Corn oil is classified as a very abundant source of phytosterols 8300–25 500 ppm and tocopherols 1130–1830 ppm among vegetable oils. The primary phytosterol and tocopherol found in corn oil are β-sitosterol 63–70% and γ-tocopherol 68–89% (Ghazani & Marangoni, 2016). The data indicates that the oil % rises with each treatment, separately and when combined, compared to the control group, Table 5.40. Applying ammonium nitrate or organic materials from various sources significantly enhances the oil content %.

However, ammonium nitrate has a statistical impact on oil content relative to organic matter. While the application of 230 kg/ha of N resulted in the highest oil content, this difference was not statistically significant compared to the other levels of N application, Table 5.40. The application of EM resulted in a substantial increase in the oil content compared to the control, and no significant differences were seen compared to the other treatments. The combined N-EM treatments yielded superior outcomes in comparison to the control group. In 2023, Hungary did not experience drought conditions, and the precipitation rate was at the average level. Consequently, irrigation did not have any notable impact. The current study demonstrates that the oil % consistently rises with each treatment used, separately and when combined, compared to the control group.

Table 5.40. The oil content of *Zea mays* L. kernels responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

OIL %						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	3.72	3.69	3.70	±	0.08	ab
160 O.M.	3.54	3.48	3.51	±	0.14	abcd
240 NH_4NO_3	3.69	3.62	3.65	±	0.08	abc
240 O.M.	3.41	3.42	3.42	±	0.08	de
320 NH_4NO_3	3.77	3.67	3.72	±	0.08	a
320 O.M.	3.44	3.48	3.46	±	0.07	cd
80 NH_4NO_3	3.77	3.64	3.71	±	0.13	ab
80 O.M.	3.48	3.54	3.51	±	0.09	abcd
CONT.	3.42	3.36	3.39	±	0.18	de
EM	3.70	3.43	3.57	±	0.20	abcd
EM + 160 NH_4NO_3	3.51	3.49	3.50	±	0.14	bcd
EM + 160 O.M.	3.45	3.48	3.46	±	0.12	cd
EM + 240 NH_4NO_3	3.62	3.57	3.60	±	0.09	abcd
EM + 240 O.M.	2.92	3.54	3.23	±	0.60	e
EM + 320 NH_4NO_3	3.76	3.65	3.71	±	0.09	ab
EM + 320 O.M.	3.47	3.53	3.50	±	0.12	bcd
EM + 80 NH_4NO_3	3.58	3.48	3.53	±	0.07	abcd
EM + 80 O.M.	3.34	3.43	3.39	±	0.15	de
$LSD_{Trt*Irrig}$.	0.28		LSD	0.21		
Irrigation means	3.53 ± 0.28	3.53 ± 0.27				
LSD_{Irrig}.	N.S					

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Protein content in the corn kernels increases with N application regardless of N sources, Table B.5. 85. Among the N application level, Protein content increases as the amount of applied N increases, starting from 160 kg/ha N active agent to 320 kg/ha N that had the heiet increases of 8.27% of kernel protein compared to the control 5.14% with an increase in percentage by 46.68%. However, the low N level, 80 kg/ha, made a statistically but insignificant increase, Table B.5. 85. Ammonium nitrate had a greater impact on boosting protein levels than organic matter. Several factors, including drought, may influence the release of accessible nitrogen. Based on the data from the table, the application of EM had no noticeable impact on the protein % in the kernels. Furthermore, the combined treatment of EM+N had a severe effect, Table B.5. 85.

The treatments did not cause any change in the starch content of the maize kernel. The data shows no substantial rise in the parameter of starch content, Table B.5. 86. In the same line, irrigation does not affect the starch percentage in an average precipitation year, 2023. The data is shown in Table B.5. 87 demonstrates a significant variation in the moisture content of maize kernels. The kernels retain the highest moisture content at the intermediate application level when several sources are used. The highest results were seen with nitrogen application rates of 160 to 240 kg/ha, compared to 320 and 80 kg/ha. In this case, the moisture content of ammonium nitrate at a level of 240 kg/ha N was 17.1%, while the control had a moisture content of 15.9%, increasing by 7.27%. The corn moisture kernels increased significantly by 3.215% with the irrigation from 15.3% to 15.8% with irrigation. The results indicate that both irrigation and nitrogen treatment had a substantial and beneficial impact on the ultimate moisture content of the internal kernel. Quantum yield (QY), the measurement of photosynthesis II efficiency, is equivalent to Fv / Fm in dark-adopted samples and Fv1 / Fm1 in light-adapted samples. The measurement presents no significant differences among the treatments and irrigation in 2023, Table B.5. 88. It means that this year, there were no significant droughts and heat stress affecting maize plants. However, there were statistical differences

The data present some statistical and significant correlations among the study parameters, Table 5.41. Kernel yield significantly correlates with SPAD values and cobs number, with r = 0.32 and 0.30, respectively. The increase in photosynthetic activity led to a higher production of dry matter, part of which ultimately contributed to the final yield. This is a logical outcome. Genotypes capable of multiple cobs may increase crop output in environments with less abiotic stress, as shown by the observed findings.

Nevertheless, cobs yield was positively correlated with all parameters either statistically or significantly, but for the starch content with a negative correlation coefficient r = -0.08. It exhibited a strong correlation with the number of kernels produced, the number of kernels per cob column, the yield of empty cobs, the number of cobs, the SPAD value, the protein content, the oil content, the moisture percentage, and the height of the plants. Yield refers to the ultimate output of a plant's health and the conditions of its surroundings. The interplay between genes and the environment plays a crucial role in determining the ultimate quality and quantity of the yield. This becomes evident when contrasting the year of heightened abiotic stress, 2022, with the year of typical environmental conditions in Hungary, 2023. In 2022, the weak plants experienced severe environmental stress, leading to a complete lack of crop production, impaired plant growth, reduced photosynthetic activity, and a decreased leaf area index. Nevertheless, under less demanding circumstances, there was an overall augmentation in the values of morphological traits, which directly impacted the ultimate output.

In summary, it can be shown that irrigation has no substantial impact on kernel yield in Hungary during a typical year of precipitation. However, in a year with low rainfall, irrigation of at least 20 mm per week is required starting from V6 growth stage to achieve yield and alleviate the effects of drought stress. Nevertheless, using the EM may somewhat improve the yield compared to the control. In addition, the chemical nitrogen source NH_4NO_3 has a more significant impact on the yield than the organic source. However, using a large quantity of organic matter might improve performance. Individually or in combination, the application of NH_4NO_3, OM, and EM has a statistically significant positive impact on various growth and quality traits, including kernel yield, cobs yield, cobs number, empty cobs yield, number of kernels per cob row, number of kernels per cob column, SPAD and LAI values, starch content, protein content, oil content, and yield moisture content. The application of 160 kg/ha of NH_4NO_3 and OM range of 160 to 240 kg/ha resulted in a more favorable outcome than higher levels of 320 kg/ha, which negatively influenced most growth parameters, particularly in the non-irrigated area. The plant could not achieve an optimal result when the amount of N treatment was lower than 160 kg/ha. When applying fertilizers containing N active agents, it is essential to consider environmental parameters, particularly moisture availability and the presence of decomposing microbes. This is because many biotic and abiotic factors may influence the breakdown of organic matter. Consequently, a larger dosage of organic matter is recommended to be used compared to artificial N sources to enhance the release and availability of nitrogen to the plant roots in the rhizosphere area.

Table 5.41. Correlation coefficients among the study parameters of maize experiment under abiotic stress experiment 2023, MATE - Gödöllő.

Traits	Cobs Yield	Kernel Per Column	Kernel Per Row	Kernel Yield	Empty Cobs Weight	Leaf Area Index	SPAD	QY	Plant Height	Cobs Number	Moisture%	Oil %	Protein %
Kernel Per Column	0.88 *												
Kernel Per Row	0.19	0.15											
Kernel Yield	0.35 *	0.32 *	0.02										
Empty Cobs weight	0.31 *	0.42 *	0.13	-0.04									
Leaf Area Index	0.08	0.08	-0.04	0.03	0.00								
SPAD	0.49 *	0.48 *	0.06	0.32 *	-0.01	0.11							
QY	0.28 *	0.24 *	-0.01	0.15	0.08	0.05	0.11						
Plant Height	0.40 *	0.40 *	-0.01	0.17	0.07	0.10	0.31 *	0.06					
Cobs Number	0.68 *	0.70 *	0.07	0.30 *	0.07	0.07	0.51 *	0.11	0.43 *				
Moisture%	0.62 *	0.62 *	0.12	0.23 *	0.40	0.07	0.46 *	0.22	0.30 *	0.45 *			
Oil %	0.43 *	0.40 *	0.11	0.18	0.02	0.10	0.33 *	0.13	0.25 *	0.48 *	0.33 *		
Protein %	0.70 *	0.67 *	-0.04	0.28 *	0.16	0.16	0.52 *	0.14	0.30 *	0.63 *	0.52 *	0.56 *	
Starch %	-0.08	-0.06	-0.13	-0.03	0.01	-0.02	0.00	0.25 *	-0.08	-0.29 *	-0.05 *	-0.17	-0.11

The correlation coefficient with * is significant at the probability level of 0.05, and QY is the quantum yield.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

I. Laboratory Germination Experiments

A. The sigmoid curves have a solid fit for the experimental data of germination and seedling growth temperatures. The optimal temperature for maize seedling growth is 20 °C, and a more comprehensive range for germination is from 20 to 35 °C. For wheat, 20 °C was ideal for seedling development. Wheat germination has a broad range of 20 °C to 30 °C. A temperature lower than the optimal range decreases the germination rate, and a higher temperature increases fungal growth for both crops.

B. Seed size influences the quantity of water needed for germination. Therefore, TKW provides a more accurate perspective for water amount application. Maize germination in different percentages can occur in a wide range of water amounts starting at 0.60 ml, representing 25% of the maize TKW, but the optimal range for germination is 0.06–5.30 ml, representing 25–225% of the TKW. The optimal range for seedling growth is 2.35–7.75 ml. As the temperature increases, the optimal range for the water amount narrows; e.g., at 20 °C, it is broader than at 25 °C. For wheat, germination of various percentages can occur in a broad range of water quantities commencing at 0.65 ml, which represents 75% of TKW, but the optimal range for germination is 4.45–7.00 ml, representing 525–825% of the TKW.

C. Dry weight can indicate seedling development because dry matter accumulation is consistent with the physical measurement of seedling growth.

D. Different seed and seedling densities present no significant difference; thus, a lower seed density is recommended for lab examination: 6 maize seeds and 15 wheat seeds per 9 cm Petri dish. This is common practice in the case of seed limitation and breeding projects.

E. The seed priming technique before planting shows a significantly better effect on seedling growth than adding the antifungal to the growth media, and the highest values were recorded with the control.

This conclusion is supported by a other laboratory optimization studies conducted by Tarnawa et al,. (2023), Haj Saghaier et al., (2022).

II. Pre-sowing seed priming experiment

Considering the conditions in Hungary for growing wheat, it is clear that irrigation of 20 mm every 6 days is beneficial starting from Feeks 6 throughout the vegetative development phases, especially during the stem elongation stages (Feekes 6 to Feekes 10). Implementing this irrigation regimen is essential for optimizing plant biomass, promoting photosynthetic activity, and ultimately increasing crop amount.

For instance, research conducted by Pálmai et al. (2017) found that regular irrigation during the vegetative phase significantly enhances biomass accumulation and photosynthetic efficiency, which in turn increases the overall yield of wheat crops. This is corroborated by Steduto et al. (2012), who emphasized the critical importance of sufficient water supply during key growth stages to maximize biomass and yield potential in cereals. Furthermore, it is necessary to engage in irrigation every 3 days throughout the grain-filling stage to enhance quality attributes such as protein content, gluten content, and sedimentation volume, which is aligns with findings from other studies. For example, Leilah et al. (2015) demonstrated that increased irrigation frequency during the grain-filling period significantly improves grain quality parameters, such as protein and gluten content, which are critical for bread-making quality. Similarly, Saini and Westgate (2000) found that adequate water supply during grain-filling is crucial for maintaining grain quality, particularly under conditions of environmental stress, reinforcing the importance of the proposed irrigation regimen.

Applying gibberellin and salicylic acid to seeds significantly improves plants' resistance to drought-induced abiotic stress. They improved several traits associated with plant development and agricultural production, including total yield, weight of individual grains, number of plant tillers, number of spikelets per plant shoot, gluten content, and Zeleny index. The enhancement of plant agronomic traits this study found is consistent with existing literature. According to Khan et al. (2015), the application of gibberellin and salicylic acid enhances drought tolerance by modulating stress-responsive pathways, leading to improved water-use efficiency, increased yield, and better grain quality under drought conditions. Moreover, Anjum et al. (2011) reported similar improvements in drought resistance and agronomic traits, including total yield and grain quality, when wheat seeds were treated with these PGRs, highlighting their efficacy in mitigating the adverse effects of drought.

The planted varieties have shown significant variations in performance, with the more recent cultivars Nemere and Felleg surpassing the traditional local variety Alföld in their ability to withstand drought stress. This finding of the current study is consistent and supported by studies on varietal performance under similar conditions. For instance, Szira et al. (2008) reported that newer wheat varieties bred for drought tolerance exhibit superior performance in terms of yield stability and quality under water-limited conditions compared to older, traditional varieties. Similarly, Fischer et al. (2012) highlighted the advancements in wheat breeding that have led to the development of cultivars with enhanced drought resilience, which are better equipped to maintain productivity and quality under stress conditions.

III. Effective Microorganisms Experiment

A. 2021-2022 experiment

Irrigation has a significant positive impact on wheat yield quantity and quality. N, EM, and their combination, along with the control in irrigated and not irrigated fields, provided innovative and unique insights into addressing abiotic stressors in agriculture, especially drought. On average, the in-crop use of EM + N + irrigation demonstrates a significant enhancement in crop production and improvements in several quality indicators. The use of EM applications has been seen to provide beneficial outcomes in enhancing the resilience of crops against the adverse effects of drought and heat conditions, although to varying extents. The in-crop application of EM has not been used by any researcher so far, and this discovery is significantly adding to the existing scientific information of the knowledge body of science. The finding that the application of effective microorganisms improves the ability of crops to withstand drought and high temperatures is consistent with the research conducted by Xu et al. (2011). Xu et al. found that EMs may boost plant resistance to environmental stress factors by promoting root development and increasing water retention in the soil.

B. 2022-2023 experiment

Based on this experiment, it can be concluded that applying EM twice at F3 and F10 has a very advantageous impact on significantly increasing the yield by 25.05% and improving the yield quality, particularly the protein content, by 3.35%. The application of EM mainly contributes to production by raising the number of tillers per plant by 14.084% and the number of spikelets per spike by 6.84%, resulting in an overall increase in yield. Applying nitrogen at a rate of 160-200 kg/ha leads to a considerable rise in all vegetative and yield metrics. Respectively, grain yield had a significant increase of 47.19% and 54.40%, leaf area by 85.10% and 85.10%, plant tillers by 32.25% and 47.05%, spikelets number per spike by 20.74% and 22.71%, plant height by 19.90% and 21.73%, and protein content by 10.78% and 11.51%. These statements may be summarized as follows: they result in the development of a more robust and resilient plant capable of enduring abiotic stressors and producing under drought. This finding is in line with the research conducted by Chen et al. (2006). They found that the combination of effective microorganisms and conventional fertilizers can enhance plant resilience and productivity in stressful environments.

IV. In-Crop N-Splitting-Timing Experiment

The plant growth, grain yield, and wheat quality parameters were significantly enhanced by implementing a nitrogen splitting strategy, which involved dividing the nitrogen into three portions and applying them during critical growth stages F3, F6, and F10. Hence, this strategy is efficacious in alleviating the effects of drought stress and enhancing nitrogen use efficiency, which is aligns with findings from other studies. For example, Fageria and Baligar (2005) demonstrate the importance of nitrogen time applications to elevate NUE and endure drought abiotic stress, which leads to improve plant growth and yield. Providing a substantial amount of nitrogen during the grain-filling stage would further improve the quality of wheat grains and flour, which is supported by the finding of Barraclough et al. (2010), which present that late nitrogen applications improve grain quality. In the Hungarian environment, irrigation of 20 mm weekly is beneficial during the dry period, typically during the booting, shooting, and grain-filling phases when there is little to non-precipitation. There was a notable disparity among the cultivated wheat varieties in their resistance to drought and heat conditions, with newer produced varieties, such as Nemere, exhibiting more resistance than the older variety, Alföld. This is supported by Reynolds et al. (2009), who demonstrated that newer wheat varieties bred for drought resistance outperform older varieties under unfavorable climatic conditions.

V. Nitrogen Doses- Wheat Quality- Abiotic-Stresses Experiment

This study provides evidence that administering fertilizers during the latter stages of the crop's life cycle, particularly under drought and heat stress conditions, has a detrimental impact on the overall yield amount. Moderate N application (80 to less than 120 kg/ha^{-1}) at this stage during abiotic stresses also increases the grain quality, including the protein and the gluten contents. However, the high rate of N application (120 kg/ha and more) increases extreme abiotic stresses (drought stress) on wheat plants and negatively impacts the yield quantity. The finding that high nitrogen fertilization (≥120 kg/ha) exacerbates drought and heat stresses and reversely affects yield is consistent with the study by Fageria et al. (2010), who demonstrate that excessive N application under stress conditions, can increase the plant's susceptibility to abiotic stresses. Furthermore, Barraclough et al. (2010), supported our finding when stating that appropriate N levels improve quality parameters of the final product of wheat without negatively impacting yield quantity.

VI. Maize Field Experiment

In maize production, irrigation does not significantly affect kernel yield in Hungary under average annual precipitation conditions. Nevertheless, during a year characterized by little precipitation, it is necessary to apply irrigation of no less than 20 mm per week starting from growth stage of V6 to attain optimal crop production and mitigate the negative impacts of drought-induced stress. According to studies by Olesen et al. (2011), supplementary irrigation is crucial for sustaining maize output under drought circumstances, which supports the conclusion of the current study. However, Traore et al. (2009) demonstrate that maize yield responses to irrigation varied depending on water availability, indicating that under normal precipitation, irrigation may not substantially influence production.

However, using the EM application technique may somewhat enhance the yield compared to the control. This finding is in line with the finding of Higa and Parr (1994), who stated that effective microorganism's application can enhance soil health and crop yields.

Furthermore, the chemical nitrogen source NH_4NO_3 has a more pronounced influence on the yield than the organic source. Nevertheless, using a substantial amount of organic matter may enhance efficiency. The conclusion is supported by study of Fageria et al. (2010), which demonstrate that chemical nitrogen source typically gives a more immediate and higher nutrient availability than the organic sources. Nevertheless, the beneficial impact of organic nutrient source (organic matter) for enhancing soil health and nutrient efficiency were pointed by Liebig et al. (2004), who stated that organic sources of fertilizers can enhance long-run soil fertility and crop yield. The application of NH_4NO_3, OM, and EM, individually or in combination, has a statistically or significant positive effect on a range of growth and quality traits. These include kernel yield, cobs yield, cobs number, empty cobs yield, number of kernels per cob row, number of kernels per cob column, SPAD and LAI values, starch content, protein content, oil content, and yield moisture content. Applying 160 kg/ha of NH_4NO_3 and a range of 160 to 240 kg/ha of organic matter had a more positive effect than higher levels of 230 kg/ha. The higher levels negatively affected most growth metrics, especially in the non-irrigated region. The plant failed to get an ideal outcome when the quantity of N treatment was below 160 kg/ha. When using fertilizers that include active nitrogen agents, it is crucial to consider environmental factors, including the availability of moisture and the presence of decomposition bacteria. This is because several biotic and abiotic variables may impact the decomposition of organic matter. Therefore, a higher quantity of organic matter should be used in contrast to synthetic sources to optimize the release and availability of nitrogen to the plant roots.

6.2 Recommendations

I. Pre-Sowing Seed Priming

This study recommends priming wheat seeds with gibberellic and salicylic acid to improve plants' resistance to drought-induced abiotic stress. It also recommends using an irrigation regime of 20 mm every 6 days during the stem elongation stages (Feekes 6 to Feekes 10) and every 3 days throughout the grain filling. Moreover, it advocates cultivating contemporary varieties such as Nemere and Felleg instead of traditional local varieties like Alföld due to their capacity to endure drought stress. The priming strategy described here stimulates important physiological mechanisms that assist plants in coping with water shortages. This observation is consistent with the research conducted by JANDA et al. (2014), who observed that salicylic acid has a role in preserving cell turgor and stabilizing membranes under drought situations. In addition, Zhang et al. (2010) documented that gibberellic acid stimulates root development and improves the absorption of nutrients, which are crucial for supporting growth in times of water scarcity.

II. Laboratory Germination Experiments

This study recommends: (A) conducting maize and wheat seed germination and seedling growth experiments at 20 °C, (B) applying the water amount as a percentage of the TKW for optimization of the water amount suitability, (C) using dry weight as a better indicator of seedlings growth and development, and (D) using a density of no more than six seeds for maize and 15 for wheat per Petri dish since there is no significance of using a higher number of seeds. (E) Seed priming technique presents a better solution for fungal growth inhabitation in laboratory experiments.

III. Effective Microorganisms Experiment

This study recommends the use of irrigation techniques, along with in-crop EM technique and nitrogen, to enhance the crop's capacity to withstand stress situations, particularly drought. It also recommends that applying EM twice at F3 and F10 has a very advantageous impact on significantly improving the yield quantity and quality along nitrogen at a rate of 160-200 kg per hectare, leading to a considerable rise in all vegetative and yield metrics. This recommendation is in line with the litriture, for instance, Hussain et al. (2019) found that integrating EM with N and proper irrigation remarkably enhanced crop abiotic stress tolerance, leading to better yields amount and improved quality.

IV. In-Crop N-Splitting-Timing Experiment

This study recommends the management strategy of N-splitting and N-timing. A total of 160 kg/ha split evenly at 53.33 kg/ha to be applied at the growth stages of Feekes 3, Feekes 6, and Feekes10 to face the abiotic stress of drought and heat and improve the grain production and flour quality. This is consistent with the literature. For instance, Fageria and Baligar (2005) directed that nitrogen splitting across key growth stages improves NUE, ending to enhanced grain quantity and quality, literately under drought and height temperature abiotic stress. This experiment also recommends, in the Hungarian environment, irrigation of 20 mm weekly starting from Feekes 6 during the dry period, typically during the booting, shooting, and grain-filling phases when there is a lack of precipitation. It also recommends cultivating modern drought-resistant wheat varieties, such as Nemere.

V. Nitrogen Doses- Wheat Quality- Abiotic-Stresses Experiment

Under abiotic stressors of drought and heat, this research recommends applying moderate N at 80 to less than 120 kg/ha at a later stage of the crop life cycle (Heading and grain filling stages), which may enhance grain quality, namely protein and gluten levels. Nevertheless, applying a high rate of nitrogen (120 kg/ha and above) exacerbates abiotic stressors, particularly drought stress, on wheat plants, ultimately leading to a detrimental effect on the yield. The recommendation is in line with other a study when applying N at later wheat growth stages (heading and grain-filling) by Millar et al. (2011), who demonstrate that late N fertilization can have a mixed impact under abiotic stress, it enhances quality parameters but also raises the abiotic stress vulnerability if over-applied.

VI. Maize Field Experiment

To face the abiotic stress of drought and heat, this study recommends (A) applying irrigation of no less than 20 mm weekly starting from growth stage V6to attain optimal crop production and mitigate the negative impacts of drought-induced stress. (B) applying 160 kg/ha of NH_4NO_3 and 240 kg/ha of organic matter is recommended for maize production in a Hungarian environment. (C) On-crop EM application is recommended for early growth stages at a concentration of 1:100 EM solution to water when the soil temperature is around 17 Celsius in the early morning. These recommendations are consistence with the literature of irrigation regime by Olesen et al. (2011), EM application by Higa and Parr (1994), N rates and sources by Fageria et al. (2010) and Liebig et al., (2004).

8 NEW SCIENTIFIC RESULTS

I. An integrated agricultural approach has been developed for better crop adaptation: (A) priming wheat seeds with salicylic acid or gibberellic acid before planting; (B) using an irrigation regime of 20mm water (every minimum 6 to maximum 9 days) during the wheat growth stages (Feekes 6 to Feekes 10); and (C) growing modern wheat varieties, which are better handling abiotic stresses than old ones. This is how to be used in practice as a recommendation.

II. A comprehensive scientific methodology for conducting laboratory experiments specifically tailored to maize and wheat has been developed. The optimization is to conduct maize and wheat seed germination and seedling growth experiments at 20 °C, applying the water amount as a percentage of the TKW, using dry weight as a better indicator of seedlings growth and development, using a density of no more than six seeds for maize and 15 for wheat per Petri dish, and using seed priming technique presents a better solution for fungal growth inhabitation in laboratory experiments. This is how to be used in practice as a recommendation.

III. The application of effective microorganisms has the potential to enhance the resilience of wheat plants under challenging environmental conditions, hence leading to improvements in both the amount and quality of output.

IV. Timing of In-crop effective microorganisms has been determined. They must be applied twice at F3 and F10 since a single application at F3 presents no effect and the best time is F10. EM, along with N, produces robust and resilient plants capable of enduring abiotic stressors and producing under drought. This is how to be used in practice as a recommendation.

V. Management strategy of nitrogen splitting and timing throughout the growth stages of Feekes3, Feekes 6, and Feekes10 is an effective technique to mitigate the abiotic stress caused by drought and heat, while enhancing grain output and improving flour quality. This is how to be used in practice as a recommendation.

VI. In Hungary, for wheat production, in an extreme year of drought and heat stress, a high N dosage of 120 kg/ha and more exacerbation of abiotic stressors because the utilization of N needed extra water, and under these conditions of water scarcity, its high rate increases the negative impact. Moderate to low (around 80 kg/ha) application in the later growth stage may enhance the flour quality. This is how to be used in practice as a recommendation.

VII. Site specific N supply and microbial applications have been identified for wheat (*Triticum* aestivum L.) and maize (*Zea mays* L.) crop varieties regarding the improvement of resistance to abiotic stresses like water scarcity. Optimum dosage have been determined concerning yield quality and quantity of both crop species. This is how to be used in practice as a recommendation.

9 SUMMARY

This dissertation investigates the profound effects of abiotic stressors, with a primary focus on drought and temperature, on two staple crops: wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.). Abiotic stresses pose significant challenges to global food security, exacerbated by climate change-induced shifts in weather patterns. Drought, in particular, presents a critical threat to agricultural productivity, influencing crop growth, development, and yield. Through an interdisciplinary approach integrating agronomy and physiology, this study examines the mechanisms underlying drought stress responses in wheat and maize, aiming to elucidate strategies for enhancing their resilience and productivity under abiotic stressors conditions.

I. Pre-Sowing Seed Priming

In the context of Hungarian wheat production, irrigation of 20 mm every 6 days is beneficial during the vegetative growth stages, particularly from stem elongation (Feekes 6) to booting (Feekes 10). This irrigation regimen is crucial for enhancing plant biomass, photosynthesis activity, and, finally yield quantity. Additionally, irrigation every 3 days during the grain-filling and stage is essential for improving quality aspects such as protein content, gluten content, and sedimentation volume. Seed priming with gibberellic acid and salicylic acid has a notable beneficial impact on enhancing plants' ability to withstand drought-induced abiotic stress. They enhanced several traits related to plant growth and crop productivity, such as the overall yield, weight of individual grains, number of plant tillers, number of spikelets per plant shoot, gluten content, and Zeleny index. The planted varieties exhibited notable differences in performance, with the newer varieties Nemere and Felleg outperforming the historic local variety Alföld in their resistance to drought stress.

II. Laboratory Germination Experiments

Germination and seedling development are essential stages in a plant's life cycle, greatly influenced by temperature and moisture conditions. The aim of this study was to determine wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) seeds' germination and seedling development under various abiotic stresses. Six different temperature levels for wheat 5, 10, 15, 20, 25, and 30 °C and eight levels for maize, 5, 10, 15, 20, 25, 30, 35, and 40 °C, were used. Drought and water-logging stresses were tested using 25 and 30 water levels based on one-milliliter intervals and as percentages of thousand kernel weight (TKW) at 20 °C for wheat and 20 and 25 °C for maize. Seedling density and the use of antifungals were also examined. For wheat, germination duration and seedling growth were impacted significantly by temperature, and a temperature of 20 °C was observed to be optimum, and an optimal range bordered at 15 °C to less than 25 °C. For maize, temperature significantly affected germination duration and seedling growth, and 20 °C was found to be ideal with an optimal range of less than 30 °C. Germination occurred for wheat at 75% and for maize at 25% of the TKW. The optimal water range for seedling growth was higher and broader than the range for germination. Seed size assisted in defining germination water requirements and providing an accurate basis. The present research established an optimum water supply range for what of 525–825 and maize of 150–325% of the TKW for maize seedling development. A total of 15 wheat seeds and of 6 maize seeds per 9 cm Petri dish may be preferable over greater densities. The technique of priming seeds with an antifungal solution before planting was observed to have a better effect than applying it in the growth media.

III. Effective Microorganisms Experiment

The objective of this experiment was to assess the interplay between microorganisms, nitrogen fertilizer (specifically ammonium nitrate, NH_4NO_3), and irrigation in wheat plants, with the goal of alleviating the effects of abiotic stresses. The evaluation was undertaken to examine the impact of these factors on both the quantity and quality of yield. Nitrogen, EM, and their combination, along with the control in irrigated and not irrigated fields, provided innovative and unique insights into addressing abiotic stressors in agriculture, especially drought. On average, the in-crop use of EM + N + irrigation demonstrates a significant enhancement in crop production and improvements in several quality indicators. Without irrigation, applying EM twice at F3 and F10 has a very advantageous impact on significantly increasing the yield by 25.05% and improving the yield quality, particularly the protein content, by 3.35%. The application of EM mainly contributes to production by raising the number of tillers per plant by 14.08% and the number of spikelets per spike by 6.84%, resulting in an overall increase in yield. Applying nitrogen at 160-200 kg per hectare significantly increases all vegetative and yield metrics. Respectively, grain yield had a significant increase of 47.19% and 54.40%, leaf area by 85.10% and 85.10%, plant tillers by 32.25% and 47.05%, spikelets number per spike by 20.74% and 22.71%, plant height by 19.90% and 21.73%, and protein content by 10.78% and 11.51%. These statements may be summarized as follows: they result in the development of a more robust and resilient plant capable of enduring abiotic stressors and producing under drought. The in-crop application of EM has not been used by any researcher so far, and this discovery is significantly adding to the existing scientific information of the knowledge body of science.

IV. In-Crop N-Splitting-Timing Experiment

This study aimed to assess the in-crop nitrogen uptake, assimilation, and mobilization in wheat plants subjected to abiotic stress conditions. The results demonstrated a superior outcome when the same total quantity of N was applied compared to applying it all at once in F3 or dividing it across F3 and F6. The grain production, protein content, gluten content, and number of spikelets per spike showed a significant rise. Nevertheless, some traits, such as plant height and leaf area index, were significantly diminished due to splitting nitrogen doses. This outcome is comprehensible since these parameters need a complete initial N dosage to achieve higher values. Hence, this strategy is efficacious in alleviating the effects of drought stress and enhancing nitrogen use efficiency. Providing a substantial amount of nitrogen during the grain-filling stage would further improve the quality of wheat grains and flour. In the Hungarian environment, irrigation of 20 mm weekly is necessary during the dry period, typically during the booting, shooting, and grain-filling phases when there is little to no precipitation. There was a notable disparity among the cultivated wheat varieties in their resistance to drought and heat conditions, with newer produced varieties, such as Nemere, exhibiting more resistance than the older variety, Alföld. However, the variety that exhibits a larger grain yield is associated with a lower protein percentage, and vice versa.

V. Nitrogen Doses- Wheat Quality- Abiotic-Stresses Experiment

The primary aim of this research was to evaluate the nitrogen acquisition, assimilation, and mobilization processes during the later developmental phases of wheat plants (post-Feekes 10) under abiotic stress conditions. The finding of this study suggests that management under abiotic stresses can improve the value of harvest index and obtain a higher yield, for example, by applying N fertilizers not only at the reproductive stage of the plant life cycles but also at the vegetative growth stages such as tillering stage Feekes 3 and also stem elongation stage Feekes 6. Moderate N application at this stage during abiotic stresses also increases the grain quality, including the protein and the gluten contents. However, a high rate of N application increases extreme abiotic stresses (drought stress) on wheat plants and negatively impacts the yield quantity. Moderate N application (80 to less than 120 kg/ha) at this stage during abiotic stresses also increases the grain quality, including the protein and the gluten contents. However, the high rate of N application (120 kg/ha and more) increases extreme abiotic stresses (drought stress) on wheat plants and negatively impacts the yield quantity.

VI. Maize Field Experiment

This experiment examines the growth and the production of maize under abiotic stress in two different climatic years. The results indicate that irrigation has no substantial impact on kernel yield in Hungary during a typical year of precipitation. However, in a year with low rainfall, irrigation of at least 20 mm per week is required to achieve yield and alleviate the effects of drought stress. Nevertheless, using the EM may somewhat improve the yield compared to the control. In addition, the chemical nitrogen source NH_4NO_3 has a more significant impact on the yield than the organic source. However, using a large quantity of organic matter might improve performance. Individually or in combination, the application of NH_4NO_3, OM, and EM has a statistically significant positive impact on various growth and quality traits, including kernel yield, cobs yield, cobs number, empty cobs yield, number of kernels per cob row, number of kernels per cob column, SPAD and LAI values, starch content, protein content, oil content, and yield moisture content. The application of 160 kg/ha of NH_4NO_3 and OM range of 160 to 240 kg/ha resulted in a more favorable outcome than higher levels of 320 kg/ha, which negatively influenced most growth parameters, particularly in the non-irrigated area.

Key Findings:

1. Agronomic Practices: Adoption of agronomic practices such as seed priming, in-crop effective microorganisms' application, and nitrogen timing and splitting, usage of an organic source of fertilizers can mitigate the adverse effects of drought on wheat and maize production.
2. Physiological Responses: Both wheat and maize exhibit a range of physiological responses to the study treatments and agricultural techniques used to cope with abiotic stress.
3. Climate-Smart Agriculture: Integration of climate-smart agricultural practices can enhance the adaptive capacity of wheat and maize production systems to withstand drought stress.
4. Germination Optimization: Optimizing various factors in laboratory conditions to enhance seed germination and seedling establishment and development of wheat and maize. It explored the interplay between water levels, temperature conditions, seedling density per petri dish, and the application of antifungal methods.

APPENDIXES

Appendix A: Bibliography

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Appendix B: List of tables and figures

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Table B.5. 1. The impact of gibberellin and salicylic acid on the green yield (kg/ha) production (harvested yield before cleaning) of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	2550.0	6850.0	7750.0	7250.0	6100.0	
	GAs	3100.0	6175.0	7550.0	7200.0	6006.0	
	SA	2700.0	6700.0	7700.0	8100.0	6300.0	
Alföld	Cont.	2453.0	6333.0	6333.0	6567.0	5422.0	
	GAs	2700.0	6300.0	6033.0	6610.0	5411.0	
	SA	2250.0	6517.0	6200.0	6383.0	5338.0	
Felleg	Cont.	3900.0	8200.0	7500.0	7050.0	6662.0	
	GAs	800.0	7600.0	7450.0	6800.0	5662.0	
	SA	3300.0	7150.0	7200.0	6650.0	6075.0	
LSD $_{V*T*I}$		242				LSD $_{V*T}$	121
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		2783.0	6575.0	7667.0	7517.0	6135.0 a	
Alföld		2468.0	6383.0	6189.0	7517.0	5390.0 b	
Felleg		2667.0	7650.0	7383.0	6833.0	6133.0 a	
LSD $_{V*I}$		139.7				LSD $_V$	69.9
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		2968.0	7128.0	7194.0	6956.0	6061.0 a	
GAs		2200.0	6692.0	7011.0	6870.0	5693.0 c	
SA		2750.0	6789.0	7033.0	7044.0	5904.0 b	
LSD $_{T*I}$		139.7				LSD $_T$	69.9
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		2639.0 c	6869.0 b	7080.0 a	6957.0 a		
LSD $_I$		80.7					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 2. The impact of gibberellin and salicylic acid on the TKW (g) of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	43.6	44.8	48.9	46.6	46.0	
	GAs	45.6	47.2	46.8	43.4	45.7	
	SA	49.9	46.3	47.3	47.7	47.8	
Alföld	Cont.	37.8	35.4	37.0	37.9	37.0	
	GAs	38.1	36.8	38.7	41.5	38.8	
	SA	37.8	36.6	37.5	36.3	37.1	
Felleg	Cont.	38.4	37.9	39.7	40.9	39.2	
	GAs	42.2	37.7	41.9	39.5	40.4	
	SA	41.7	35.3	42.2	41.7	40.2	
LSD $_{V*T*I}$		1.501				LSD $_{V*T}$	0.751
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		46.4	46.1	47.7	45.9	46.5 a	
Alföld		37.9	36.3	37.7	45.9	37.6 c	
Felleg		40.8	37.0	41.3	40.7	39.9 b	
LSD $_{V*I}$		0.867				LSD $_{V}$	0.433
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		39.9	39.3	41.9	41.8	40.7 b	
GAs		42.0	40.6	42.5	41.5	41.6 a	
SA		43.2	39.4	42.3	41.9	41.7 a	
LSD $_{T*I}$		0.867				LSD $_{T}$	0.433
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		41.7 b	39.8 c	42.2 a	41.7 b		
LSD $_{I}$		0.5					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 3. The impact of gibberellin and salicylic acid on the test weight (kg/hl) of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T
		0	3 Days	6 Days	9 Days	
Nemere	Cont.	77.3	75.7	75.0	75.0	75.7
	GAs	73.7	76.4	75.2	74.8	75.0
	SA	77.7	76.1	76.4	76.6	76.7
Alföld	Cont.	75.9	76.7	77.6	76.8	76.7
	GAs	78.8	77.6	78.2	75.3	77.5
	SA	77.9	77.8	77.4	76.3	77.4
Felleg	Cont.	77.7	75.2	76.6	77.0	76.6
	GAs	82.0	74.6	77.9	76.1	77.6
	SA	77.5	70.3	77.5	77.3	75.6
LSD_{V*T*I}		0.963				LSD_{V*T} 0.481
V * I						
Varieties		0	3 Days	6 Days	9 Days	Variety means
Nemere		76.2	76.0	75.5	75.4	75.8 c
Alföld		77.5	77.3	77.7	75.4	77.2 a
Felleg		79.0	73.4	77.3	76.8	76.6 b
LSD_{V*I}		0.556				LSD_{V} 0.278
T * I						
Treatments		0	3 Days	6 Days	9 Days	T. mean
Cont.		77.0	75.9	76.4	76.3	76.4 a
GAs		78.1	76.2	77.1	75.4	76.7 a
SA		77.7	74.7	77.1	76.7	76.6 a
LSD_{T*I}		0.556				LSD_{T} N.S
I						
Irrigation		0	3 Days	6 Days	9 Days	
Irrigation means		77.6 a	75.6 d	76.8 b	76.1 c	
LSD_{I}		0.321				

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 4. The impact of gibberellin and salicylic acid on the Quantum yield (QY) of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles measured at the anthesis in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	0.800	0.810	0.820	0.770	0.800	
	GAs	0.680	0.780	0.800	0.810	0.770	
	SA	0.730	0.810	0.820	0.770	0.780	
Alföld	Cont.	0.660	0.760	0.770	0.740	0.730	
	GAs	0.730	0.780	0.760	0.730	0.750	
	SA	0.650	0.770	0.780	0.750	0.740	
Felleg	Cont.	0.640	0.750	0.710	0.770	0.720	
	GAs	0.700	0.730	0.760	0.750	0.730	
	SA	0.540	0.760	0.730	0.810	0.710	
LSD_{V*T*I}		0.075				LSD_{V*T}	N.S
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		0.740	0.800	0.810	0.780	0.780 a	
Alföld		0.680	0.770	0.770	0.780	0.740 b	
Felleg		0.630	0.750	0.730	0.780	0.720 b	
LSD_{V*I}		0.044				LSD_{V}	0.022
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		0.700	0.770	0.770	0.760	0.750 a	
GAs		0.700	0.760	0.770	0.760	0.750 a	
SA		0.640	0.780	0.780	0.780	0.740 a	
LSD_{T*I}		N.S				LSD_{T}	N.S
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		0.680 b	0.770 a	0.770 a	0.770 a		
LSD_{I}		0.025					

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 5. The impact of gibberellin and salicylic acid on the plant height (cm) of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	68.3	73.7	78.3	79.7	75.0	
	GAs	75.7	76.3	80.0	81.7	78.4	
	SA	70.3	76.7	81.3	80.0	77.1	
Alföld	Cont.	74.7	87.4	87.6	90.2	85.0	
	GAs	84.0	85.6	88.1	77.4	83.8	
	SA	79.0	87.7	86.8	89.6	85.8	
Felleg	Cont.	74.3	84.3	78.3	76.7	78.4	
	GAs	70.3	82.0	78.3	78.7	77.3	
	SA	73.0	79.0	77.0	74.0	75.8	
LSD $_{V*T*I}$		3.3				LSD $_{V*T}$	1.65
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		71.4	75.6	79.9	80.4	76.8 b	
Alföld		79.2	86.9	87.5	80.4	84.8 a	
Felleg		72.6	81.8	77.9	76.4	77.2 b	
LSD $_{V*I}$		1.91				LSD $_{V}$	0.95
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		72.4	81.8	81.4	82.2	79.5 a	
GAs		76.7	81.3	82.1	79.3	79.8 a	
SA		74.1	81.1	81.7	81.2	79.5 a	
LSD $_{T*I}$		1.91				LSD $_{T}$	N.S
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		74.4 b	81.4 a	81.8 a	80.9 a		
LSD $_{I}$		1.1					

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 6. The impact of gibberellin and salicylic acid on the plant tillers' number of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	3.4	4.0	4.4	4.4	4.0	
	GAs	4.4	5.2	5.2	5.0	5.0	
	SA	4.2	5.0	5.8	5.2	5.1	
Alföld	Cont.	4.2	4.7	5.3	4.9	4.8	
	GAs	5.6	5.3	4.5	4.8	5.1	
	SA	6.0	5.5	4.6	6.2	5.6	
Felleg	Cont.	3.4	4.0	4.8	4.4	4.1	
	GAs	4.2	5.0	5.0	4.0	4.6	
	SA	4.0	4.8	5.2	4.8	4.7	
LSD $_{V*T*I}$		0.7				LSD $_{V*T}$	N.S
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		4.0	4.7	5.1	4.9	4.7 b	
Alföld		5.3	5.2	4.8	4.9	5.1 a	
Felleg		3.9	4.6	5.0	4.4	4.5 c	
LSD $_{V*I}$		0.41				LSD $_{V}$	0.2
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		3.7	4.2	4.8	4.6	4.3 c	
GAs		4.7	5.2	4.9	4.6	4.9 b	
SA		4.7	5.1	5.2	5.4	5.1 a	
LSD $_{T*I}$		0.41				LSD $_{T}$	0.2
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		4.4 b	4.8 a	5.0 a	4.9 a		
LSD $_{I}$		0.23					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 7. The impact of gibberellin and salicylic acid on the plant spikes number per square meter of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T
		0	3 Days	6 Days	9 Days	
Nemere	Cont.	440.0	740.0	820.0	1000.0	750.0
	GAs	660.0	700.0	900.0	500.0	690.0
	SA	640.0	760.0	1160.0	800.0	840.0
Alföld	Cont.	420.0	886.7	913.3	873.3	773.3
	GAs	500.0	866.7	753.3	726.7	711.7
	SA	460.0	946.7	893.3	800.0	775.0
Felleg	Cont.	440.0	720.0	1040.0	540.0	685.0
	GAs	500.0	780.0	780.0	420.0	620.0
	SA	480.0	660.0	1040.0	560.0	685.0
LSD $_{V*T*I}$		73.08				LSD $_{V*T}$ 36.54

V * I

Varieties	0	3 Days	6 Days	9 Days	Variety means	
Nemere	580.0	733.3	960.0	766.7	760.0	a
Alföld	460.0	900.0	853.3	766.7	753.3	a
Felleg	473.3	720.0	953.3	506.7	663.3	b
LSD $_{V* I}$	42.19				LSD $_{V}$	21.1

T * I

Treatments	0	3 Days	6 Days	9 Days	T. mean	
Cont.	433.3	782.2	924.4	804.4	736.1	b
GAs	553.3	782.2	811.1	548.9	673.9	c
SA	526.7	788.9	1031.1	720.0	766.7	a
LSD $_{T* I}$	42.19				LSD $_{T}$	21.1

I

Irrigation	0	3 Days	6 Days	9 Days
Irrigation means	504.4 d	784.4 b	922.2 a	691.1 c
LSD $_{I}$	24.36			

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 8. The impact of gibberellin and salicylic acid on the plant spikes number per square meter of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	12.8	17.0	15.6	15.8	15.3	
	GAs	15.2	17.8	16.0	17.0	16.5	
	SA	11.4	15.8	15.8	17.2	15.0	
Alföld	Cont.	15.0	20.4	20.5	20.3	19.1	
	GAs	15.2	20.7	19.5	17.5	18.2	
	SA	14.6	20.6	20.0	20.5	18.9	
Felleg	Cont.	12.4	18.3	18.5	18.9	17.0	
	GAs	15.6	18.9	18.3	18.1	17.7	
	SA	11.4	18.9	17.9	19.3	16.9	
LSD $_{V*T*I}$		0.87				LSD $_{V*T}$	0.43
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		13.1	16.9	15.8	16.7	15.6 c	
Alföld		14.9	20.6	20.0	16.7	18.7 a	
Felleg		13.1	18.7	18.3	18.8	17.2 b	
LSD $_{V*I}$		0.5				LSD $_V$	0.25
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		13.4	18.6	18.2	18.4	17.1 b	
GAs		15.3	19.2	18.0	17.5	17.5 a	
SA		12.5	18.4	17.9	19.0	17.0 b	
LSD $_{T*I}$		0.5				LSD $_T$	0.25
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		13.7 c	18.7 a	18.0 b	18.3 b		
LSD $_I$		0.29					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 9. The impact of gibberellin and salicylic acid on the whole grain gluten percentage of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles measured on the harvest day in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	24.60	25.80	23.60	21.10	23.78	
	GAs	23.50	22.00	22.60	26.70	23.70	
	SA	24.20	23.70	22.90	26.10	24.23	
Alföld	Cont.	24.30	27.87	25.47	25.53	25.79	
	GAs	23.40	26.80	23.07	25.13	24.60	
	SA	24.00	26.87	23.97	27.50	25.58	
Felleg	Cont.	26.80	29.30	27.80	24.80	27.18	
	GAs	23.60	29.80	26.60	28.20	27.05	
	SA	22.80	30.00	23.80	26.00	25.65	
LSD $_{V*T*I}$		1.57				LSD $_{V*T}$	0.78
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		24.10	23.83	23.03	24.63	23.90 c	
Alföld		23.90	27.18	24.17	24.63	25.33 b	
Felleg		24.40	29.70	26.07	26.33	26.63 a	
LSD $_{V*I}$		0.90				LSD $_{V}$	0.45
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		25.23	27.66	25.62	23.81	25.58 a	
GAs		23.50	26.20	24.09	26.68	25.12 a	
SA		23.67	26.86	23.56	26.53	25.15 a	
LSD $_{T*I}$		0.90				LSD $_{T}$	N.S
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		24.13 c	26.90 a	24.42 c	25.67 b		
LSD $_{I}$		0.52					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 10. The impact of gibberellin and salicylic acid on the whole grain gluten percentage of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles measured a month after the harvest in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	24.80	27.30	23.90	23.00	24.75	
	GAs	17.50	23.10	22.90	26.20	22.43	
	SA	24.10	24.90	23.20	26.00	24.55	
Alföld	Cont.	24.50	29.53	26.43	26.43	26.73	
	GAs	24.30	27.70	24.43	27.63	26.02	
	SA	24.80	27.93	25.57	28.77	26.77	
Felleg	Cont.	26.10	29.90	29.90	25.90	27.95	
	GAs	24.30	30.80	24.30	28.70	27.03	
	SA	25.50	31.60	25.70	24.70	26.88	
LSD $_{V*T*I}$		1.01				LSD $_{V*T}$	0.51
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		22.13	25.10	23.33	25.07	23.91 c	
Alföld		24.53	28.39	25.48	25.07	26.50 b	
Felleg		25.30	30.77	26.63	26.43	27.28 a	
LSD $_{V*I}$		0.58				LSD $_{V}$	0.29
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		25.13	28.91	26.74	25.11	26.48 a	
GAs		22.03	27.20	23.88	27.51	25.16 c	
SA		24.80	28.14	24.82	26.49	26.06 b	
LSD $_{T*I}$		0.58				LSD $_{T}$	0.29
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		23.99 d	28.09 a	25.15 c	26.37 b		
LSD $_{I}$		0.34					

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 11. The impact of gibberellin and salicylic acid on the whole grain protein percentage of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles measured on the harvest in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	12.40	12.50	11.80	10.80	11.88	
	GAs	11.70	11.20	11.60	13.00	11.88	
	SA	12.30	11.50	11.60	12.50	11.98	
Alföld	Cont.	12.60	13.57	12.67	12.70	12.88	
	GAs	12.30	12.83	12.20	12.73	12.52	
	SA	12.30	12.60	12.13	13.37	12.60	
Felleg	Cont.	13.10	13.70	13.40	12.30	13.13	
	GAs	12.20	13.90	12.90	13.50	13.13	
	SA	12.10	14.10	12.10	12.90	12.80	
LSD $_{V*T*I}$		0.51				LSD $_{V*T}$	0.26
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		12.13	11.73	11.67	12.10	11.91 c	
Alföld		12.40	13.00	12.33	12.10	12.67 b	
Felleg		12.47	13.90	12.80	12.90	13.02 a	
LSD $_{V*I}$		0.29				LSD $_{V}$	0.15
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		12.70	13.26	12.62	11.93	12.63 a	
GAs		12.07	12.64	12.23	13.08	12.51 a	
SA		12.23	12.73	11.94	12.92	12.46 a	
LSD $_{T*I}$		0.29				LSD $_{T}$	N.S
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		12.33 c	12.88 a	12.27 c	12.64 b		
LSD $_{I}$		0.17					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 12. The impact of gibberellin and salicylic acid on the whole grain protein percentage of *Triticum aestivum* L. influenced by seed priming interventions and irrigation and drought cycles measured a month after the harvest in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	12.30	12.80	12.10	11.40	12.15	
	GAs	11.38	11.40	11.40	12.30	11.62	
	SA	11.80	12.00	11.40	12.40	11.90	
Alföld	Cont.	12.40	13.93	12.70	12.77	12.95	
	GAs	12.30	13.20	12.03	12.93	12.62	
	SA	12.60	13.27	12.33	13.47	12.92	
Felleg	Cont.	11.30	13.70	14.00	12.70	12.93	
	GAs	12.30	14.00	13.20	13.60	13.28	
	SA	14.70	14.40	12.40	12.20	13.43	
LSD_{V*T*I}		0.42				LSD_{V*T}	0.21
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety means	
Nemere		11.83	12.07	11.63	12.03	11.89 c	
Alföld		12.43	13.47	12.36	12.03	12.83 b	
Felleg		12.77	14.03	13.20	12.83	13.21 a	
LSD_{V*I}		0.24				LSD_{V}	0.12
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		12.00	13.48	12.93	12.29	12.68 a	
GAs		11.99	12.87	12.21	12.94	12.50 b	
SA		13.03	13.22	12.04	12.69	12.75 a	
LSD_{T*I}		0.24				LSD_{T}	0.12
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation means		12.34 c	13.19 a	12.40 c	12.64 b		
LSD_{I}		0.14					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 13. The impact of gibberellin and salicylic acid on the Zeleny Index (ml) of *Triticum aestivum* L. influenced by seed priming interventions as well as irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	41.90	46.00	41.40	38.40	41.92	
	GAs	41.20	40.80	41.30	51.20	43.62	
	SA	40.20	40.90	42.10	46.10	42.32	
Alföld	Cont.	39.70	49.20	43.80	44.37	44.27	
	GAs	39.40	44.87	41.67	48.57	43.62	
	SA	39.20	50.60	43.70	52.50	46.50	
Felleg	Cont.	48.60	46.20	42.50	40.70	44.50	
	GAs	43.60	44.80	44.10	42.50	43.75	
	SA	39.90	46.70	39.40	12.60	34.65	
LSD_{V*T*I}		3.12				LSD_{V*T}	1.56
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety mean	
Nemere		41.10	42.57	41.60	45.23	42.62 b	
Alföld		39.43	48.22	43.06	45.23	44.80 a	
Felleg		44.03	45.90	42.00	31.93	40.97 c	
LSD_{V*I}		1.80				LSD_V	0.90
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		43.40	47.13	42.57	41.16	43.56 a	
GAs		41.40	43.49	42.36	47.42	43.67 a	
SA		39.77	46.07	41.73	37.07	41.16 b	
LSD_{T*I}		1.80				LSD_T	0.90
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation mean		41.52 b	45.56 a	42.22 b	41.88 b		
LSD_I		1.04					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 14. The impact of gibberellin and salicylic acid on the Zeleny Index (ml) of *Triticum aestivum* L. influenced by seed priming interventions as well as irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	33.10	45.70	36.00	34.10	37.22	
	GAs	66.80	33.30	32.70	37.20	42.50	
	SA	34.90	39.70	31.70	36.10	35.60	
Alföld	Cont.	30.10	42.23	38.70	38.33	37.34	
	GAs	31.30	40.90	33.43	45.07	37.67	
	SA	29.30	40.80	37.27	44.43	37.95	
Felleg	Cont.	23.00	45.10	57.40	35.20	40.17	
	GAs	31.60	46.90	34.70	41.10	38.57	
	SA	37.60	59.10	47.10	32.20	44.00	
LSD_{V*T*I}		2.20				LSD_{V*T}	1.10
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety mean	
Nemere		44.93	39.57	33.47	35.80	38.44 b	
Alföld		30.23	41.31	36.47	35.80	37.66 c	
Felleg		30.73	50.37	46.40	36.17	40.92 a	
LSD_{V*I}		1.27				LSD_{V}	0.64
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		28.73	44.34	44.03	35.88	38.25 b	
GAs		43.23	40.37	33.61	41.12	39.58 a	
SA		33.93	46.53	38.69	37.58	39.18 a	
LSD_{T*I}		1.27				LSD_{T}	0.64
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation mean		35.30 c	43.75 a	38.78 b	38.19 b		
LSD_{I}		0.74					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 15. The impact of gibberellin and salicylic acid on the flour moisture (%) of *Triticum aestivum* L. influenced by seed priming interventions as well as irrigation and drought cycles in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	12.63	13.00	13.30	12.00	12.73	
	GAs	12.53	11.90	12.00	11.80	12.06	
	SA	12.43	12.50	11.70	12.20	12.21	
Alföld	Cont.	12.00	12.53	12.63	12.93	12.53	
	GAs	12.50	12.53	12.90	12.67	12.65	
	SA	12.00	12.57	12.70	12.97	12.56	
Felleg	Cont.	12.00	12.60	13.00	12.40	12.50	
	GAs	12.30	12.50	12.30	12.90	12.50	
	SA	11.90	12.30	12.90	12.50	12.40	
LSD_{V*T*I}		0.35				LSD_{V*T}	0.17
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety mean	
Nemere		12.53	12.47	12.33	12.00	12.33 c	
Alföld		12.17	12.54	12.74	12.00	12.58 a	
Felleg		12.07	12.47	12.73	12.60	12.47 b	
LSD_{V*I}		0.20				LSD_V	0.10
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		12.21	12.71	12.98	12.44	12.59 a	
GAs		12.44	12.31	12.40	12.46	12.40 b	
SA		12.11	12.46	12.43	12.56	12.39 b	
LSD_{T*I}		0.20				LSD_T	0.10
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation mean		12.26 b	12.49 a	12.60 a	12.49 a		
LSD_I		0.12					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 16. The impact of gibberellin and salicylic acid on the grain moisture percentage of *Triticum aestivum* L. influenced by seed priming interventions as well as irrigation and drought cycles a month after the harvest day in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I) 0	3 Days	6 Days	9 Days	V* T	
Nemere	Cont.	11.60	12.50	12.50	11.40	12.00	
	GAs	11.80	11.30	11.00	11.20	11.33	
	SA	11.50	11.90	10.90	11.60	11.48	
Alföld	Cont.	11.10	11.60	11.83	11.97	11.63	
	GAs	11.50	11.70	11.73	12.07	11.75	
	SA	11.00	11.67	11.83	12.17	11.67	
Felleg	Cont.	11.00	11.90	13.20	11.50	11.90	
	GAs	11.30	11.80	11.10	11.80	11.50	
	SA	10.60	12.90	13.00	11.50	12.00	
LSD $_{V*T*I}$		0.26				LSD $_{V*T}$	0.13

V * I

Varieties	0	3 Days	6 Days	9 Days	Variety mean	
Nemere	11.63	11.90	11.47	11.40	11.60 c	
Alföld	11.20	11.66	11.80	11.40	11.68 b	
Felleg	10.97	12.20	12.43	11.60	11.80 a	
LSD $_{V*I}$	0.15				LSD $_{V}$	0.08

T * I

Treatments	0	3 Days	6 Days	9 Days	T. mean	
Cont.	11.23	12.00	12.51	11.62	11.84 a	
GAs	11.53	11.60	11.28	11.69	11.53 c	
SA	11.03	12.16	11.91	11.76	11.71 b	
LSD $_{T*I}$	0.15				LSD $_{T}$	0.08

I

Irrigation	0	3 Days	6 Days	9 Days	
Irrigation mean	11.27 c	11.92 a	11.90 a	11.69 b	
LSD $_{I}$	0.09				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 17. The impact of gibberellin and salicylic acid on the grain moisture percentage of *Triticum aestivum* L. influenced by seed priming interventions as well as irrigation and drought cycles a at the harvest day in 2023, MATE - Gödöllő.

Varieties (V)	Treatments (T)	Irrigation (I)				V* T	
		0	3 Days	6 Days	9 Days		
Nemere	Cont.	13.80	13.90	13.60	13.90	13.80	
	GAs	13.40	13.70	13.60	14.40	13.78	
	SA	13.70	14.20	13.60	13.80	13.83	
Alföld	Cont.	13.80	14.00	13.77	13.97	13.88	
	GAs	13.70	13.83	14.00	14.13	13.92	
	SA	13.70	13.80	13.77	15.03	14.08	
Felleg	Cont.	13.90	13.70	13.40	14.00	13.75	
	GAs	13.80	13.40	13.70	14.50	13.85	
	SA	13.90	13.40	13.90	14.20	13.85	
LSD $_{V*T*I}$		0.53				LSD $_{V*T}$	N.S
V * I							
Varieties		0	3 Days	6 Days	9 Days	Variety mean	
Nemere		13.63	13.93	13.60	14.03	13.80 a	
Alföld		13.73	13.88	13.84	14.03	13.96 a	
Felleg		13.87	13.50	13.67	14.23	13.82 a	
LSD $_{V*I}$		0.31				LSD $_{V}$	N.S
T * I							
Treatments		0	3 Days	6 Days	9 Days	T. mean	
Cont.		13.83	13.87	13.59	13.96	13.81 a	
GAs		13.63	13.64	13.77	14.34	13.85 a	
SA		13.77	13.80	13.76	14.34	13.92 a	
LSD $_{T*I}$		N.S				LSD $_{T}$	N.S
I							
Irrigation		0	3 Days	6 Days	9 Days		
Irrigation mean		13.74 b	13.77 b	13.70 b	14.22 a		
LSD $_{I}$		0.18					

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*T*I}$ is the interaction among the varieties, treatments, and irrigation, V*I is the interaction between the varieties and the irrigation, T*I is the interaction between the treatments and irrigation, and 0, 3, 6, and 9 days are the irrigation time of every duration with 20 mm of water.

Table B.5. 18. Germination and seedling characteristic variables of *Zea mays* L. seeds respond to the water potential of 1 ml water amount intervals at 20 °C, MATE - Gödöllő.

[1] Water (ml)	[2] Germinated Seeds	[3] Radicle (cm)	[4] Plumule (cm)	[5] Seedling (cm)	[6] Radicle DW (g)	[7] Plumule DW (g)	[8] Seedling DW (g)	[9] Corrected DW (g)
0	0.00 ± 0.00 f	0.00 ± 0.00 e	0.00 ± 0.00 c	0.00 ± 0.00 f	0.00 ± 0.00 c	0.00 ± 0.00 d	0.00 ± 0.00 c	0.00 ± 0.00 f
1	10.0 ± 0.00 a	8.04 ± 0.96 abc	1.35 ± 0.39 c	4.70 ± 0.57 cde	0.17 ± 0.02 bc	0.07 ± 0.02 c	0.24 ± 0.19 b	0.237 ± 0.02 b
2	9.80 ± 0.45 a	8.66 ± 0.88 ab	4.22 ± 0.56 b	6.44 ± 0.65 abcde	0.18 ± 0.03 b	0.12 ± 0.01 abc	0.29 ± 0.03 b	0.284 ± 0.02 a
3	9.20 ± 0.84 ab	8.92 ± 1.21 ab	5.46 ± 0.48 ab	7.19 ± 0.68 abcd	0.18 ± 0.05 b	0.14 ± 0.02 ab	0.29 ± 0.07 b	0.291 ± 0.08 b
4	9.60 ± 0.55 a	10.90 ± 2.08 a	6.16 ± 0.73 ab	8.53 ± 1.33 a	0.19 ± 0.04 b	0.14 ± 0.03 ab	0.31 ± 010 b	0.321 ± 0.08 b
5	8.80 ± 1.30 ab	9.18 ± 4.22 ab	5.56 ± 1.88 ab	7.37 ± 2.95 abc	0.15 ± 0.06 bc	0.13 ± 0.03 ab	0.33 ± 0.08 ab	0.255 ± 0.12 c
6	8.00 ± 1.41 abc	9.14 ± 3.32 ab	5.88 ± 1.21 ab	7.51 ± 2.20 ab	0.15 ± 0.06 bc	0.14 ± 0.03 ab	0.28 ± 0.10 b	0.244 ± 0.10 def
7	7.20 ± 2.49 bcde	6.84 ± 3.70 bcd	5.24 ± 2.63 ab	6.04 ± 3.14 abcde	0.14 ± 0.09 bc	0.12 ± 0.06 ab	0.29 ± 0.08 b	0.213 ± 0.13 def
8	7.40 ± 1.67 bcd	7.90 ± 2.58 abc	7.16 ± 1.48 a	7.53 ± 1.99 ab	0.14 ± 0.04 bc	0.16 ± 0.03 a	0.26 ± 0.14 b	0.232 ± 0.10 ef
9	6.60 ± 2.07 cde	4.86 ± 2.66 cd	4.84 ± 1.49 b	4.85 ± 2.05 bcde	0.10 ± 0.05 bc	0.13 ± 0.05 ab	0.30 ± 0.07 b	0.158 ± 0.09 cd
10	5.60 ± 2.30 de	4.72 ± 2.78 cd	5.18 ± 2.40 ab	4.95 ± 2.57 bcde	0.09 ± 0.04 bc	0.13 ± 0.05 ab	0.22 ± 0.09 b	0.136 ± 0.10 ef
11	5.20 ± 2.17 e	4.72 ± 4.28 cd	4.44 ± 3.02 b	4.58 ± 3.61 de	0.41 ± 0.46 a	0.10 ± 0.08 bc	0.51 ± 0.09 a	0.302 ± 0.28 de
12	6.00 ± 2.55 cde	4.16 ± 2.93 d	4.42 ± 2.95 b	4.29 ± 2.87 e	0.07 ± 0.04 c	0.11 ± 0.06 abc	0.18 ± 0.10 bc	0.096 ± 0.09 def
LSD *	2.07	3.49	2.26	2.78	0.172	0.054	0.20	0.053

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; [1] the amount of applied water per 9 cm diameter Petri dish (ml); [2] the number of non-germinated seeds of the total examined seeds per treatment; [3] the mean length of the radicles of each treatment (cm); [4] the mean of the length of the plumules of each treatment (cm); [5] the mean of the length of the seedling of each treatment (cm); [6] the means of the dry weight of the radicles of each treatment (g); [7] the means of the dry weight of the plumules of each treatment (g); [8] the means of the dry weight of the seedlings of each treatment (g); and [9] the mean of the corrected dry weight, which is the dry weight of the actual existing seedling after discarding the non-germinated ones.

Table B.5. 19. Germination and seedling characteristic variables of *Zea mays* L. seeds respond to the water potential of 1 ml water amount intervals at 25 °C, MATE - Gödöllő.

[1] **Water (ml)**	[2] **Germinated Seeds**	[3] **Radicle (cm)**	[4] **Plumule (cm)**	[5] **Seedling (cm)**	[6] **Radicle DW (g)**	[7] **Plumule DW (g)**	[8] **Seedling DW (g)**	[9] **Corrected DW (g)**
0	0.0 ± 0.00 g	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 h	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 g	0.00 ± 0.00 f
1	9.8 ± 0.45 a	8.04 ± 0.93 a	2.34 ± 0.26 de	5.19 ± 0.44 bcd	0.15 ± 0.03 ab	0.06 ± 0.01 cde	0.11 ± 0.01 bc	0.21 ± 0.03 b
2	10 ± 0.00 a	8.76 ± 0.75 3	4.82 ± 0.48 abc	6.79 ± 0.54 ab	0.18 ± 0.01 a	0.11 ± 0.01 ab	0.15 ± 0.01 a	0.29 ± 0.01 a
3	8.2 ± 0.45 bc	7.50 ± 1.07 ab	5.58 ± 0.82 ab	6.54 ± 0.86 abc	0.15 ± 0.02 ab	0.13 ± 0.02 a	0.14 ± 0.02 ab	0.23 ± 0.04 b
4	9.4 ± 0.89 ab	9.16 ± 1.92 a	6.02 ± 0.65 a	7.59 ± 1.13 a	0.12 ± 0.03 b	0.13 ± 0.02 ab	0.13 ± 0.02 ab	0.22 ± 0.08 b
5	7.2 ± 1.79 c	4.90 ± 4.39 bc	4.00 ± 2.39 bcd	4.45 ± 3.31 cde	0.06 ± 0.05 c	0.10 ± 0.05 abcd	0.08 ± 0.02 cd	0.11 ± 0.07 c
6	5.2 ± 2.28 d	3.54 ± 2.95 cd	4.06 ± 2.74 abcd	3.80 ± 2.81 def	0.06 ± 0.05 c	0.09 ± 0.05 abcd	0.08 ± 0.04 cde	0.04 ± 0.01 def
7	4.8 ± 1.48 de	2.08 ± 1.21 def	2.96 ± 1.99 cde	2.52 ± 1.58 efg	0.04 ± 0.02 cde	0.07 ± 0.04 bcd	0.05 ± 0.03 def	0.05 ± 0.03 def
8	3.2 ± 1.30 de	0.68 ± 0.36 ef	1.00 ± 0.66 ef	0.84 ± 0.51 gh	0.01 ± 0.01 ef	0.04 ± 0.03 ef	0.02 ± 0.02 fg	0.02 ± 0.02 ef
9	4.8 ± 1.64 de	3.28 ± 3.78 cde	3.72 ± 2.67 bcd	3.50 ± 3.14 def	0.05 ± 0.06 cd	0.11 ± 0.07 abc	0.08 ± 0.06 cd	0.09 ± 0.07 cd
10	3.8 ± 0.84 ef	0.90 ± 0.78 ef	2.38 ± 1.20 de	1.64 ± 0.94 fgh	0.02 ± 0.01 df	0.07 ± 0.03 bcde	0.04 ± 0.02 ef	0.04 ± 0.02 ef
11	5.4 ± 1.14 f	1.06 ± 0.88 ef	2.18 ± 1.25 de	1.62 ± 1.04 fgh	0.03 ± 0.01 cdef	0.07 ± 0.04 bcde	0.05 ± 0.03 def	0.05 ± 0.03 de
12	4.6 ± 1.14 def	1.68 ± 2.17 def	2.16 ± 1.89 de	1.92 ± 1.96 fgh	0.03 ± 0.03 cdef	0.06 ± 0.04 de	0.04 ± 0.04 ef	0.04 ± 0.05 def
LSD *	1.55	2.64	2.01	2.22	0.038	0.047	0.035	0.053

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; [1] the amount of applied water per 9 cm diameter Petri dish (ml); [2] the number of germinated seeds of the total examined seeds per treatment; [3] the mean length of the radicles of each treatment (cm); [4] the mean of the length of the plumules of each treatment (cm); [5] the mean of the length of the seedling of each treatment (cm); [6] the means of the dry weight of the radicles of each treatment (g); [7] the means of the dry weight of the plumules of each treatment (g); [8] the means of the dry weight of the seedlings of each treatment (g); [9] the mean of the corrected dry weight, which is the dry weight of the actual existing seedling after discarding the non-germinated ones.

Table B.5. 20. Germination and seedling characteristic variables of *Zea mays* L. seeds respond to the water potential of the TKW base at 25 °C, MATE - Gödöllő.

[1] Water (ml)	[2] Water (TKW)	[3] Germinated Seeds	[4] Radicle (cm)	[5] Plumule (cm)	[6] Seedling (cm)	[7] Radicle DW (g)	[8] Plumule DW (g)	[9] Seedling DW (g)	[10] Corrected DW (g)
0	25%	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 f	0.00 ± 0.00 h	0.00 ± 0.00 e	0.00 ± 0.00 f	0.00 ± 0.00 i	0.00 ± 0.00 h
0.60	50%	10.0 ± 0.00 a	7.08 ± 0.88 bc	0.32 ± 0.19 ef	3.70 ± 0.38 de	0.07 ± 0.01 cde	0.03 ± 0.02 ef	0.10 ± 0.01 ef	0.10 ± 0.01 def
1.20	75%	10.0 ± 0.00 a	8.46 ± 0.89 ab	1.50 ± 0.22 def	4.98 ± 0.39 bcd	0.15 ± 0.01 abc	0.05 ± 0.01 e	0.19 ± 0.01 b	0.19 ± 0.01 b
1.75	100%	9.80 ± 0.45 a	8.50 ± 0.59 ab	2.40 ± 0.71 cd	5.45 ± 0.37 bcd	0.18 ± 0.01 ab	0.09 ± 0.02 cd	0.28 ± 0.02 a	0.27 ± 0.01 a
2.35	125%	9.60 ± 0.55 ab	9.98 ± 0.90 a	5.64 ± 0.51 a	7.81 ± 0.38 a	0.16 ± 0.03 abc	0.15 ± 0.01 a	0.16 ± 0.01 bcd	0.15 ± 0.02 c
2.95	150%	9.20 ± 0.84 ab	8.62 ± 2.47 ab	6.58 ± 0.55 a	7.60 ± 1.40 a	0.11 ± 0.04 bcd	0.13 ± 0.02 ab	0.12 ± 0.03 cde	0.11 ± 0.03 cde
3.55	175%	8.20 ± 1.79 abc	6.04 ± 1.07 cd	5.38 ± 0.93 a	5.71 ± 0.99 bc	0.09 ± 0.02 bcde	0.12 ± 0.00 abc	0.11 ± 0.01 def	0.09 ± 0.02 ef
4.20	200%	7.80 ± 1.79 bc	6.68 ± 3.45 bc	5.26 ± 1.81 a	5.97 ± 2.62 abc	0.09 ± 0.04 bcde	0.11 ± 0.03 bcd	0.10 ± 0.04 ef	0.08 ± 0.04 ef
4.70	225%	6.80 ± 2.86 cd	5.62 ± 2.94 cd	5.00 ± 2.22 ab	5.31 ± 2.56 bcd	0.07 ± 0.03 cde	0.10 ± 0.03 bcd	0.08 ± 0.03 efg	0.06 ± 0.04 fg
5.30	250%	7.80 ± 2.05 bc	7.16 ± 3.29 bc	6.02 ± 2.16 a	6.59 ± 2.71 ab	0.23 ± 0.30 a	0.12 ± 0.04 abcd	0.17 ± 0.15 bc	0.13 ± 0.11 cd
5.90	275%	5.00 ± 1.58 de	4.10 ± 2.00 de	5.12 ± 1.39 a	4.61 ± 1.70 cd	0.04 ± 0.02 de	0.10 ± 0.04 bcd	0.07 ± 0.03 efgh	0.04 ± 0.02 gh
6.50	300%	3.80 ± 0.84 e	1.20 ± 1.01 f	1.84 ± 2.84 cde	1.52 ± 1.40 fgh	0.02 ± 0.01 de	0.03 ± 0.03 ef	0.02 ± 0.02 hi	0.01 ± 0.01 h
7.65	325%	4.80 ± 1.79 e	1.94 ± 1.74 ef	2.46 ± 2.22 cd	2.20 ± 1.98 efg	0.03 ± 0.03 de	0.05 ± 0.04 e	0.04 ± 0.03 ghi	0.02 ± 0.02 gh
8.25	350%	3.40 ± 1.67 e	0.44 ± 0.31 f	0.52 ± 0.40 ef	0.48 ± 0.34 gh	0.01 ± 0.01 e	0.03 ± 0.03 ef	0.02 ± 0.02 hi	0.01 ± 0.01 h
8.80	375%	4.80 ± 0.45 e	1.76 ± 0.84 f	3.36 ± 1.48 dc	2.56 ± 1.13 ef	0.04 ± 0.02 de	0.09 ± 0.03 d	0.06 ± 0.03 fgh	0.03 ± 0.01 gh
9.40	400%	5.20 ± 2.95 de	0.60 ± 0.26 f	1.14 ± 0.75 def	0.87 ± 0.50 fgh	0.02 ± 0.01 de	0.04 ± 0.02 e	0.03 ± 0.02 hi	0.02 ± 0.02 h
LSD *		1.950	2.25	1.67	1.86	0.098	0.034	0.055	0.043

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; [1] the amount of applied water per 9 cm diameter Petri dish (ml); [2] percentage of water in relation to the TKW; [3] the number of non-germinated seed portions in the average of the total examined seeds per each treatment; [4] the mean length of the radicles of each treatment (cm); [5] the mean of the length of the plumules of each treatment (cm); [6] the mean of the length of the seedling of each treatment (cm); [7] the means of the dry weight of the radicles of each treatment (g); [8] the means of the dry weight of the plumules of each treatment (g); [9] the means of the dry weight of the seedlings of each treatment (g); [10] the mean of the corrected dry weight (g), which is the dry weight of the actual existing seedling after discarding the non-germinated one.

Table B.5. 21. Parameters relating to germination and seedling characteristics of *Triticum aestivum* L. seeds respond to the water potential of the TKW base, MATE - Gödöllő.

[1] Water ml	[2] Water based on TKW	[3] Not germ seeds	[4] Radicles (cm)	[5] Shoots (cm)	[6] Seedlings (cm)	[7] Radicles Dry W (g)	[8] Shoots Dry W (g)	[9] Seedlings Dry W (g)	[10] Corrected Dry W (g)
0.65	75%	11.60 ± 10.2 a	1.07 ± 1.62 e	0.19 ± 0.37 g	2.18 ± 2.30 d	0.020 ± 0.03 d	0.006 ± 0.01	0.262 ± 0.04 d	0.027 ± 0.04 d
1.30	150%	5.60 ± 8.76 b	3.16 ± 3.54 e	0.69 ± 0.98 g	3.85 ± 4.51 d	0.020 ± 0.02 d	0.009 ± 0.01	0.029 ± 0.03 d	0.029 ± 0.03 d
1.90	225%	0.60 ± 0.89 c	12.79 ± 2.25 d	7.25 ± 1.86 f	20.04 ± 4.04 c	0.113 ± 0.02 bc	0.119 ± 0.01	0.231 ± 0.03 c	0.239 ± 0.03 c
2.55	300%	0.40 ± 0.54 c	14.16 ± 1.69 bc	7.89 ± 1.01 f	22.05 ± 2.55 c	0.135 ± 0.02 abc	0.126 ± 0.02	0.261 ± 0.04 bc	0.267 ± 0.04 bc
3.20	375%	0.00 ± 0.00 c	16.14 ± 0.68 bc	9.57 ± 0.89 e	25.71 ± 1.46 b	0.141 ± 0.02 a	0.147 ± 0.01	0.289 ± 0.02 b	0.289 ± 0.02 b
3.85	450%	0.40 ± 0.55 c	18.69 ± 0.57 a	10.25 ± 0.75 cde	28.94 ± 1.08 a	0.142 ± 0.01 a	0.148 ± 0.01	0.290 ± 0.01 b	0.296 ± 0.02 b
4.45	525%	0.20 ± 0.45 c	16.50 ± 1.39 b	10.17 ± 0.94 de	26.67 ± 2.15 ab	0.136 ± 0.01 ab	0.147 ± 0.02	0.283 ± 0.03 b	0.285 ± 0.03 b
5.15	600%	0.40 ± 0.55 c	16.92 ± 1.20 ab	10.47 ± 1.05 bcde	27.40 ± 2.04 ab	0.125 ± 0.01 abc	0.147 ± 0.01	0.272 ± 0.02 b	0.277 ± 0.02 b
5.75	675%	0.40 ± 0.89 c	16.80 ± 0.68 ab	11.32 ± 0.87 abcd	28.12 ± 0.62 ab	0.133 ± 0.01 abc	0.151 ± 0.03	0.284 ± 0.03 b	0.290 ± 0.02 b
6.40	750%	0.20 ± 0.45 c	16.71 ± 0.96 ab	11.49 ± 0.20 abc	28.21 ± 1.10 ab	0.147 ± 0.04 a	0.184 ± 0.01 a	0.331 ± 0.02 a	0.334 ± 0.02 a
7.00	825%	0.40 ± 0.55 c	16.03 ± 1.22bc	12.32 ± 1.13 a	28.35 ± 0.96 ab	0.124 ± 0.01 abc	0.167 ± 0.01	0.291 ± 0.01 b	0.297 ± 0.01 b
7.50	900%	0.60 ± 0.89 c	17.42 ± 1.68 ab	11.66 ± 0.70 ab	29.04 ± 1.67 a	0.119 ± 0.01 bc	0.169 ± 0.01 ab	0.288 ± 0.03 b	0.296 ± 0.02 b
L.S.D *		4.99	2.11	1.25	2.98	0.022	0.0186	0.035	0.035

* Different lowercase letters (column) present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant, [1] the quantity of water application per a 9 cm Petri dish (ml), [2] proposed percentage of water application relating to the TKW, [3] the not germinated seeds number fraction of the total tested seeds, [4] the mean of each treatment's radicle lengths (cm), [5] the mean of each treatments' shoot lengths (cm), [6] the mean of each treatments' seedling lengths (cm), [7] the mean of each treatments' radicles dry weights (g), [8] the mean of each treatments' shoots dry weights (g), [9] the mean of each treatments' seedlings dry weights (g), and [10] the mean of the statistically corrected dry weight that was gained by subtracting the not germinated ones from the dry weight of the existed seedling.

Table B.5. 22. Thousand kernel weight (g) under drought stress and different treatments and of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	45.18	45.93	48.41	45	46.13	
	Nemere	48	48.34	49.22	48.18	48.43	
	Alföld	38.1	39.76	39.2	40.18	39.31	
Irrigated	Menrot	47.07	48.34	47.91	47.29	47.65	
	Nemere	48.2	49.34	49.13	48.82	48.87	
	Alföld	38.91	39.96	40.4	39.54	39.7	
LSD $_{I*V*T}$		1.889 $^{N.S}$				LSD $_{I*V}$	1.041 $^{N.S}$
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		43.76	44.68	45.61	44.45	44.62 a	
Irrigated		45.22	45.53	45.66	45.22	45.41 a	
LSD $_{I*T}$		1.158 $^{N.S}$				LSD $_I$	0.903 $^{N.S}$
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		46.12	47.14	48.16	46.15	46.89 b	
Nemere		48.1	48.84	49.17	48.5	48.65 a	
Alföld		39.25	39.33	39.58	39.86	39.51 c	
LSD $_{V*T}$		1.311 $^{N.S}$				LSD $_V$	0.656
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		44.49 b	45.1 ab	45.64 a	44.83 b		
LSD $_T$		0.757					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 23. Test weight, Hectoliter weight, (kg/hl) values under drought stress and different treatments and of *Triticum aestivum* L, of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	79.9	78.35	79.833	80.883	79.742	
	Nemere	78.8	78.583	77.6	78.283	78.317	
	Alföld	81.25	80.75	81.717	81.217	81.233	
Irrigated	Menrot	80.6	79.917	80.283	79.81	80.153	
	Nemere	78.15	79.083	77.833	77.467	78.133	
	Alföld	77.9	80.733	79.317	81.05	79.75	
LSD $_{I*V*T}$		1.0373				LSD $_{I*V}$	0.4766
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		79.983	79.228	79.717	80.128	79.764 a	
Irrigated		78.883	79.911	79.144	79.442	79.345 b	
LSD $_{I*T}$		0.5662				LSD $_I$	0.268
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		80.25	79.133	80.058	80.347	79.947 b	
Nemere		78.475	78.833	77.717	77.875	78.225 c	
Alföld		79.575	80.742	80.517	81.133	80.492 a	
LSD $_{V*T}$		0.7537				LSD $_V$	0.3769
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		79.433 a	79.569 a	79.431 a	79.785 a		
LSD $_T$		0.4352 $^{N.S}$					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 24. Zeleny index (ml) of the grain measured one month storage after harvest of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	39	24.73	47.97	52.97	41.17	
	Nemere	43.4	34.73	57.33	51.73	46.8	
	Alföld	38.6	63.97	51.9	47.07	50.38	
Irrigated	Menrot	63.1	56.83	60.4	71.17	62.88	
	Nemere	54.3	37.4	56.67	61.5	52.47	
	Alföld	56.3	31	55.73	70.63	53.42	
LSD_{I*V*T}		10.226				LSD_{I*V}	4.618

I * T

Irrigation	Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated	40.33	41.14	52.4	50.59	46.12 b	
Irrigated	57.9	41.74	57.6	67.77	56.25 a	
LSD_{I*T}	5.525				LSD_{I}	2.326

V * T

Varieties	Cont.	EM	EM+N	N	Mean varieties	
Menrot	51.05	40.78	54.18	62.07	52.02 a	
Nemere	48.85	36.07	57	56.62	49.63 a	
Alföld	47.45	47.48	53.82	58.85	51.90 a	
LSD_{V*T}	7.458 N.S				LSD_{V}	3.72 N.S

T

Treatments	Cont.	EM	EM+N	N
Mean treatments	49.12 b	41.44 c	55.00 a	59.18 a
LSD_{T}	4.306			

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 25. Zeleny index (ml) of the grain measured at the harvest day of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	Varieties (V)	Treatments (T) Cont.	EM	EM+N	N	I * V	
Non Irrigated	Menrot	34.1	24.53	50.37	52.67	40.42	
	Nemere	43.4	34.03	54.77	56.8	47.25	
	Alföld	34.8	26.33	54.17	56.53	42.96	
Irrigated	Menrot	25.9	22.37	48.83	48.4	36.38	
	Nemere	24.9	33.57	57.5	57.23	43.3	
	Alföld	36.5	29.9	59.1	62.13	46.91	
LSD $_{I*V*T}$		4.191				LSD $_{I*V}$	3.258
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		37.43	28.3	53.1	55.33	43.54 a	
Irrigated		29.1	28.61	55.14	55.92	42.19 a	
LSD $_{I*T}$		3.327				LSD $_{I}$	3.312
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		30	23.45	49.6	50.53	38.4 b	
Nemere		34.15	33.8	56.13	57.02	45.28 a	
Alföld		35.65	28.12	56.63	59.33	44.93 a	
LSD $_{V*T}$		2.457				LSD $_{V}$	1.229
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		33.27 b	28.46 c	54.12 a	55.63 a		
LSD $_{T}$		1.419					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 26. Protein content (%) of the grain measured one month storage after harvest of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	11.5	9.13	13.63	14.3	12.14	
	Nemere	11.7	9.34	15.07	13.87	12.49	
	Alföld	11.6	16.27	13.98	13.86	13.93	
Irrigated	Menrot	15.9	14.67	14.37	17.67	15.65	
	Nemere	13.5	9.66	16.53	16.13	13.96	
	Alföld	14	9.72	14.47	17.67	13.96	
LSD $_{I*V*T}$		2.952				LSD $_{I*V}$	1.524
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		11.6	11.58	14.23	14.01	12.85 b	
Irrigated		14.47	11.35	15.12	17.16	14.52 a	
LSD $_{I*T}$		1.732				LSD $_{I}$	1.211
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		13.7	11.9	14	15.98	13.90 a	
Nemere		12.6	9.5	15.8	15	13.22 a	
Alföld		12.8	12.99	14.22	15.76	13.94 a	
LSD $_{V*T}$		2.087				LSD $_{V}$	1.04 $^{N.S}$
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		13.03 b	11.46 c	14.67 a	15.58 a		
LSD $_{T}$		1.205					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 27. Protein content (%) of the grain measured at the harvest day of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	11.8	8.44	15.7	16.033	12.993	
	Nemere	12.1	9.523	15.067	15.933	13.156	
	Alföld	11.8	9.56	14.867	15.433	12.915	
Irrigated	Menrot	11.3	10.5	15.833	15.7	13.333	
	Nemere	12	9.827	16.233	15.8	13.465	
	Alföld	11.5	9.857	16.133	16.867	13.589	
LSD $_{I*V*T}$		1.0724				LSD $_{I*V}$	0.770 $^{N.S}$
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		11.9	9.174	15.211	15.8	13.021 a	
Irrigated		11.6	10.061	16.067	16.122	13.463 a	
LSD $_{I*T}$		0.7987				LSD $_I$	0.773 $^{N.S}$
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		11.55	9.47	15.767	15.867	13.163 a	
Nemere		12.05	9.675	15.65	15.867	13.31 a	
Alföld		11.65	9.708	15.5	16.15	13.252 a	
LSD $_{V*T}$		0.664 $^{N.S}$				LSD $_V$	0.3325
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		11.75 bc	9.618 c	15.639 b	15.961 a		
LSD $_T$		0.3839					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 28. Gluten content (%) of the whole flour measured one month storage after harvest of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)**				**I * V**	
		Cont.	EM	EM+N	N		
Non Irrigated	Menrot	24.7	18.83	29.73	35	27.07	
	Nemere	24.6	19.53	35.57	31.43	27.78	
	Alföld	18.1	40.77	33.2	42.87	33.73	
Irrigated	Menrot	38.2	36.37	36.37	46.37	39.32	
	Nemere	36.5	20.1	38.67	35.03	32.58	
	Alföld	25.7	24.57	28.23	44.6	30.78	
LSD $_{I*V*T}$		10.505				LSD $_{I*V}$	6.239
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		22.47	26.38	32.83	36.43	29.53 a	
Irrigated		33.47	27.01	34.42	42	34.23 a	
LSD $_{I*T}$		6.778				LSD $_{I}$	5.77 $^{N.S}$
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		31.45	27.6	33.05	40.68	33.2 a	
Nemere		30.55	19.82	37.12	33.23	30.18 a	
Alföld		21.9	32.67	30.72	43.73	32.25 a	
LSD $_{V*T}$		7.117 $^{N.S}$				LSD $_{V}$	3.559
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		27.97 c	26.69 c	33.63 b	39.22 a		
LSD $_{T}$		4.109					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 29. Gluten content (%) of the grain measured one month storage after harvest of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	23.2	16.27	29.33	31.5	25.07	
	Nemere	25.1	19.1	34.8	31.4	27.6	
	Alföld	24.1	37	30.47	31.67	30.81	
Irrigated	Menrot	36	32.87	34.17	40.87	35.98	
	Nemere	37.8	20	37.23	37.7	33.18	
	Alföld	26.8	18.5	35.1	41.2	30.4	
LSD $_{I*V*T}$		1.962				LSD $_{I*V}$	1.028
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		24.13	24.12	31.53	31.52	27.83 b	
Irrigated		33.53	23.79	35.5	39.92	33.19 a	
LSD $_{I*T}$		1.163				LSD $_I$	0.837
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		29.6	24.57	31.75	36.18	30.52 a	
Nemere		31.45	19.55	36.02	34.55	30.39 a	
Alföld		25.45	27.75	32.78	36.43	30.60 a	
LSD $_{V*T}$		1.381				LSD $_V$	0.691 N.S
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		28.83 c	23.96 d	33.52 b	35.72 a		
LSD $_T$		0.797					

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 30. Gluten content (%) of the grain measured at the harvest day of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	26.1	18.2	26.83	37.43	27.14	
	Nemere	27.5	20.73	35.33	37.63	30.3	
	Alföld	25.1	19.8	34.33	36.07	28.82	
Irrigated	Menrot	25	22.53	37.03	36.4	30.24	
	Nemere	27	21.73	38.63	37.47	31.21	
	Alföld	25.1	20.57	37.83	39.93	30.86	
LSD $_{I*V*T}$		6.716 $^{N.S}$				LSD $_{I*V}$	4.404 $^{N.S}$
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		26.23	19.58	32.17	37.04	28.76 a	
Irrigated		25.7	21.61	37.83	37.93	30.77 a	
LSD $_{I*T}$		4.658 $^{N.S}$				LSD $_{I}$	4.293 $^{N.S}$
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		25.55	20.37	31.93	36.92	28.69 a	
Nemere		27.25	21.23	36.98	37.55	30.75 a	
Alföld		25.1	20.18	36.08	38	29.84 a	
LSD $_{V*T}$		4.373 $^{N.S}$				LSD $_{V}$	2.187 $^{N.S}$
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		25.97 c	20.59 d	35 b	37.49 a		
LSD $_{T}$		2.525					

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 31. Moisture (%) of the whole flour measured one month storage after harvest of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	Cont.	EM	EM+N	N	**I * V**
Non Irrigated	Menrot	10.2	10.233	10.567	11.067	10.517
	Nemere	10.4	10.367	10.267	10.6	10.408
	Alföld	10.2	10.967	10.733	11.3	10.8
Irrigated	Menrot	10.9	10.833	11.267	11.267	11.067
	Nemere	10.9	10.9	11.633	11.167	11.15
	Alföld	10.5	11.033	10.7	11.167	10.85
LSD $_{I*V*T}$		0.5351 $^{N.S}$				LSD 0.2583
I * T						
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation
Non Irrigated		10.267	10.522	10.522	10.989	10.575 b
Irrigated		10.767	10.922	11.2	11.2	11.022 a
LSD $_{I*T}$		0.2938				LSD 0.1465
V * T						
Varieties		Cont.	EM	EM+N	N	Mean varieties
Menrot		10.55	10.533	10.917	11.167	10.792 a
Nemere		10.65	10.633	10.95	10.883	10.779 a
Alföld		10.35	11	10.717	11.233	10.825 a
LSD $_{V*T}$		0.388 $^{N.S}$				LSD 0.194 $^{N.S}$
T						
Treatments		Cont.	EM	EM+N	N	
Mean treatments		10.517 c	10.722 bc	10.861 ab	11.094 a	
LSD $_T$		0.224				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 32. Moisture (%) of the grain measured one month storage after harvest of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	10.5	10.133	10.5	10.633	10.442	
	Nemere	10.3	10.187	10.5	10.28	10.317	
	Alföld	9.98	10.567	10.467	10.533	10.387	
Irrigated	Menrot	10.5	10.6	10.667	10.6	10.592	
	Nemere	11	10.5	10.667	10.633	10.7	
	Alföld	10.4	10.467	10.6	10.633	10.525	
LSD $_{I*V*T}$		0.2532				LSD $_{I*V}$	0.1302
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		10.26	10.296	10.489	10.482	10.382 b	
Irrigated		10.633	10.522	10.644	10.622	10.606 a	
LSD $_{I*T}$		0.1482				LSD $_{I}$	0.1027
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		10.5	10.367	10.583	10.617	10.517 a	
Nemere		10.65	10.343	10.583	10.457	10.508 a	
Alföld		10.19	10.517	10.533	10.583	10.456 a	
LSD $_{V*T}$		0.1792 $^{N.S}$				LSD $_{V}$	0.089 $^{N.S}$
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		10.447 b	10.409 b	10.567 a	10.552 a		
LSD $_{T}$		0.1035					

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 33. Moisture (%) of the grain measured at the harvest day of *Triticum aestivum* L of the year 2021-2022, MATE - Gödöllő.

Irrigation (I)	**Varieties (V)**	**Treatments (T)** Cont.	EM	EM+N	N	**I * V**	
Non Irrigated	Menrot	8.15	9.627	8.033	8.15	8.49	
	Nemere	9.64	9.367	9.69	9.673	9.592	
	Alföld	9.53	9.573	9.013	9.663	9.445	
Irrigated	Menrot	7.51	7.43	7.61	7.553	7.526	
	Nemere	9.69	9.363	9.55	9.61	9.553	
	Alföld	9.61	9.763	9.607	9.71	9.672	
LSD $_{I*V*T}$		0.4225				LSD $_{I*V}$	0.2415
I * T							
Irrigation		Cont.	EM	EM+N	N	Mean Irrigation	
Non Irrigated		9.107	9.522	8.912	9.162	9.176 a	
Irrigated		8.937	8.852	8.922	8.958	8.917 b	
LSD $_{I*T}$		0.2654				LSD $_{I}$	0.217
V * T							
Varieties		Cont.	EM	EM+N	N	Mean varieties	
Menrot		7.83	8.528	7.822	7.852	8.008 b	
Nemere		9.665	9.365	9.62	9.642	9.573 a	
Alföld		9.57	9.668	9.31	9.687	9.559 a	
LSD $_{V*T}$		0.29				LSD $_{V}$	0.145
T							
Treatments		Cont.	EM	EM+N	N		
Mean treatments		9.022 b	9.187 a	8.917 b	9.06 b		
LSD $_{T}$		0.1674					

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, $_{V*I}$ is the interaction between the varieties and the irrigation, and $_{I*T}$ is the interaction between the treatments and irrigation. EM is the treatment of effective microorganisms application, and N is the nitrogen application.

Table B.5. 34. Green yield production (kg/ha) of *Triticum aestivum* L under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N*	
	0 EM	EM at F3	EM at F3 and F10		
0	2900	2583	4833	3439 ± 1362 d	
40	3767	3650	5700	4372 ± 1180 c	
80	5083	5000	6200	5428 ± 879 b	
120	5250	5950	7167	6122 ± 995 a	
160	5850	5750	7067	6222 ± 812 a	
200	6300	6267	7617	6728 ± 741 a	
LSD T*N	N.S			LSD N	652.9
Mean T	4858 ± 1352 b	4867 ± 1418b	6431 ± 4858 a		
LSD T	461.7				

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 35. TKW (g) of *Triticum aestivum* L grains produced under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	37.16	36.73	38.16	37.35 ± 1.83 a	
40	37.03	37.48	37.45	37.32 ± 1.19 a	
80	36.59	39.19	35.41	37.07 ± 1.93 a	
120	36.99	37.39	34.48	36.29 ± 2.16 a	
160	36.78	37.03	35.44	36.42 ± 1.80 a	
200	36.6	36.79	35.54	36.31 ± 1.68 a	
LSD T*N	N.S			LSD N	N.S
Mean T	36.86 ± 1.46a	37.44 ± 1.55 a	36.08 ± 2.06 a		
LSD T	N.S				

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 36. Test weight (kg/hl) of *Triticum aestivum* L grains produced under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	79.3	78.9	77.6	78.6 ± 2.02 a	
40	78.3	78.5	77.8	78.2 ± 0.99 a	
80	77.5	78.9	77.4	78.0 ± 1.55 a	
120	77.7	76.6	77.4	77.2 ± 1.86 a	
160	75.4	78	77.3	76.9 ± 1.61 a	
200	76.8	77.8	77.4	77.3 ± 1.81 a	
LSD T*N	N.S			LSD N	N.S
Mean T	77.5 ± 1.68 a	78.1 ± 1.74 a	77.5 ± 1.69 a		
LSD T	N.S				

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 37. Photosynthesis activity (SPAD) at anthesis of *Triticum aestivum* L plants grown under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	41.1	38.7	38.6	39.5 ± 4.38 a	
40	36.2	41.0	41.0	39.4 ± 8.35 a	
80	38.7	35.2	42.3	38.7 ± 9.05 a	
120	46.9	49.4	46.8	47.7 ± 8.15 a	
160	34.1	39.4	46.7	40.1 ± 6.69 a	
200	38.8	43.9	42.9	41.9 ± 10.18 a	
LSD T*N	N.S			LSD N	N.S
Mean T	39.3 ± 8.76 a	41.3 ± 8.59 a	43 ± 6.78a		
LSD T	N.S				

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 38. Quantum yield (QY), photosynthesis II efficiency, at anthesis of *Triticum aestivum* L plants grown under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	0.713	0.693	0.720	0.709 ± 0.06 a	
40	0.703	0.733	0.717	0.718 ± 0.03 a	
80	0.667	0.727	0.757	0.717 ± 0.08 a	
120	0.640	0.707	0.687	0.678 ± 0.08 a	
160	0.733	0.733	0.750	0.739 ± 0.03 a	
200	0.710	0.687	0.747	0.714 ± 0.05 a	
LSD_{T*N}	N.S			LSD_N	N.S
Mean T	0.694 ± 0.07 a	0.713 ± 0.04 a	0.729 ± 0.06a		
LSD_T	N.S				

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 39. Number of spikes square meter of *Triticum aestivum* L grown under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	500	573	640	571 ± 91.7 c	
40	747	507	580	611 ± 214.7bc	
80	967	887	673	842 ± 219.9 a	
120	753	673	820	749 ± 77.5 ab	
160	920	733	847	833 ± 123.7 a	
200	780	747	693	740 ± 139.3ab	
LSD T*N	N.S			LSD N	138.7
Mean T	778 ± 216.5a	687 ± 178.5a	709 ± 131.8 a		
LSD T	N.S				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 40. Days from planting to heading date of *Triticum aestivum* L grown under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	179.0	179.0	178.7	178.9 ± 0.78 a	
40	179.3	178.7	180.0	179.3 ± 0.87 a	
80	180.0	179.7	180.0	179.9 ± 0.78 a	
120	179.3	179.3	180.0	179.6 ± 0.73 a	
160	179.3	179.3	180.3	179.7 ± 0.71 a	
200	179.0	180.0	180.0	179.7 ± 0.71 a	
LSD T*N	N.S			LSD N	N.S
Mean T	179.3 ± 0.69 a	179.3 ± 0.69 a	179.8 ± 0.92 a		
LSD T	N.S				

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 41. Protein content (%) of the grain of *Triticum aestivum* L grown under drought stress and different treatments of effective microorganisms and nitrogen treatments measured at the harvest day of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	11.9	11.2	11.8	11.7 ± 0.46 c	
40	11.5	10.8	11.9	11.4 ± 0.87 c	
80	11.9	11.2	12.7	11.9 ± 0.79 c	
120	12.5	12.4	13	12.6 ± 0.76 b	
160	13.4	12.7	13.5	13.2 ± 0.59 a	
200	13.4	13.5	13.6	13.5 ± 0.34 a	
LSD T*N	N.S			LSD N	0.56
Mean T	12.4 ± 0.85 a	12.0 ± 1.16 b	12.8 ± 0.88 a		
LSD T	0.4				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 42. Protein content (%) of the grain of *Triticum aestivum* L grown under drought stress and different treatments of effective microorganisms and nitrogen treatments measured month after harvest of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	11.73	11.3	11.23	11.42 ± 0.36 b	
40	11.97	10.9	11.97	11.61 ± 1.04 b	
80	11.73	10.93	12.33	11.67 ± 0.88 b	
120	13.7	12.93	12.33	12.99 ± 1.65 a	
160	13.47	12.77	13.5	13.24 ± 0.71 a	
200	14	13.5	13.63	13.71 ± 0.36 a	
LSD $_{T*N}$	N.S			LSD $_N$	0.828
Mean T	12.77 ± 1.36a	12.06 ± 1.38a	12.5 ± 1.04 a		
LSD $_T$	N.S				

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 43. Gluten (%) of the white flour of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	24.09	21.86	22.27	22.74 ± 1.90 bc	
40	22.76	21.44	23.26	22.48 ± 1.46 c	
80	24.17	24.06	25.88	24.71 ± 1.82 b	
120	25.20	27.06	28.71	26.99 ± 3.44 a	
160	28.55	26.87	30.09	28.50 ± 2.39 a	
200	28.23	29.78	29.01	29.00 ± 1.73 a	
LSD T*N	N.S			LSD N	2.036
Mean T	25.5 ± 2.82	25.18 ± 3.81	26.54 ± 3.45		
LSD T	N.S				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 44. Gluten (%) of the whole flour of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	24.4	22.2	23.6	23.4 ± 2.09 d	
40	21.6	21.2	24.0	22.3 ± 2.50 d	
80	22.5	25.0	27.1	24.9 ± 2.79 cd	
120	26.2	25.0	28.8	26.7 ± 3.61 bc	
160	30.5	28.1	29.4	29.3 ± 2.35 a	
200	27.5	28.7	29.1	28.4 ± 3.14 ab	
LSD T*N	N.S			LSD N	2.61
Mean T	25.4 ± 4.14	25.0 ± 3.48	27.0 ± 3.36		
LSD T	N.S				

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 45. Gluten (%) of the grain of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments meadured at the harvest day of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	22.4	20	21.6	21.4 ± 1.31 d	
40	21.3	19	23.6	21.3 ± 3.13 d	
80	23.2	21	25.8	23.3 ± 2.42 c	
120	27.9	24.5	26.9	26.4 ± 3.23 b	
160	27.8	25.8	28.1	27.2 ± 1.72 ab	
200	28.2	28.2	28.5	28.3 ± 1.19 a	
LSD T*N	N.S			LSD N	1.8
Mean T	25.1 ± 3.48a	23.1 ± 3.91 b	25.8 ± 2.94a		
LSD T	1.27				

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 46. Gluten (%) of the grain of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments measured a month after harvest of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	23.1	21.6	21.7	22.1 ± 1.13 c	
40	22.7	20.3	24.5	22.5 ± 3.10 c	
80	23.6	21.2	25.8	23.5 ± 2.76 c	
120	24.8	25.7	26.8	25.8 ± 2.58 b	
160	28.5	26.8	29	28.1 ± 1.91 a	
200	30.1	29.3	29.6	29.7 ± 0.97 a	
LSD T*N	N.S			LSD N	1.89
Mean T	25.5 ± 3.25 ab	24.1 ± 4.05 b	26.2 ± 3.20 a		
LSD T	1.34				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 47. Falling number (second) of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	351.0	347.3	344.7	347.7 ± 20.62bc	
40	339.0	308.7	361.3	336.3 ± 41.00 c	
80	352.7	343.3	394.7	363.6 ± 38.00 b	
120	398.3	395.7	384.0	392.7 ± 39.60 a	
160	381.3	390.0	351.0	374.1 ± 45.70 a	
200	433.3	419.0	421.3	424.6 ± 29.35 a	
LSD T*N	N.S			LSD N	37.18
Mean T	375.9 ± 44.60	367.3 ± 49.70	376.2 ± 44.60		
LSD T	N.S				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 48. Zeleny index (ml) of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments neasured at the harvest day of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	35.8	30	35.2	33.7 ± 3.57 d	
40	38.4	27.9	38.1	34.8 ± 8.14 cd	
80	39.1	33.8	41.9	38.3 ± 4.68 c	
120	42.6	42.1	45.6	43.4 ± 3.84 b	
160	47.6	43.8	47.9	46.4 ± 2.53 ab	
200	48.7	47.5	48.5	48.2 ± 2.77 a	
LSD T*N	N.S			LSD N	3.87
Mean T	42.0 ± 6.15 a	37.5 ± 8.63 b	42.9 ± 5.52 a		
LSD T	2.73				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 49. Zeleny index (ml) of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments measured a month harvest of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	24.67	19.37	23.67	22.57 ± 3.60 d	
40	24.37	18.5	30.47	24.44 ± 7.54 cd	
80	29.2	23.3	32.93	28.48 ± 5.71 bc	
120	29.97	23.23	37.77	30.32 ± 9.33 b	
160	38.5	34.43	39.57	37.5 ± 3.57 a	
200	41.37	40.7	37.87	39.98 ± 2.85 a	
LSD_{T*N}	N.S			LSD_N	4.81
Mean T	31.34 ± 7.22a	26.59 ± 10.1 b	33.71 ± 6.6 a		
LSD_T	3.401				

Various lowercase letters(a - d) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 50. Moisture (%) of the whole flour of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	11.4	11.5	11.4	11.4 ± 0.14 a	
40	11.5	11.6	11.1	11.4 ± 0.29 a	
80	11.5	11.5	11.2	11.4 ± 0.33 a	
120	11.5	11.8	8.6	10.6 ± 3.14 a	
160	12.2	11.4	11.4	11.7 ± 0.61 a	
200	11.7	11.8	11.6	11.7 ± 0.44 a	
LSD T*N	N.S			LSD N	N.S
Mean T	11.6 ± 0.51	11.6 ± 0.31	10.9 ± 2.16		
LSD T	N.S				

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 51. Moisture (%) of the grain of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments measured at the harvest day of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	13.9	14.1	13.7	13.9 ± 0.27 a	
40	13.9	13.8	13.6	13.8 ± 0.20 ab	
80	13.9	14	13.8	13.9 ± 0.15 a	
120	13.8	13.8	13.7	13.8 ± 0.15 abc	
160	13.7	13.8	13.5	13.7 ± 0.17 bc	
200	13.7	13.7	13.5	13.6 ± 0.23 c	
LSD T*N	N.S			LSD N	0.16
Mean T	13.8 ± 0.20 a	13.9 ± 0.19 a	13.6 ± 0.19 b		
LSD T	0.11				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 52. Moisture (%) of the grain of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments measured a month after harvest of the year 2022-2023, MATE - Gödöllő.

Nitrogen kg/ha	EM Treatment			Mean N	
	0 EM	EM at F3	EM at F3 and F10		
0	10.7	10.7	10.8	10.7 ± 0.13 a	
40	10.8	10.7	10.8	10.8 ± 0.18 a	
80	10.8	11	10.7	10.8 ± 0.16 a	
120	10.6	10.8	10.9	10.8 ± 0.21 a	
160	10.8	10.8	10.8	10.8 ± 0.16 a	
200	10.8	11	10.9	10.9 ± 0.17 a	
LSD $_{T*N}$	N.S			LSD $_{N}$	N.S
Mean T	10.7 ± 0.17a	10.9 ± 0.20a	10.8 ± 0.15 a		
LSD $_{T}$	N.S				

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, 0EM is the non application of effective microorganisms, EM at F3, is single time application at Feekes3 growth stage. EM at F3 and F10 is two application times at Feekes 3 and 10 growth stages. and N is the nitrogen application (NH_4NO_3).

Table B.5. 53. Probability of correlation coefficients among the study parameters of *Triticum aestivum* L produced under drought stress and different treatments of effective microorganisms and nitrogen treatments, MATE - Gödöllő.

	Final Yield	Green Yield	TGW	TW	LAI	SPAD	QY	Tillers n	Spikes n m2	Spikelets n	Heading date	Plant height	FN	Gluten%	Moisture% *	Protein% *	Gluten% *	Gluten% **	Moisture% **	Protein% **	SDS **	Gluten% ***	Moisture% ***	Protein% ***
Green Yield	0.000																							
TGW	0.004	0.017																						
TW	0.012	0.002	0.044																					
LAI	0.000	0.000	0.032	0.009																				
SPAD	0.247	0.255	0.515	0.623	0.831																			
QY	0.127	0.108	0.651	0.429	0.853	0.357																		
Tillers n	0.000	0.000	0.195	0.015	0.000	0.204	0.844																	
Spikes n m2	0.009	0.002	0.292	0.004	0.000	0.164	0.751	0.018																
Spikelets n	0.000	0.000	0.140	0.021	0.000	0.772	0.541	0.000	0.016															
Heading Date	0.000	0.000	0.055	0.998	0.004	0.781	0.694	0.001	0.051	0.000														
Plant Height	0.000	0.000	0.064	0.002	0.000	0.377	0.341	0.000	0.004	0.000	0.001													
FN	0.000	0.000	0.130	0.017	0.007	0.628	0.818	0.000	0.516	0.000	0.279	0.001												
Gluten %	0.000	0.000	0.000	0.000	0.000	0.415	0.656	0.000	0.017	0.000	0.003	0.000	0.000											
Moisture% *	0.240	0.324	0.005	0.105	0.704	0.575	0.715	0.883	0.953	0.585	0.042	0.647	0.330	0.643										
Protein% *	0.000	0.000	0.019	0.002	0.000	0.249	0.832	0.000	0.006	0.000	0.055	0.000	0.001	0.000	0.466									
Gluten% *	0.000	0.000	0.005	0.000	0.000	0.393	0.397	0.000	0.041	0.000	0.037	0.000	0.000	0.000	0.507	0.000								
Gluten% **	0.000	0.000	0.001	0.006	0.000	0.438	0.896	0.000	0.021	0.000	0.010	0.000	0.000	0.000	0.408	0.000	0.000							
Moisture% **	0.000	0.000	0.066	0.249	0.001	0.431	0.087	0.011	0.853	0.007	0.247	0.000	0.062	0.001	0.260	0.006	0.001	0.000						
Protein% **	0.000	0.000	0.001	0.003	0.000	0.823	0.601	0.000	0.047	0.000	0.013	0.000	0.000	0.000	0.442	0.000	0.000	0.000	0.000					
SDS **	0.000	0.000	0.004	0.003	0.000	0.486	0.803	0.000	0.024	0.000	0.012	0.000	0.000	0.000	0.806	0.000	0.000	0.000	0.002	0.000				
Gluten% ***	0.000	0.000	0.000	0.001	0.000	0.780	0.603	0.000	0.019	0.000	0.020	0.000	0.000	0.000	0.792	0.000	0.000	0.000	0.000	0.000	0.000			
Moisture% ***	0.186	0.080	0.254	0.400	0.348	0.241	0.220	0.197	0.202	0.434	0.702	0.045	0.603	0.594	0.740	0.390	0.875	0.931	0.023	0.556	0.484	0.604		
Protein% ***	0.000	0.000	0.002	0.006	0.000	0.559	0.941	0.000	0.018	0.003	0.183	0.000	0.000	0.000	0.990	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.456	
SDS ***	0.000	0.000	0.011	0.175	0.000	0.893	0.576	0.000	0.017	0.000	0.006	0.000	0.000	0.000	0.268	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.085	0.000

r ≥ 0.27 is significant at 0.05, and r ≤ 0.35 is significant at 0.01; * is the quality parameters of the whole flour, ** is the quality parameters measured with an NIR at the harvest day, *** is the quality parameters measured with an NIR a month after harvest; TKW is the thousand kernel weight; TW is the test weight; LAI is the leaf area index; QY is the quantum yield; FN in the fulling number (enzymic activity); SDS is the SDS-sedimentation volume.

Table B.5. 54. Green Yield production (kg/ha) of *Triticum aestivum* L under drought stress and different treatments of irrigation and N-splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F) F3	F3 + F6	F3 + F6 + F10	V * I
Alföld	Irrigated	5300	7700	6717	6572
	Not Irrigated	6683	5842	6433	6319
Felleg	Irrigated	7717	8617	7883	8072
	Not Irrigated	7108	6417	6950	6825
Nemere	Irrigated	8708	9367	9167	9081
	Not Irrigated	8875	6667	8733	8092
LSD_{V*I*F}		N.S			LSD N.S

V * F						
Varieties	F3	F3 + F6	F3 + F6 + F10	Variety mean		
Alföld	5992	6771	6575	6446	±	1293 c
Felleg	7412	7517	7417	7449	±	1021 b
Nemere	8792	8017	8950	8586	±	865 a
LSD_{V*F}		N.S		LSD		441.7

I * F						
Irrigation	F3	F3 + F6	F3 + F6 + F10	Irrigation mean		
Irrigated	7242	8561	7922	7908	±	1440 a
Not Irrigated	7556	6308	7372	7079	±	1192 b
LSD_{I*F}		624.7		LSD		360.7

F				
Fertilization	F3	F3 + F6	F3 + F6 + F10	
Mean fertilization	7399 ± 1419	7435 ± 1615	7647 ± 1109	
LSD_F		N.S		

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 for each growth stages.

Table B.5. 55. TKW (g) of *Triticum aestivum* L seeds produced under drought stress and different treatments of irrigation and N-splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3 + F6 + F10		
Alföld	Irrigated	32.62	34.72	34.51	33.95	
	Not Irrigated	33.05	33.98	39.17	35.40	
Felleg	Irrigated	39.28	37.83	34.86	37.32	
	Not Irrigated	34.45	37.18	34.05	35.23	
Nemere	Irrigated	38.85	43.92	40.01	40.93	
	Not Irrigated	41.97	45.16	39.75	42.29	
LSD_{V*I*F}		N.S			LSD_{V*I}	N.S
V * F						
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety mean	
Alföld		32.83	34.35	36.84	34.68 ± 4.83	
Felleg		36.87	37.50	34.46	36.28 ± 3.36	
Nemere		40.41	44.54	39.88	41.61 ± 3.43	
LSD_{V*F}		N.S			LSD_V	2.28
I * F						
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation mean	
Irrigated		36.91	38.83	36.46	37.40 ± 4.35 a	
Not Irrigated		36.49	38.77	37.66	37.64 ± 5.45 a	
LSD_{I*F}		N.S			LSD_I	N.S
F						
Fertilization		F3	F3 + F6	F3 + F6 + F10		
Mean fertilization		36.70±5.09 a	38.80±4.66 a	37.06 ± 4.90 a		
LSD_F		N.S				

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 for each growth stages.

Table B.5. 56. Test weight (kg/hl) of *Triticum aestivum* L grain yield produced under drought stress and different treatments of irrigation and N- splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3 + F6 + F10		
Alföld	Irrigated	75.97	78.35	77.02	77.11	
	Not Irrigated	77.23	77.62	76.32	77.06	
Felleg	Irrigated	76.27	78.50	77.32	77.36	
	Not Irrigated	77.00	78.22	74.60	76.61	
Nemere	Irrigated	75.13	78.13	77.08	76.78	
	Not Irrigated	75.20	76.57	73.57	75.11	
LSD_{V*I*F}		N.S			LSD_{V*I}	N.S
V * F						
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety mean	
Alföld		76.60	77.98	76.67	77.08 ± 2.23 a	
Felleg		76.63	78.36	75.96	76.98 ± 1.88 a	
Nemere		75.17	77.35	75.33	75.95 ± 1.68 a	
LSD_{V*F}		N.S			LSD_V	N.S
I * F						
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation mean	
Irrigated		75.79	78.33	77.14	77.09 ± 2.02	
Not Irrigated		76.48	77.47	74.83	76.26 ± 1.88	
LSD_{I*F}		1.65			LSD_I	N.S
F						
Fertilization		F3	F3 + F6	F3 + F6 + F10		
Mean fertilization		76.13±2.18 b	77.90±1.12a	75.98 ± 1.95 b		
LSD_F		1.17				

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 for each growth stages.

Table B.5. 57. Spikes number per a plant (n per m^2) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N- splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties	Irrigation	Fertilization (F)			V * I	
(V)	(I)	F3	F3 + F6	F3 + F6 + F10		
Alföld	Irrigated	947	933	913	931	
	Not Irrigated	767	533	667	656	
Felleg	Irrigated	1187	967	1260	1138	
	Not Irrigated	1387	1060	1027	1158	
Nemere	Irrigated	973	813	1087	958	
	Not Irrigated	1140	860	1087	1029	
LSD_{V*I*F}		N.S			LSD_{V*I}	192.4
V * F						
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety mean	
Alföld		857	733	790	793 ± 193.90 c	
Felleg		1287	1013	1143	1148 ± 250.70 a	
Nemere		1057	837	1087	993 ± 273.20 b	
LSD_{V*F}		N.S			LSD_V	136.1
I * F						
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation mean	
Irrigated		1036	904	1087	1009 ± 230.90	
Not Irrigated		1098	818	927	947 ± 320.80	
LSD_{I*F}		N.S			LSD_I	N.S
F						
Fertilization		F3	F3 + F6	F3 + F6 + F10		
Mean fertilization		1067±234.9 a	861 ± 271.5 b	1007 ±299.0 a		
LSD_F		136.1				

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 for each growth stages.

Table B.5. 58. Plight height (cm) of *Triticum aestivum* L under drought stress and different treatments of irrigation and N- splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F) F3	F3 + F6	F3 + F6 + F10	V * I	
Alföld	Irrigated	98.8	94.0	94.8	95.9	
	Not Irrigated	99.2	91.2	93.2	94.6	
Felleg	Irrigated	85.6	84.3	84.4	84.8	
	Not Irrigated	86.0	80.0	83.4	83.1	
Nemere	Irrigated	89.4	85.8	85.4	86.9	
	Not Irrigated	84.8	82.0	86.1	84.3	
LSD_{V*I*F}		N.S			LSD_{V*I}	N.S

V * F					
Varieties	F3	F3 + F6	F3 + F6 + F10	Variety mean	
Alföld	99.0	92.6	94.0	95.2 ± 3.44 a	
Felleg	85.8	82.2	83.9	84.0 ± 2.87 b	
Nemere	87.1	83.9	85.8	85.6 ± 3.55 b	
LSD_{V*F}	N.S			LSD_V	1.7

I * F					
Irrigation	F3	F3 + F6	F3 + F6 + F10	Irrigation mean	
Irrigated	91.3	88.0	88.2	89.2 ± 5.38 a	
Not Irrigated	90.0	84.4	87.6	87.3 ± 6.46 b	
LSD_{I*F}	N.S			LSD_I	1.4

F				
Fertilization	F3	F3 + F6	F3 + F6 + F10	
Mean fertilization	90.6±6.91 a	86.2 ± 5.42 b	87.9 ± 4.82 b	
LSD_F	1.7			

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 59. Leaf area index (m^2) of *Triticum aestivum* L measured at anthesis resulted under drought stress and different treatments of irrigation and N- splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties	Irrigation	Fertilization (F)			V * I
(V)	(I)	F3	F3 + F6	F3 + F6 + F10	
Alföld	Irrigated	4.16	3.57	4.43	4.05
	Not Irrigated	4.82	2.51	3.92	3.75
Felleg	Irrigated	6.03	3.54	4.77	4.78
	Not Irrigated	5.22	2.76	4.47	4.15
Nemere	Irrigated	4.51	3.72	3.90	4.05
	Not Irrigated	4.61	2.20	4.23	3.68
LSD_{V*I*F}		N.S			LSD_{V*I} N.S
V * F					
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety mean
Alföld		4.49	3.04	4.18	3.9 ± 1.00 b
Felleg		5.63	3.15	4.62	4.4 ± 1.18 a
Nemere		4.56	2.96	4.07	3.8 ± 1.18 b
LSD_{V*F}		N.S			LSD_V 0.5
I * F					
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation mean
Irrigated		4.90	3.61	4.37	4.2 ± 1.03 a
Not Irrigated		4.88	2.49	4.20	3.8 ± 1.21 b
LSD_{I*F}		N.S			LSD_I 0.4
F					
Fertilization		F3	F3 + F6	F3 + F6 + F10	
Mean fertilization		4.89 ± 1.04 a	3.05 ± 0.72 c	4.2905 ± 0.73 b	
LSD_F		0.51			

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH4NO3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 60. Photosynthesis activity (SPAD) of *Triticum aestivum* L measured at anthesis produced under drought stress and different treatments of irrigation and N- splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F) F3	F3 + F6	F3 + F6 + F10	V * I
Alföld	Irrigated	40.23	45.17	44.63	43.34
	Not	50.57	51.13	47.40	49.70
Felleg	Irrigated	41.80	40.00	45.30	42.37
	Not	39.43	37.60	41.83	39.62
Nemere	Irrigated	49.53	44.00	46.43	46.66
	Not	43.00	47.13	54.80	48.31
LSD_{V*I*F}		N.S			LSD_{V*I} N.S
V * F					
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety mean
Alföld		45.40	48.15	46.02	46.52 ± 6.61 a
Felleg		40.62	38.80	43.57	40.99 ± 8.35 b
Nemere		46.27	45.57	50.62	47.48 ± 3.87
LSD_{V*F}		N.S			LSD_V 4.4
I * F					
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation mean
Irrigated		43.86	43.06	45.46	44.12 ± 5.20
Not Irrigated		44.33	45.29	48.01	45.88 ± 8.50
LSD_{I*F}		N.S			LSD_I N.S
F					
Fertilization		F3	F3 + F6	F3 + F6 + F10	
Mean fertilization		44.09±7.70	44.17±7.320	46.73 ± 0.73	
LSD_F		N.S			

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 61. Quantum yield (QY), photosynthesis II efficiency, of *Triticum aestivum* L measured at anthesis produced under drought stress and different treatments of irrigation and N- splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties	Irrigation (I)	Fertilization (F)			V * I
		F3	F3 + F6	F3 + F6 + F10	
Alföld	Irrigated	0.813	0.837	0.837	0.829
	Not	0.733	0.763	0.757	0.751
Felleg	Irrigated	0.757	0.723	0.767	0.749
	Not	0.750	0.790	0.800	0.780
Nemere	Irrigated	0.780	0.797	0.810	0.796
	Not	0.813	0.817	0.830	0.820
LSD_{V*I*F}		N.S			LSD_{V*I} 0.02
V * F					
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety mean
Alföld		0.773	0.800	0.797	0.790 ± 0.05 b
Felleg		0.753	0.757	0.783	0.764 ± 0.02 c
Nemere		0.797	0.807	0.820	0.808 ± 0.03 a
LSD_{V*F}		N.S			LSD_V 0.01
I * F					
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation mean
Irrigated		0.783	0.786	0.804	0.791 ± 0.04
Not Irrigated		0.766	0.790	0.796	0.784 ± 0.04
LSD_{I*F}		0.024			LSD_I N.S
F					
Fertilization		F3	F3 + F6	F3 + F6 + F10	
Mean fertilization		0.77±0.04 b	0.78±0.04 ab	0.80 ± 0.03 a	
LSD_F					

Various lowercase letters(a - c) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 62. Whole flour gluten content (%) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N- splitting in different growth stages measured with an NIR of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3 + F6 + F10		
Alföld	Irrigated	35.90	37.29	38.17	37.12	
	Not	33.50	33.27	37.30	34.69	
Felleg	Irrigated	37.23	34.60	38.03	36.62	
	Not	33.01	32.37	36.40	33.92	
Nemere	Irrigated	30.83	31.63	32.87	31.78	
	Not	28.53	30.00	25.12	27.88	
N.S		4.78			LSD_V	N.S
V * F						
Varieties		F3	F3 + F6	F3 + F6 + F10	Variety mean	
Alföld		34.70	35.28	37.73	35.90 ± 2.12 a	
Felleg		35.12	33.48	37.22	35.27 ± 4.55 a	
Nemere		29.68	30.82	28.99	29.83 ± 2.63 b	
LSD_{V*F}		N.S			LSD_V	1.95
I * F						
Irrigation		F3	F3 + F6	F3 + F6 + F10	Irrigation mean	
Irrigated		34.66	34.51	36.36	35.17 ± 3.06 a	
Not Irrigated		31.68	31.88	32.94	32.17 ± 4.73 b	
LSD_{I*F}		N.S			LSD_I	1.59
F						
Fertilization		F3	F3 + F6	F3 + F6 + F10		
Mean fertilization		33.17 ±	33.19 ± 2.64	34.65 ± 6.09		
LSD_F		N.S				

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 63. Whole grain gluten content (%) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N- splitting in different growth stages measured one month after harvesting of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3+F6+F10		
Alföld	Irrigated	32.40	32.70	34.17	33.09	
	Not	29.50	30.47	33.93	31.30	
Felleg	Irrigated	33.20	30.57	33.87	32.54	
	Not	30.37	29.97	33.50	31.28	
Nemere	Irrigated	29.40	30.03	32.13	30.52	
	Not	28.10	29.43	31.50	29.68	
LSD_{V*I*F}		N.S			LSD_{V*I}	N.S
V * F						
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean	
Alföld		30.95	31.59	34.05	32.20 ± 1.95 a	
Felleg		31.78	30.27	33.68	31.91 ± 1.60 a	
Nemere		28.75	29.73	31.82	30.10 ± 1.91 b	
LSD_{V*F}		1.13			LSD_{V}	0.65
I * F						
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean	
Irrigated		31.67	31.10	33.39	32.05 ± 1.82 a	
Not Irrigated		29.32	29.96	32.98	30.75 ± 2.04 b	
LSD_{I*F}		0.92			LSD_{I}	0.53
F						
Fertilization		F3	F3 + F6	F3+F6+F10		
Mean fertilization		30.49±2.11 b	30.53±1.29 b	33.18±1.27 a		
LSD_{F}		0.65				

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 64. Whole grain gluten content (%) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N- splitting in different growth stages measured at the harvest day of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I			
		F3	F3 + F6	F3+F6+F10				
Alföld	Irrigated	33.23	32.57	33.37	33.06			
	Not Irrigated	30.10	31.70	34.47	32.09			
Felleg	Irrigated	33.67	31.10	34.63	33.13			
	Not Irrigated	30.80	30.33	35.13	32.09			
Nemere	Irrigated	32.17	31.17	32.70	32.01			
	Not Irrigated	28.80	30.73	33.70	31.08			
LSD_{V*I*F}		N.S			LSD_{V*I}			N.S
V * F								
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean			
Alföld		31.67	32.13	33.92	32.57	±	1.96 a	
Felleg		32.23	30.72	34.88	32.61	±	1.96 a	
Nemere		30.48	30.95	33.20	31.54	±	2.31 b	
LSD_{V*F}		1.44			LSD_V			0.83
I * F								
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean			
Irrigated		33.02	31.61	33.57	32.73	±	1.62 a	
Not Irrigated		29.90	30.92	34.43	31.75	±	2.42 b	
LSD_{I*F}		1.18			LSD_I			0.68
F								
Fertilization		F3	F3 + F6	F3+F6+F10				
Mean fertilization		31.46 ± 2.09	31.27±1.24	34.00±1.72 a				
LSD_F		0.83						

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 65. Whole grain protein content (%) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N-splitting in different growth stages measured at the harvest day of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F) F3	F3 + F6	F3+F6+F10	V * I			
Alföld	Irrigated	14.90	14.67	15.23	14.93			
	Not Irrigated	14.03	14.37	15.43	14.61			
Felleg	Irrigated	14.83	13.97	15.17	14.66			
	Not Irrigated	13.97	13.90	15.20	14.36			
Nemere	Irrigated	13.53	13.63	14.33	13.83			
	Not Irrigated	13.17	13.73	14.13	13.68			
LSD_{V*I*F}		N.S			LSD_{V*I}			N.S
V * F								
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean			
Alföld		14.47	14.52	15.33	14.77	±	0.57 a	
Felleg		14.40	13.93	15.18	14.51	±	0.56 a	
Nemere		13.35	13.68	14.23	13.76	±	0.68 b	
LSD_{V*F}		N.S			LSD_V			0.27
I * F								
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean			
Irrigated		14.42	14.09	14.91	14.47	±	0.68 a	
Not Irrigated		13.72	14.00	14.92	14.22	±	0.78 b	
LSD_{I*F}		0.38			LSD_I			0.22
F								
Fertilization		F3	F3 + F6	F3+F6+F10				
Mean fertilization		14.07±0.76b	14.04±0.43 b	14.92±0.64 a				
LSD_F		0.27						

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 66. Whole grain protein content (%) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N- splitting in different growth stages measured one month after harvest of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F) F3	F3 + F6	F3+F6+F10	V * I	
Alföld	Irrigated	14.83	14.67	15.13	14.88	
	Not	13.93	14.57	15.63	14.71	
Felleg	Irrigated	14.90	14.10	15.27	14.76	
	Not	13.93	13.90	15.70	14.51	
Nemere	Irrigated	14.13	14.00	14.57	14.23	
	Not	13.47	14.07	15.47	14.33	
LSD_{V*I*F}		N.S			LSD_{V*I}	N.S
V * F						
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean	
Alföld		14.38	14.62	15.38	14.79 ± 0.65 a	
Felleg		14.42	14.00	15.48	14.63 ± 0.85 ab	
Nemere		13.80	14.03	15.02	14.28 ± 0.89 b	
LSD_{V*F}		N.S			LSD_V	0.37
I * F						
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean	
Irrigated		14.62	14.26	14.99	14.62 ± 0.17	
Not Irrigated		13.78	14.18	15.60	14.52 ± 0.25	
LSD_{I*F}		N.S			LSD_I	N.S
F						
Fertilization		F3	F3 + F6	F3+F6+F10		
Mean fertilization		14.20±0.67 b	14.22±0.45 b	15.29±0.77 a		
LSD_F		0.37				

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 67. Falling number (seconds) of *Triticum aestivum* L produced under drought stress and different treatments of irrigation and N-splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F) F3	F3 + F6	F3+F6+F10	V * I	
Alföld	Irrigated	426.3	407.7	321.7	385.2	
	Not Irrigated	416.7	478.7	434.7	443.3	
Felleg	Irrigated	395.3	415.7	421.0	410.7	
	Not Irrigated	405.0	448.0	409.7	420.9	
Nemere	Irrigated	417.7	408.3	404.3	410.1	
	Not Irrigated	412.3	512.7	549.0	491.3	
LSD_{V*I*F}		49.7			LSD_{V*I}	28.7
V * F						
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean	
Alföld		421.5	443.2	378.2	414.3 ± 57.10	
Felleg		400.2	431.8	415.3	415.8 ± 62.00	
Nemere		415.0	460.5	476.7	450.7 ± 29.55	
LSD_{V*F}		35.2			LSD_V	20.3
I * F						
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean	
Irrigated		413.1	410.6	382.3	402.0 ± 39.32 b	
Not Irrigated		411.3	479.8	464.4	451.9 ± 54.50 a	
LSD_{I*F}		28.7			LSD_I	16.6
F						
Fertilization		F3	F3 + F6	F3+F6+F10		
Mean fertilization		412 ± 25.94 b	445.2 ± 46.30 a	423.4±74.0 b		
LSD_F		20.3				

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3
, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 68. Zeleny index (ml) of *Triticum aestivum* L grains produced under drought stress and different treatments of irrigation and N- splitting in different growth stages measured at the harvest day of the year 2022-2023, MATE - Gödöllő.

Varieties	Irrigation (I)	Fertilization (F)			V * I			
		F3	F3 + F6	F3+F6+F10				
Alföld	Irrigated	50.23	47.87	49.73	49.28			
	Not Irrigated	49.37	51.50	54.53	51.80			
Felleg	Irrigated	48.00	47.57	49.33	48.30			
	Not Irrigated	47.97	46.00	50.63	48.20			
Nemere	Irrigated	41.63	45.87	46.03	44.51			
	Not Irrigated	34.73	49.27	48.27	44.09			
LSD_{V*I*F}		N.S			LSD_{V*I}			N.S
V * F								
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean			
Alföld		49.80	49.68	52.13	50.54	±	3.25 a	
Felleg		47.98	46.78	49.98	48.25	±	10.41a	
Nemere		38.18	47.57	47.15	44.30	±	1.71 b	
LSD_{V*F}		N.S			LSD_V			4.39
I * F								
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean			
Irrigated		46.62	47.10	48.37	47.36	±	3.40 a	
Not Irrigated		44.02	48.92	51.14	48.03	±	9.04 a	
LSD_{I*F}		N.S			LSD_I			N.S
F								
Fertilization		F3	F3 + F6	F3+F6+F10				
Mean fertilization		45.32±10.64 a	48.0±2.97 a	49.7±3.23 a				
LSD_F		N.S						

Various lowercase letters reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 69. Zeleny index (ml) of *Triticum aestivum* L grains produced under drought stress and different treatments of irrigation and N- splitting in different growth stages measured a month after harvest with an NIR of the year 2022-2023, MATE - Gödöllő.

Varieties	Irrigation (I)	Fertilization (F)			V * I		
		F3	F3 + F6	F3+F6+F10			
Alföld	Irrigated	49.00	50.57	49.07	49.54		
	Not Irrigated	44.20	45.93	50.37	46.83		
Felleg	Irrigated	48.47	47.00	49.60	48.36		
	Not Irrigated	42.20	41.87	44.97	43.01		
Nemere	Irrigated	57.23	46.90	48.63	50.92		
	Not Irrigated	43.97	44.57	44.33	44.29		
LSD_{V*I*F}		N.S			LSD_{V*I}	3.53	
V * F							
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean		
Alföld		46.60	48.25	49.72	48.19	±	4.03a
Felleg		45.33	44.43	47.28	45.68	±	6.16a
Nemere		50.60	45.73	46.48	47.61	±	3.31a
LSD_{V*F}		N.S			LSD_V		N.S
I * F							
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean		
Irrigated		51.57	48.16	49.10	49.61	±	4.74 a
Not Irrigated		43.46	44.12	46.56	44.71	±	3.17 b
LSD_{I*F}		N.S			LSD_I		2.04
F							
Fertilization		F3	F3 + F6	F3+F6+F10			
Mean fertilization		47.5±6.37 a	46.14±3.16 a	47.8±4.07 a			
LSD_F		N.S					

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 70. Moisture content (%) of *Triticum aestivum* L flour produced under drought stress and different treatments of irrigation and N- splitting in different growth stages of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3+F6+F10		
Alföld	Irrigated	11.77	11.93	11.97	11.89	
	Not Irrigated	12.27	12.33	12.70	12.43	
Felleg	Irrigated	11.67	11.80	11.67	11.71	
	Not Irrigated	11.80	12.20	11.97	11.99	
Nemere	Irrigated	11.67	11.50	11.23	11.47	
	Not Irrigated	12.27	11.93	12.03	12.08	
LSD_{V*I*F}		N.S			LSD_{V*I}	N.S
V * F						
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean	
Alföld		12.02	12.13	12.33	12.16 ± 0.37 a	
Felleg		11.73	12.00	11.82	11.85 ± 0.40 b	
Nemere		11.97	11.72	11.63	11.77 ± 0.27 b	
LSD_{V*F}		0.25			LSD_V	0.14
I * F						
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean	
Irrigated		11.70	11.74	11.62	11.69 ± 0.29 b	
Not Irrigated		12.11	12.16	12.23	12.17 ± 0.31 a	
LSD_{I*F}		N.S			LSD_I	0.12
F						
Fertilization		F3	F3 + F6	F3+F6+F10		
Mean fertilization		11.91± 0.35	11.95 ± 0.33	11.93 ±0.47		
LSD_F		N.S				

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 71. Moisture content (%) of *Triticum aestivum* L flour produced under drought stress and different treatments of irrigation and N- splitting in different growth stages measured at the harvest day of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3+F6+F10		
Alföld	Irrigated	12.33	11.67	11.83	11.94	
	Not Irrigated	13.07	13.40	13.33	13.27	
Felleg	Irrigated	12.27	12.37	12.30	12.31	
	Not Irrigated	13.07	13.10	13.33	13.17	
Nemere	Irrigated	12.00	12.10	11.83	11.98	
	Not Irrigated	13.27	13.47	13.13	13.29	
LSD_{V*I*F}		N.S			LSD_{V*I}	N.S

V * F							
Varieties	F3	F3 + F6	F3+F6+F10	Variety mean			
Alföld	12.70	12.53	12.58	12.61	±	0.79	
Felleg	12.67	12.73	12.82	12.74	±	0.74	
Nemere	12.63	12.78	12.48	12.63	±	0.49	
LSD_{V*F}	N.S			LSD_V			N.S

I * F							
Irrigation	F3	F3 + F6	F3+F6+F10	Irrigation mean			
Irrigated	12.20	12.04	11.99	12.08	±	0.33	b
Not Irrigated	13.13	13.32	13.27	13.24	±	0.36	a
LSD_{I*F}	0.32			LSD_I			0.19

F				
Fertilization	F3	F3 + F6	F3+F6+F10	
Mean fertilization	12.67 ± 0.53	12.68 ± 0.76	12.63 ± 0.76	
LSD_F	N.S			

Various lowercase letters(a -b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at $\alpha=0.05$, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 72. Moisture content (%) of *Triticum aestivum* L flour produced under drought stress and different treatments of irrigation and N- splitting in different growth stages measured a month after harvest of the year 2022-2023, MATE - Gödöllő.

Varieties (V)	Irrigation (I)	Fertilization (F)			V * I	
		F3	F3 + F6	F3+F6+F10		
Alföld	Irrigated	10.80	10.97	10.87	10.88	
	Not Irrigated	11.27	11.30	11.57	11.38	
Felleg	Irrigated	11.00	10.97	11.00	10.99	
	Not Irrigated	10.97	11.07	11.00	11.01	
Nemere	Irrigated	10.83	10.67	10.90	10.80	
	Not Irrigated	11.30	11.20	11.07	11.19	
LSD_{V*I*F}		N.S			LSD_{V*I}	0.18
V * F						
Varieties		F3	F3 + F6	F3+F6+F10	Variety mean	
Alföld		11.03	11.13	11.22	11.13 ± 0.30 a	
Felleg		10.98	11.02	11.00	11.00 ± 0.28 a	
Nemere		11.07	10.93	10.98	10.99 ± 0.19 a	
LSD_{V*F}		N.S			LSD_V	N.S
I * F						
Irrigation		F3	F3 + F6	F3+F6+F10	Irrigation mean	
Irrigated		10.88	10.87	10.92	10.89 ± 0.59 b	
Not Irrigated		11.18	11.19	11.21	11.19 ± 1.00 a	
LSD_{I*F}		N.S			LSD_I	0.10
F						
Fertilization		F3	F3 + F6	F3+F6+F10		
Mean fertilization		11.03± 0.28	11.03 ± 0.25	11.07 ± 0.28		
LSD_F		N.S				

Various lowercase letters(a - b) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, F3 is the N application at a single time of 160 kg/ha N at growth stage of Feekes3, F3+F6 the total amount of N split in two 80+80 kg/ha NH_4NO_3, and F3+F6+F10 is the total N amount were split into three portions 53.3 kg/ha for each growth stages.

Table B.5. 73. Probability of the correlation coefficients among the study parameters of N- splitting and wheat abiotic stress experiment, MATE - Gödöllő.

	Final_Yield	Green Yield	TGW	TW	LAI	SPAD	QY	Tillers n	Spikes n m2	Spikelets n	Plant Height	FN	Gluten %	Moisture% *	Protein% *	Gluten% *	Gluten% **	Moisture% **	Protein% **	SDS **	Gluten% ***	Moisture% ***	Protein% ***
Green Yield	0.000																						
TGW	0.003	0.010																					
TW	0.158	0.251	0.835																				
LAI	0.025	0.031	0.188	0.043																			
SPAD	0.518	0.710	0.571	0.254	0.342																		
QY	0.164	0.831	0.307	0.050	0.393	0.490																	
Tillers n	0.362	0.265	0.872	0.810	0.622	0.399	0.846																
Spikes n m2	0.038	0.073	0.632	0.113	0.000	0.048	0.800	0.398															
Spikelets n	0.009	0.012	0.003	0.579	0.817	0.949	0.506	0.262	0.080														
Plant Height	0.041	0.059	0.001	0.874	0.183	0.260	0.815	0.020	0.015	0.000													
FN	0.867	0.668	0.010	0.382	0.004	0.053	0.742	0.870	0.447	0.002	0.055												
Gluten %	0.947	0.734	0.740	0.584	0.739	0.147	0.173	0.393	0.716	0.029	0.865	0.586											
Moisture% *	0.000	0.000	0.516	0.149	0.041	0.272	0.416	0.024	0.026	0.600	0.233	0.111	0.773										
Protein% *	0.037	0.094	0.012	0.112	0.004	0.910	0.450	0.473	0.355	0.012	0.072	0.139	0.001	0.261									
Gluten% *	0.031	0.071	0.019	0.289	0.150	0.046	0.651	0.257	0.561	0.000	0.055	0.001	0.009	0.804	0.000								
Gluten% **	0.076	0.104	0.060	0.365	0.199	0.823	0.242	0.635	0.473	0.000	0.176	0.057	0.000	0.837	0.000	0.000							
Moisture% **	0.005	0.008	0.944	0.219	0.059	0.242	0.175	0.626	0.203	0.000	0.102	0.000	0.045	0.000	0.645	0.030	0.061						
Protein% **	0.002	0.005	0.008	0.278	0.291	0.994	0.510	0.647	0.810	0.000	0.031	0.100	0.000	0.373	0.000	0.000	0.000	0.386					
SDS **	0.002	0.011	0.070	0.879	0.211	0.488	0.451	0.509	0.128	0.262	0.205	0.508	0.073	0.284	0.003	0.008	0.002	0.243	0.000				
Gluten% ***	0.470	0.471	0.374	0.019	0.088	0.444	0.235	0.070	0.351	0.024	0.477	0.829	0.000	0.658	0.000	0.000	0.000	0.357	0.000	0.010			
Moisture% ***	0.006	0.020	0.689	0.356	0.054	0.033	0.311	0.225	0.129	0.273	0.671	0.017	0.775	0.000	0.743	0.672	0.838	0.000	0.619	0.306	0.881		
Protein% ***	0.277	0.330	0.226	0.004	0.143	0.299	0.209	0.358	0.630	0.047	0.261	0.863	0.000	0.456	0.000	0.006	0.000	0.774	0.000	0.015	0.000	0.503	
SDS ***	0.243	0.304	0.427	0.928	0.112	0.615	0.852	0.296	0.787	0.002	0.054	0.215	0.442	0.066	0.439	0.167	0.127	0.002	0.316	0.928	0.004	0.129	0.021

r= 0.27 - 0.34 is significant at 0.05, and r ≥ 0.35 is significant at 0.01; * is the quality parameters measured with an NIR at the harvest day, ** is the quality parameters measured with an NIR a moth after harvest; TKW is the thousand kernel weight; TW is the test weight; LAI is the leaf area index; QY is the quantum yield; FN in the fulling number (enzymic activity); SDS is the SDS-sedimentation volume.

Table B.5. 74. Cobs yield (kg/ha) of *Zea mays* L. responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

Cobs Yield kg/ha						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	18898	20268	19583	±	981	a
160 O.M.	10640	9104	9872	±	389	fghi
240 NH_4NO_3	18144	17442	17793	±	432	ab
240 O.M.	11380	12408	11894	±	216	defg
320 NH_4NO_3	18300	20881	19590	±	207	a
320 O.M.	7224	9687	8455	±	319	ghi
80 NH_4NO_3	11317	18301	14809	±	660	bcd
80 O.M.	8899	7461	8180	±	349	hi
CONT.	9102	12831	10966	±	355	efgh
EM	16415	15319	15867	±	158	bc
EM + 160 NH_4NO_3	12783	14003	13393	±	154	cdef
EM + 160 O.M.	8634	9348	8991	±	136	ghi
EM + 240 NH_4NO_3	12145	13866	13006	±	218	cdef
EM + 240 O.M.	6141	6574	6357	±	158	i
EM + 320 NH_4NO_3	14022	15501	14761	±	158	bcd
EM + 320 O.M.	10159	6443	8301	±	369	ghi
EM + 80 NH_4NO_3	14627	12952	13789	±	190	cde
EM + 80 O.M.	9275	7118	8197	±	184	hi
LSD $_{Trt*Irrig}$.	4783.8		LSD $_{Trt}$	3604.1		
Irrigation mean	12117±4731	12750±4960				
LSD_{Irrig}.	N.S					

Various lowercase letters(a - i) reveal significant differences among the means values ($p < 0.05$), following L.S.D multiple beginnings in sequence with the latter (a) is the most significant, LSD is the Least Significant Difference at α=0.05, NH_4NO_3 is the ammonium nitrate, O.M. is the organic matter, and $_{Trt*Irrig}$ is the interaction between then N treatments and the irrigation.

Table B.5. 75. Empty Cobs yield (kg/ha) of *Zea mays* L. responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

Empty Cobs kg/ha						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	2597	2820	2709	±	173	a
160 O.M.	1592	1331	1461	±	557	ab
240 NH_4NO_3	2555	2655	2605	±	632	bc
240 O.M.	1574	1749	1661	±	307	bc
320 NH_4NO_3	2547	2881	2714	±	324	bc
320 O.M.	1109	1422	1265	±	427	bc
80 NH_4NO_3	2296	2493	2394	±	196	bc
80 O.M.	1369	3497	2433	±	1603	c
CONT.	1436	8583	5009	±	5843	c
EM	2283	5796	4040	±	3702	c
EM + 160 NH_4NO_3	1843	1936	1889	±	238	c
EM + 160 O.M.	1262	1486	1374	±	206	c
EM + 240 NH_4NO_3	1699	1912	1805	±	300	c
EM + 240 O.M.	1091	1060	1076	±	313	c
EM + 320 NH_4NO_3	2112	2185	2148	±	229	c
EM + 320 O.M.	1507	1186	1346	±	490	c
EM + 80 NH_4NO_3	2016	1913	1965	±	303	c
EM + 80 O.M.	1407	1232	1319	±	247	c
LSD $_{Trt*Irrig.}$	2373.7		LSD	1685.7		
Irrigation mean	1794 ± 597 b	2563 ± 2502 a				
$LSD_{Irrig.}$	577					

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 76. Number of kernels per a cob column of *Zea mays* L. responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

Number of Kernels per a Cob Column						
Treatments	Irrigation		Treatment Mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	41.2	45.2	43.2	±	3.6	a
160 O.M.	31.8	28.7	30.3	±	4.6	a
240 NH_4NO_3	40.7	41.5	41.1	±	3.7	ab
240 O.M.	32.2	31.8	32.0	±	1.8	ab
320 NH_4NO_3	41.3	45.7	43.5	±	2.9	bc
320 O.M.	22.3	29.8	26.1	±	5.6	bc
80 NH_4NO_3	39.0	43.3	41.2	±	2.8	c
80 O.M.	28.5	28.0	28.3	±	5.2	cd
CONT.	29.0	42.8	35.9	±	8.1	cd
EM	37.7	38.7	38.2	±	2.0	cd
EM + 160 NH_4NO_3	36.3	36.7	36.5	±	3.9	de
EM + 160 O.M.	26.2	29.3	27.8	±	2.8	ef
EM + 240 NH_4NO_3	33.0	37.5	35.2	±	4.3	efg
EM + 240 O.M.	26.5	24.5	25.5	±	4.0	efg
EM + 320 NH_4NO_3	36.7	39.3	38.0	±	3.1	fg
EM + 320 O.M.	30.2	27.3	28.8	±	4.1	fg
EM + 80 NH_4NO_3	35.5	34.8	35.2	±	2.5	g
EM + 80 O.M.	28.7	26.7	27.7	±	1.5	g
LSD $_{Trt*Irrig}$.	5.68		LSD $_{Trt}$	4.16		
Irrigation mean	33.1 ± 7.3 b	35.1 ± 6.4 a				
LSD$_{Irrig}$.	1.34					

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 77. Number of kernels per a cob column of *Zea mays* L. responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

Number of Kernels per a cob Row						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	16.0	17.2	16.6	±	1.4	a
160 O.M.	16.7	16.7	16.7	±	1.0	a
240 NH_4NO_3	15.7	16.7	16.2	±	1.0	a
240 O.M.	16.0	17.3	16.7	±	1.2	a
320 NH_4NO_3	15.7	16.7	16.2	±	1.0	a
320 O.M.	15.3	15.5	15.4	±	0.9	a
80 NH_4NO_3	16.3	16.5	16.4	±	1.0	a
80 O.M.	15.8	17.3	16.6	±	1.2	a
CONT.	16.7	16.8	16.8	±	0.6	a
EM	17.0	16.3	16.7	±	1.2	a
EM + 160	16.3	17.7	17.0	±	1.3	a
EM + 160 O.M.	17.0	17.3	17.2	±	1.2	a
EM + 240	16.0	17.7	16.8	±	1.5	a
EM + 240 O.M.	15.7	16.3	16.0	±	1.1	a
EM + 320	16.0	17.7	16.8	±	1.0	a
EM + 320 O.M.	17.0	15.8	16.4	±	0.9	a
EM + 80 NH_4NO_3	16.7	16.7	16.7	±	1.0	a
EM + 80 O.M.	15.3	16.2	15.8	±	1.2	a
$LSD_{Trt*Irrig.}$	1.74		LSD_{Trt}	N.S		
Irrigation mean	16.2 ± 0.91 b	16.8 ± 1.21 a				
$LSD_{Irrig.}$	0.42					

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 78. Number of cobs of *Zea mays* L. per a plant responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

NUMBER OF COBS				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
160 NH_4NO_3	1.9	2.0	1.9 ± 0.14	a
160 O.M.	1.7	1.3	1.5 ± 0.55	a
240 NH_4NO_3	2.0	2.0	2.0 ± 0.00	a
240 O.M.	1.2	1.1	1.2 ± 0.28	ab
320 NH_4NO_3	1.6	2.0	1.8 ± 0.27	bc
320 O.M.	1.2	1.0	1.1 ± 0.27	bc
80 NH_4NO_3	1.8	2.0	1.9 ± 0.27	bc
80 O.M.	1.2	1.0	1.1 ± 0.27	c
CONT.	1.0	1.0	1.0 ± 0.00	c
EM	1.6	1.3	1.4 ± 0.34	cd
EM + 160 NH_4NO_3	1.6	1.7	1.6 ± 0.25	de
EM + 160 O.M.	1.0	1.1	1.1 ± 0.14	e
EM + 240 NH_4NO_3	1.6	1.4	1.5 ± 0.46	e
EM + 240 O.M.	1.0	1.0	1.0 ± 0.00	e
EM + 320 NH_4NO_3	1.6	1.6	1.6 ± 0.34	e
EM + 320 O.M.	1.2	1.2	1.2 ± 0.34	e
EM + 80 NH_4NO_3	1.4	1.7	1.6 ± 0.27	e
EM + 80 O.M.	1.0	1.0	1.0 ± 0.00	e
$LSD_{Trt*Irrig.}$	0.47		LSD	0.23
Irrigation mean	1.4 ±0.40	1.4 ± 0.44		
$LSD_{Irrig.}$	N.S			

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 79. Plant leaf area index (m^2) of *Zea mays* L. responding to different treatment applications under drought stress measured at tasseling growth stage (VT) in 2022, MATE - Gödöllő.

Leaf Area Index				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
CONT	0.75	1.09	0.92 ± 0.19	
EM	1.6	1.31	1.45± 0.19	
NH_4NO_3	0.99	1.43	1.21± 0.24	
O.M	1.02	1.67	1.84± 84.3	
EM + NH_4NO_3	0.83	1.42	1.12± 0.33	
EM + O.M.	0.7	1.08	0.89± 0.23	
$LSD_{Trt*Irrig.}$	4.707		LSD_{Trt}	1.608
Irrigation mean	0.98± 0.32 b	1.83± 58.9 a		
$LSD_{Irrig.}$	1.998			

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 80. Year interactions of plant leaf area index (m^2) of *Zea mays* L. responding to different treatment applications under drought stress measured at the tasselling growth stage (VT) in 2022 and 2023, MATE - Gödöllő.

leaf area index					
Year (Y)	Treatments (T)	irrigation (I)		Y * T	
		No-Irrigation	Irrigation		
2022	Cont.	0.75	1.09	0.92	
	EM	1.60	1.31	1.45	
	NH_4NO_3	0.83	1.42	1.12	
	O.M.	0.70	1.08	0.89	
	EM + NH_4NO_3	0.99	1.43	1.21	
	EM + O.M.	1.02	1.67	1.84	
2023	Cont.	1.35	1.58	1.46	
	EM	1.66	1.90	1.78	
	NH_4NO_3	1.45	1.49	1.47	
	O.M.	1.47	1.52	1.50	
	EM + NH_4NO_3	2.14	2.27	2.21	
	EM + O.M.	1.35	1.47	1.41	
LSD_{Y*T*I}		1.26		LSD_{Y*T}	1.41
Y * I					
Year		No-Irrigation	Irrigation		
2022		0.98	26.83	13.91 ± 43.1 a	
2023		1.57	1.71	1.64 ± 0.39 b	
LSD_{Y*I}		1.60		LSD_Y	2.10
T * I					
Treatments		No-Irrigation	Irrigation		
Cont.		1.05	1.34	1.19 ± 0.34 b	
EM		1.63	1.61	1.62 ± 0.28 b	
NH_4NO_3		1.14	1.46	1.30 ± 0.43 b	
O.M.		1.09	1.30	1.19 ± 0.36 b	
EM + NH_4NO_3		1.56	1.85	1.71 ± 0.56 b	
EM + O.M.		1.18	78.07	39.62 ± 69.5 a	
LSD_{T*I}		2.30		LSD_T	1.70
I					
Irrigation		No-Irrigation	Irrigation		
Irrigation means		1.28 ± 0.45 b	14.27 ± 43.0 a		
LSD_I		0.95			

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 81. Number of leaves of *Zea mays* L. responding to different treatment applications under drought stress in 2022, MATE - Gödöllő.

Number of Leaves				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
CONT	14	14	14± 0	
EM	14	14	14± 0	
NH_4NO_3	14	14	14± 0	
O.M	14	14	14± 0	
EM + NH_4NO_3	14	14	14± 0	
EM + O.M.	14	14	14± 0	
LSD $_{Trt*Irrig}$.	NS		LSD $_{Trt}$	NS
Irrigation mean	14± 0	14± 0		
LSD$_{Irrig}$.	NS			

* Different lowercase letters present significant differences between the means (p < 0.05), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means (p < 0.05), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 82. Plant height (cm) of *Zea mays* L. responding to different treatment applications under drought stress in 2022, MATE - Gödöllő.

Plant Height (cm)				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
CONT	157.3	151.7	154.5 ± 8.8 a	
EM	120.3	130.3	125.3± 12.9 bc	
NH_4NO_3	142	139.7	140.8± 17.2 ab	
O.M	131.7	142.7	137.2± 23.3 ab	
EM + NH_4NO_3	153.3	150.7	152.0± 8.0 a	
EM + O.M.	94	125.7	109.8± 29.8 c	
LSD $_{Trt*Irrig}$.	27.23		LSD $_{Trt}$	21.19
Irrigation mean	133.1± 28.3 a	140.1± 16.5 a		
LSD$_{Irrig}$.	11.36			

* Different lowercase letters present significant differences between the means (p < 0.05), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means (p < 0.05), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 83. Plant height (cm) of *Zea mays* L. responding to different treatment applications under drought stress in 2022 and 2023, MATE - Gödöllő.

Plant height					
Year (Y)	Treatments (T)	Irrigation (I)		Y * T	
		No-Irrigation	Irrigation		
2022	Cont.	157.3	151.7	154.5	
	EM	120.3	130.3	125.3	
	NH_4NO_3	153.3	150.7	152	
	O.M.	94	125.7	109.8	
	EM +	142	139.7	140.8	
	EM + O.M.	131.7	142.7	137.2	
2023	Cont.	200	210	205	
	EM	206.7	216.7	211.7	
	NH_4NO_3	226.7	233.3	230	
	O.M.	233.3	233.3	233.3	
	EM +	263.3	276.7	270	
	EM + O.M.	223.3	230	226.7	
LSD_{Y*T*I}		N.S		LSD_{Y*T}	23.48
Y * I					
Year		No-Irrigation	Irrigation		
2022		133.1	140.1	136.6 ± 23.12 b	
2023		225.6	233.3	229.4 ± 22.80 a	
LSD_{Y*I}		N.S		LSD_Y	29.79
Y * I					
Treatments		No-Irrigation	Irrigation		
Cont.		178.7	180.8	179.8 ± 27.6 bcd	
EM		163.5	173.5	168.5± 46.6 d	
NH_4NO_3		190	192	191± 43.6 b	
O.M.		163.7	179.5	171.6± 66.0 cd	
EM + NH_4NO_3		202.7	208.2	205.4± 68.7 a	
EM + O.M.		177.5	186.3	181.9± 49.6 bc	
LSD_{T*I}		N.S		LSD_T	12.3
I					
Irrigation		No-Irrigation	Irrigation		
Irrigation means		179.3 ± 53.12 b	186.7 ± 51.3 a		
LSD_I		5.65			

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 84. Stem diameter (cm) of *Zea mays* L. responding to different treatment applications under drought stress in 2022, MATE - Gödöllő.

Stem Diameter (cm)				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
CONT	0.67	1.20	0.93 ± 0.40 c	
EM	1.17	1.73	1.45 ± 0.31 ab	
NH_4NO_3	1.53	1.57	1.55 ± 0.24 a	
O.M	1.13	1.23	1.18 ± 0.19 bc	
EM + NH_4NO_3	1.20	1.43	1.32 ± 0.22 ab	
EM + O.M.	1.16	1.71	1.43 ± 0.32 ab	
$LSD_{Trt*Irrig.}$	0.3956		LSD_{Trt}	0.353
Irrigation mean	1.14 ± 0.44 b	1.47 ± 0.25 a		
$LSD_{Irrig.}$	0.127			

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 85. Protein content (%) of *Zea mays* L. kernels responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

PROTEIN %				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
160 NH_4NO_3	8.34	7.33	7.83 ± 0.63	a
160 O.M.	5.87	4.54	5.21 ± 1.56	a
240 NH_4NO_3	8.14	7.86	8.00 ± 0.67	a
240 O.M.	5.66	4.91	5.29 ± 0.73	a
320 NH_4NO_3	8.53	8.02	8.27 ± 0.43	ab
320 O.M.	5.38	5.15	5.26 ± 0.69	ab
80 NH_4NO_3	7.54	6.98	7.26 ± 1.11	bc
80 O.M.	5.42	4.68	5.05 ± 1.24	bcd
CONT.	5.06	5.22	5.14 ± 0.54	cde
EM	6.87	5.87	6.37 ± 0.96	cdef
EM + 160 NH_4NO_3	6.72	4.5	5.61 ± 2.76	cdef
EM + 160 O.M.	5.47	4.48	4.97 ± 0.83	def
EM + 240 NH_4NO_3	7.71	7.25	7.48 ± 0.70	efg
EM + 240 O.M.	4.33	4.44	4.38 ± 0.70	efg
EM + 320 NH_4NO_3	8.51	7.61	8.06 ± 0.70	efg
EM + 320 O.M.	5.77	3.29	4.53 ± 1.95	efg
EM + 80 NH_4NO_3	6.89	5.77	6.33 ± 0.84	fg
EM + 80 O.M.	4.69	3.29	3.99 ± 1.43	g
$LSD_{Trt*Irrig.}$	1.582		LSD	1.16
Irrigation mean	6.49 ± 1.60 a	5.62 ± 1.80 b		
$LSD_{Irrig.}$	0.372			

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 86. Starch content (%) of *Zea mays* L. kernels responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

STARCH %						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	69.1	69.5	69.3	±	0.6	a
160 O.M.	70.7	50.7	60.7	±	26.2	a
240 NH_4NO_3	69.0	69.0	69.0	±	0.4	a
240 O.M.	71.2	72.5	71.8	±	1.0	a
320 NH_4NO_3	68.7	68.9	68.8	±	0.4	a
320 O.M.	70.7	72.4	71.6	±	1.1	a
80 NH_4NO_3	69.8	70.1	69.9	±	1.2	a
80 O.M.	70.1	72.4	71.2	±	1.4	a
CONT.	71.9	71.8	71.8	±	0.7	a
EM	70.0	71.2	70.6	±	1.1	a
EM + 160 NH_4NO_3	70.2	70.9	70.6	±	1.3	a
EM + 160 O.M.	71.4	72.5	71.9	±	0.9	a
EM + 240 NH_4NO_3	69.9	70.8	70.4	±	0.6	a
EM + 240 O.M.	72.5	72.4	72.4	±	1.8	a
EM + 320 NH_4NO_3	68.7	69.8	69.2	±	1.0	a
EM + 320 O.M.	71.0	72.0	71.5	±	1.4	a
EM + 80 NH_4NO_3	70.2	71.3	70.8	±	0.9	a
EM + 80 O.M.	72.7	71.9	72.3	±	0.7	a
$LSD_{Trt*Irrig.}$	10.3		LSD_{Trt}	N.S		
Irrigation mean	70.4 ± 1.56	70.0 ± 8.79				
$LSD_{Irrig.}$	N.S					

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 87. Moisture content (%) of *Zea mays* L. kernels responding to different treatment applications under drought stress in 2023, MATE - Gödöllő.

MOISTURE %						
Treatments	Irrigation		Treatment mean			
	No Irrigation	Irrigation				
160 NH_4NO_3	16.3	17.2	16.8	±	1.14	a
160 O.M.	14.5	14.6	14.5	±	0.27	ab
240 NH_4NO_3	16.3	17.9	17.1	±	0.99	ab
240 O.M.	14.6	14.8	14.7	±	0.34	ab
320 NH_4NO_3	16.2	17.2	16.7	±	0.96	bc
320 O.M.	15.1	15.3	15.2	±	0.70	bc
80 NH_4NO_3	16.5	17	16.7	±	0.95	bc
80 O.M.	14.8	16.2	15.5	±	1.25	c
CONT.	15.3	16.5	15.9	±	0.78	cd
EM	15.4	16.5	15.9	±	0.65	cde
EM + 160 NH_4NO_3	15	15.3	15.2	±	0.33	cde
EM + 160 O.M.	14.9	14.2	14.5	±	0.81	cde
EM + 240 NH_4NO_3	15.2	16	15.6	±	0.78	de
EM + 240 O.M.	14.3	14.7	14.5	±	0.63	e
EM + 320 NH_4NO_3	15.8	15.9	15.9	±	0.34	e
EM + 320 O.M.	14.8	14.3	14.6	±	0.67	e
EM + 80 NH_4NO_3	14.9	15.8	15.3	±	1.03	e
EM + 80 O.M.	14.8	14.2	14.5	±	0.75	e
LSD $_{Trt*Irrig.}$	1.2		LSD $_{Trt}$	0.9		
Irrigation mean	15.3 ± 0.90 b	15.8 ± 1.28 a				
$LSD_{Irrig.}$	0.28					

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

Table B.5. 88. Quantum yield (QY) of *Zea mays* L. responding to different treatment applications under drought stress measured at the tasselling growth stage (VT) in 2023, MATE - Gödöllő.

QY				
Treatments	Irrigation		Treatment mean	
	No Irrigation	Irrigation		
160 NH_4NO_3	0.73	0.78	0.76 ± 0.07	a
160 O.M.	0.75	0.74	0.74 ± 0.10	a
240 NH_4NO_3	0.78	0.8	0.79 ± 0.03	a
240 O.M.	0.74	0.75	0.75 ± 0.04	a
320 NH_4NO_3	0.81	0.77	0.79 ± 0.03	a
320 O.M.	0.78	0.75	0.77 ± 0.07	a
80 NH_4NO_3	0.75	0.75	0.75 ± 0.06	a
80 O.M.	0.78	0.71	0.75 ± 0.06	a
CONT.	0.75	0.76	0.75 ± 0.07	a
EM	0.75	0.8	0.77 ± 0.07	a
EM + 160 NH_4NO_3	0.78	0.78	0.78 ± 0.05	a
EM + 160 O.M.	0.72	0.75	0.74 ± 0.04	a
EM + 240 NH_4NO_3	0.74	0.78	0.76 ± 0.04	a
EM + 240 O.M.	0.69	0.77	0.73 ± 0.05	a
EM + 320 NH_4NO_3	0.74	0.81	0.78 ± 0.05	a
EM + 320 O.M.	0.74	0.75	0.74 ± 0.02	a
EM + 80 NH_4NO_3	0.75	0.74	0.75 ± 0.04	a
EM + 80 O.M.	0.7	0.75	0.72 ± 0.04	a
$LSD_{Trt*Irrig.}$	0.091		LSD_{Trt}	N.S
Irrigation mean	0.75 ± 0.06	0.76 ± 0.05		
$LSD_{Irrig.}$	N.S			

* Different lowercase letters present significant differences between the means ($p < 0.05$), according to LSD multiple, starting sequentially with the letter (a) being the most significant; NS means non-significant differences in (column) between the means ($p < 0.05$), according to LSD multiple; O.M. is the organic matter, EM is the effective microorganisms.

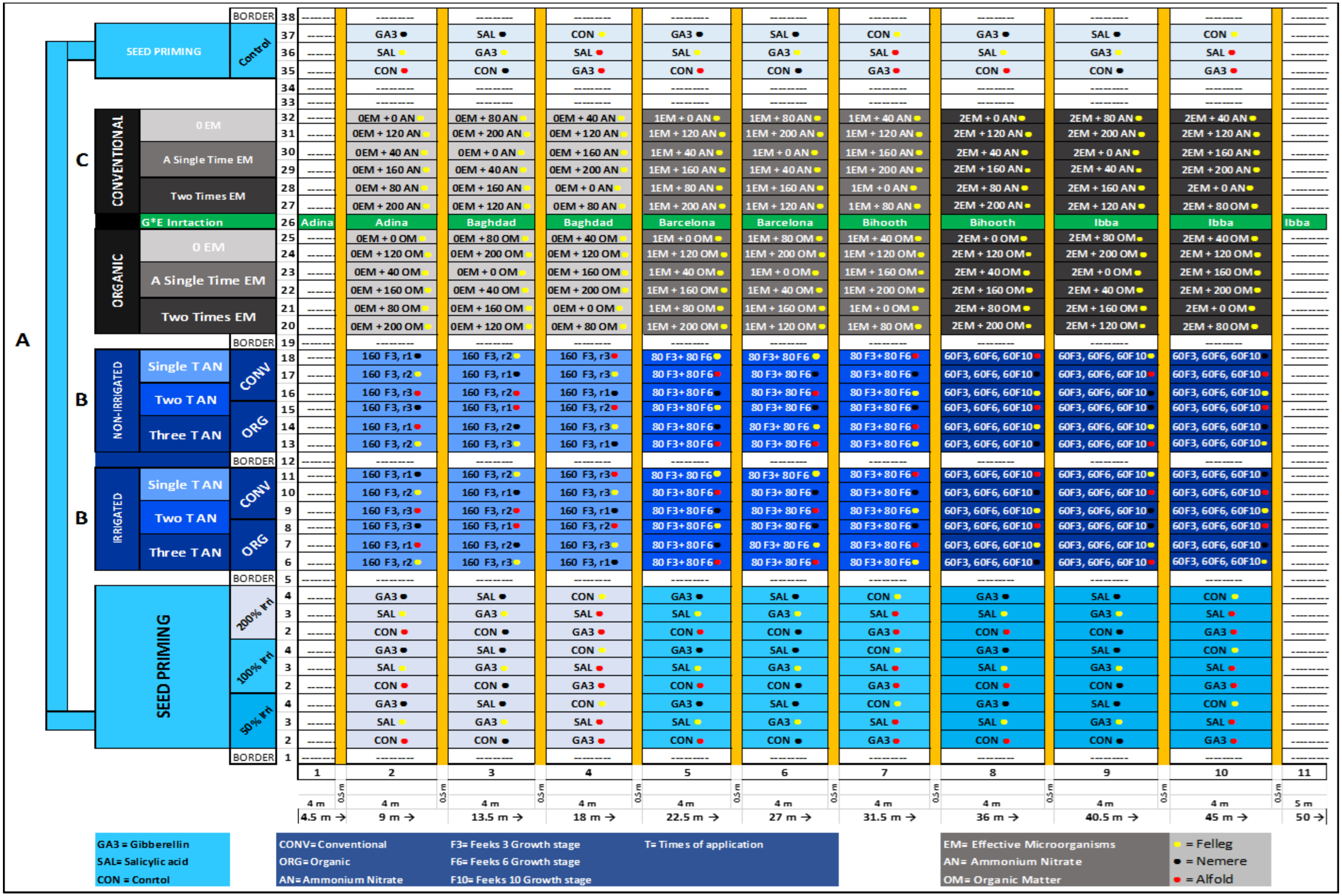


Figure B.4. 1. Wheat field set up map for the agricultural season 2022-2023, MATE - Gödöllő.

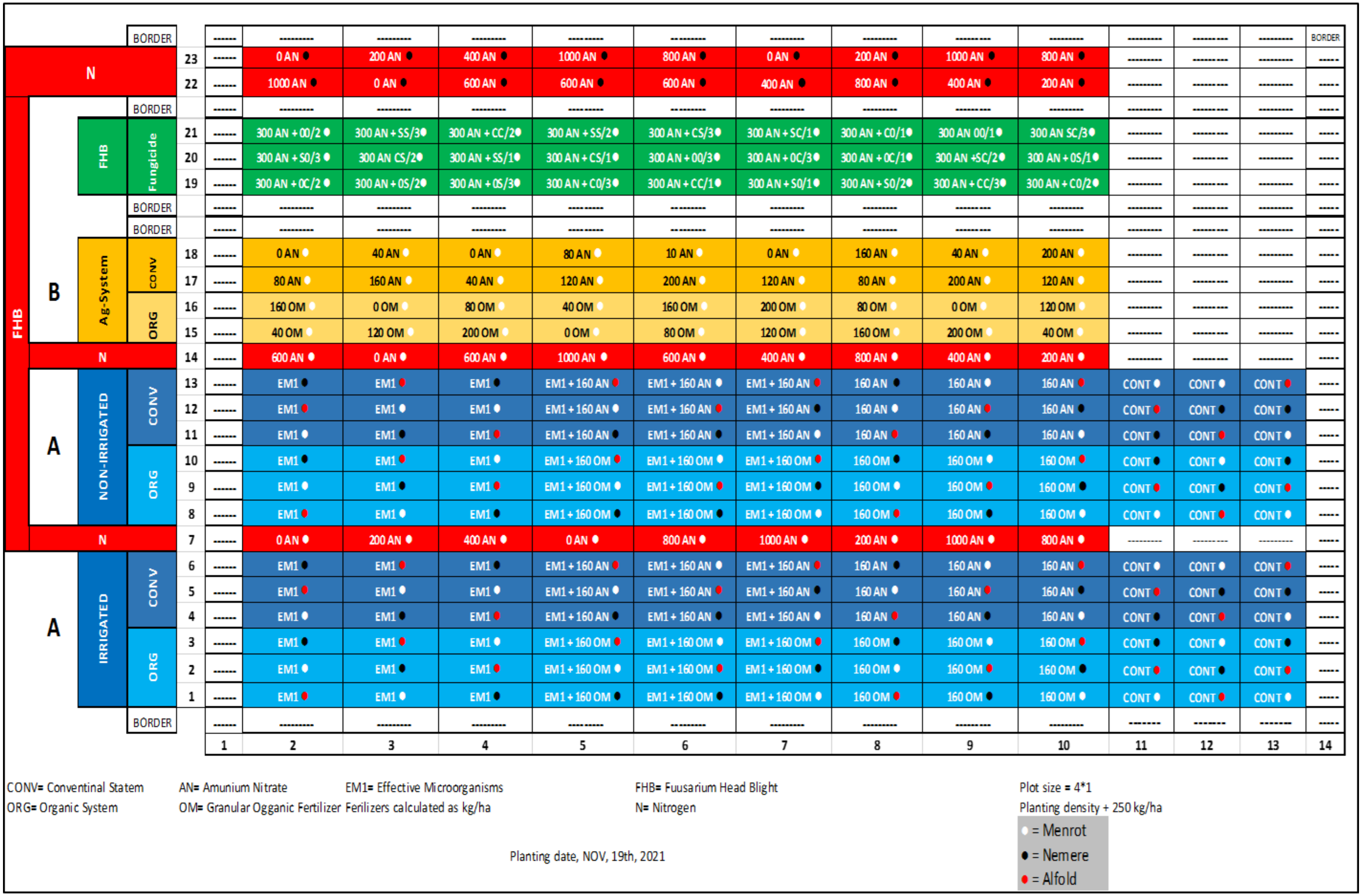


Figure B.4. 2. Wheat field set up map for the agricultural season 2021-2022, MATE - Gödöllő.

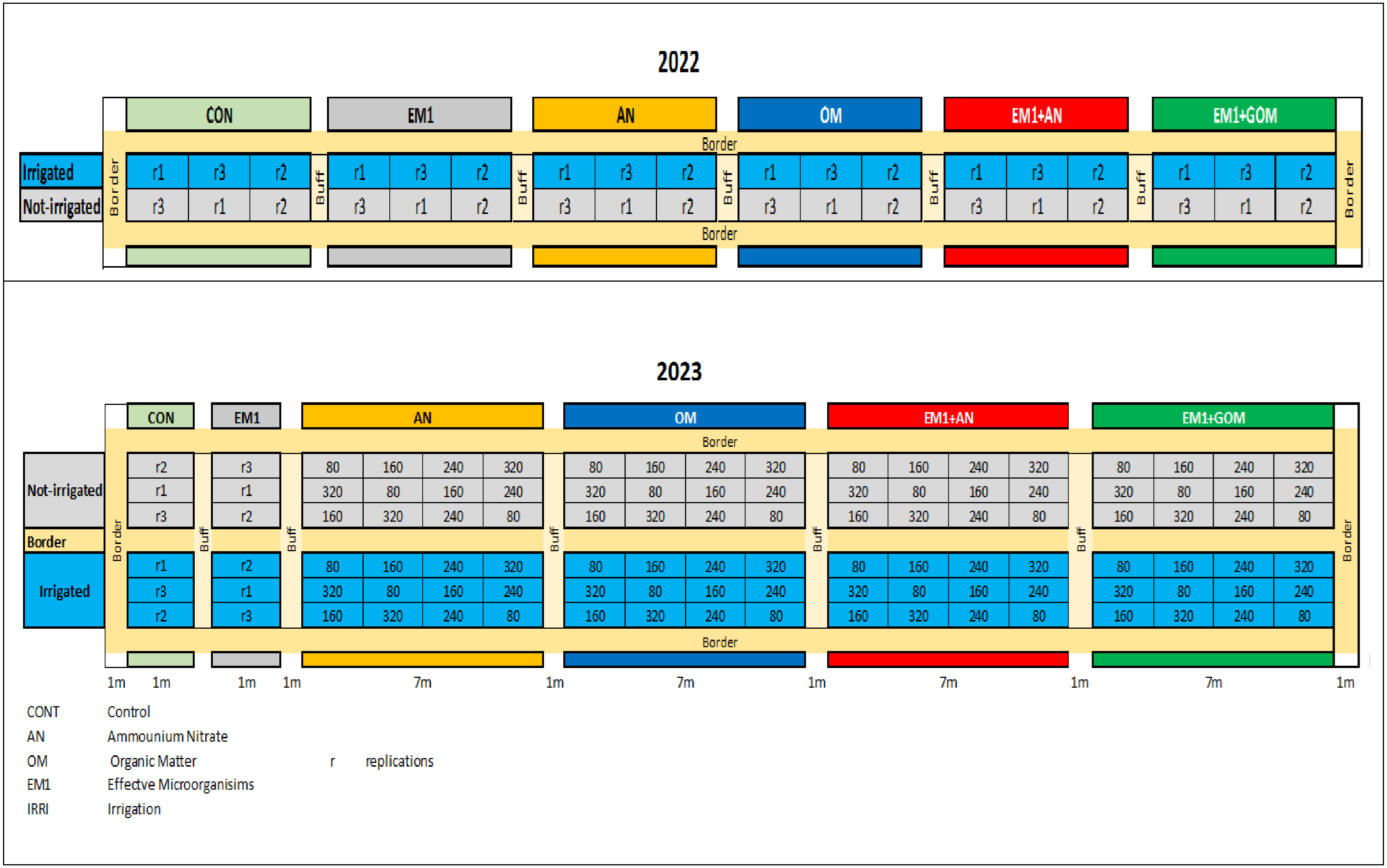


Figure B.4. 3. Maize field set up map for the agricultural season 2022 and 2023, MATE - Gödöllő.

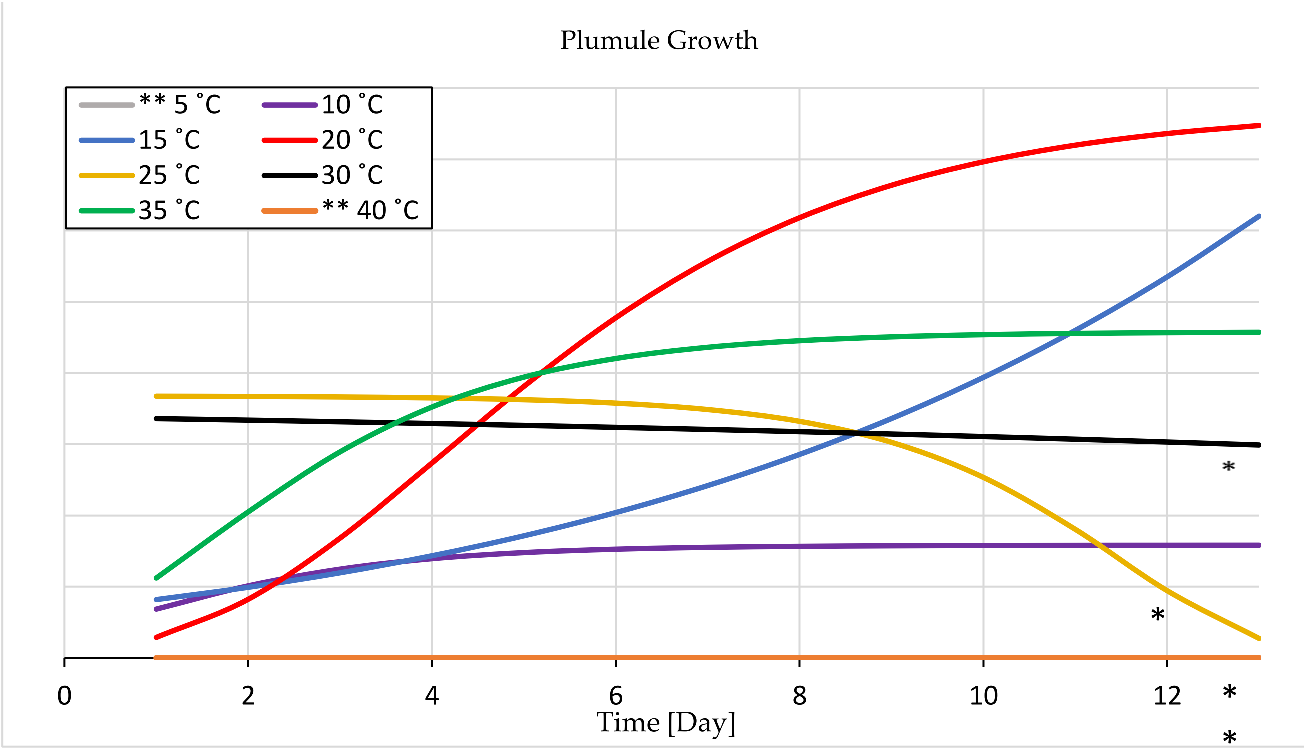


Figure B.5. 1. Maize shoot growth in response to temperature.

* growth dropped down because of fungal growth at favorable temperature conditions. ** they are not shown on the graph because their value is zero (no plumule growth).

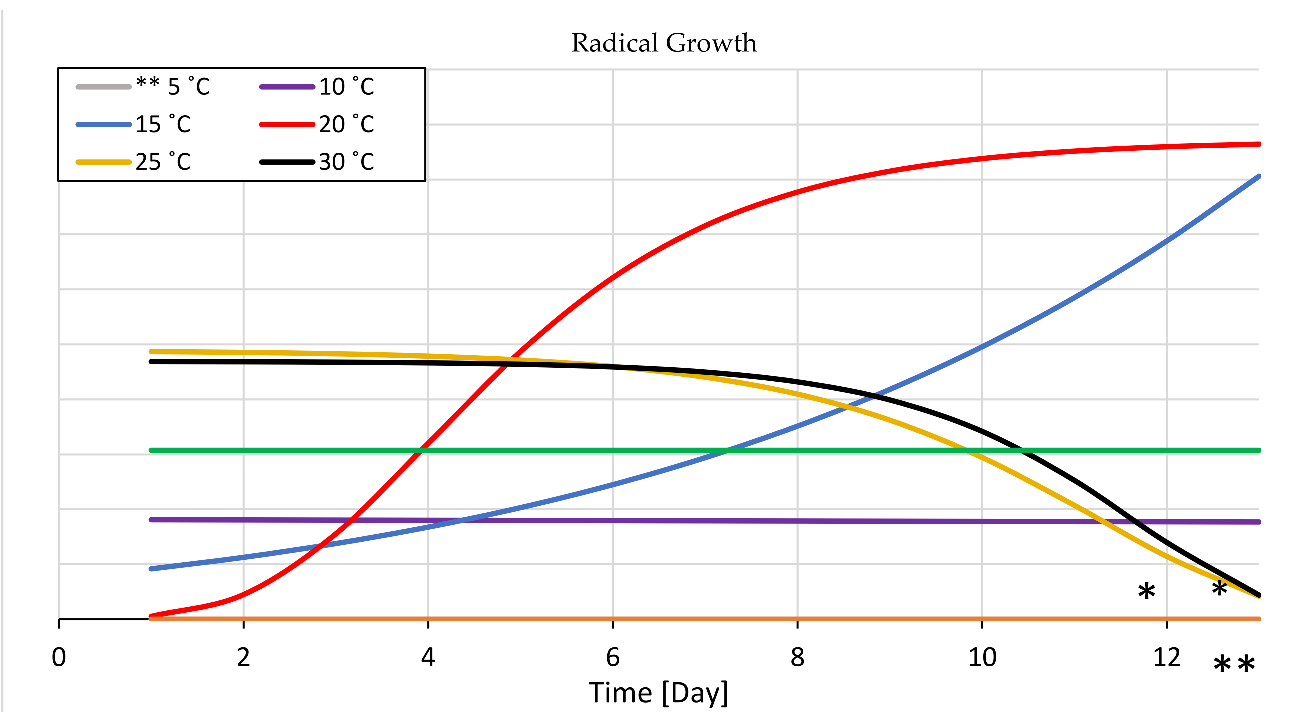


Figure B.5. 2. Maize radicle growth in response to temperature.

* growth dropped down because of fungal growth at favorable temperature conditions. ** they are not shown on the graph because their value is zero (no radicle growth).

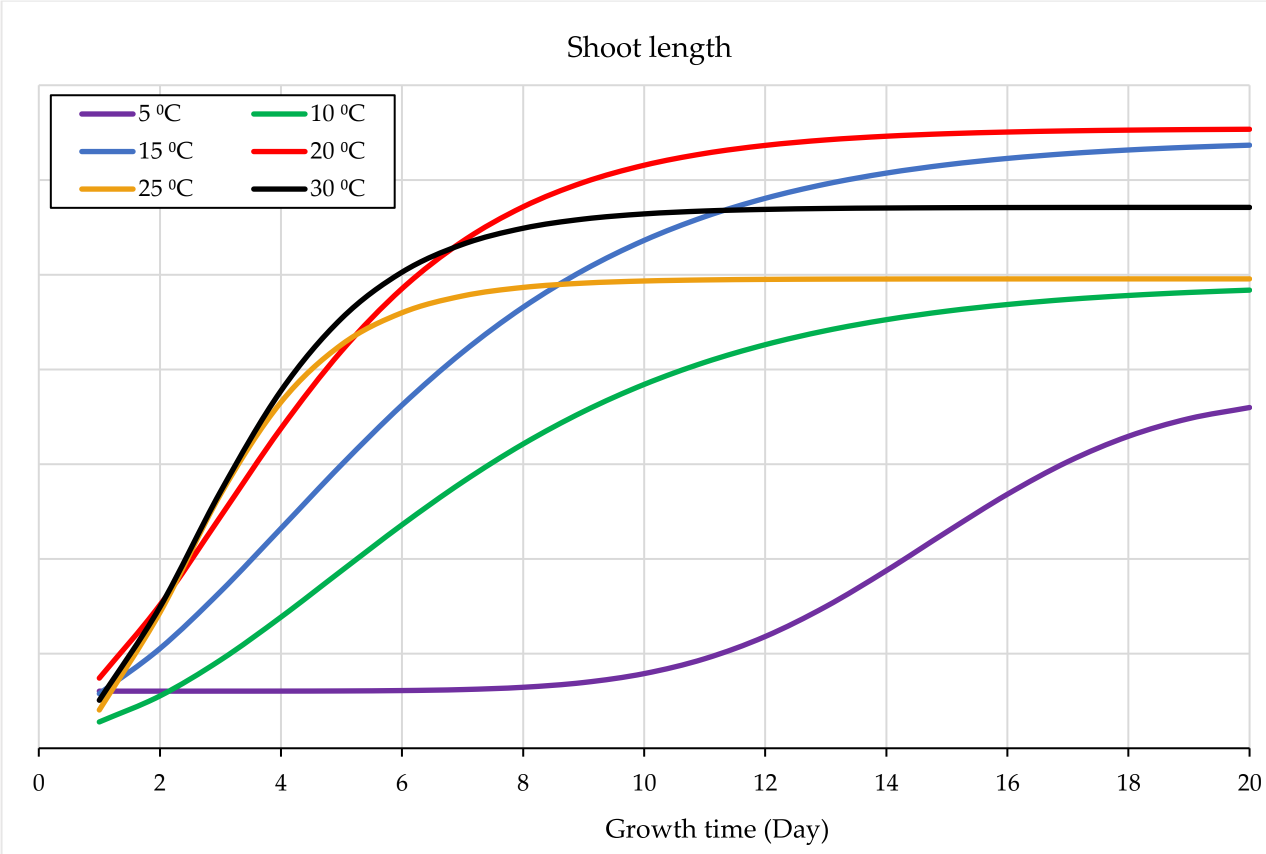


Figure B.5. 3. Patterns of wheat shoot development in response to temperature-induced.

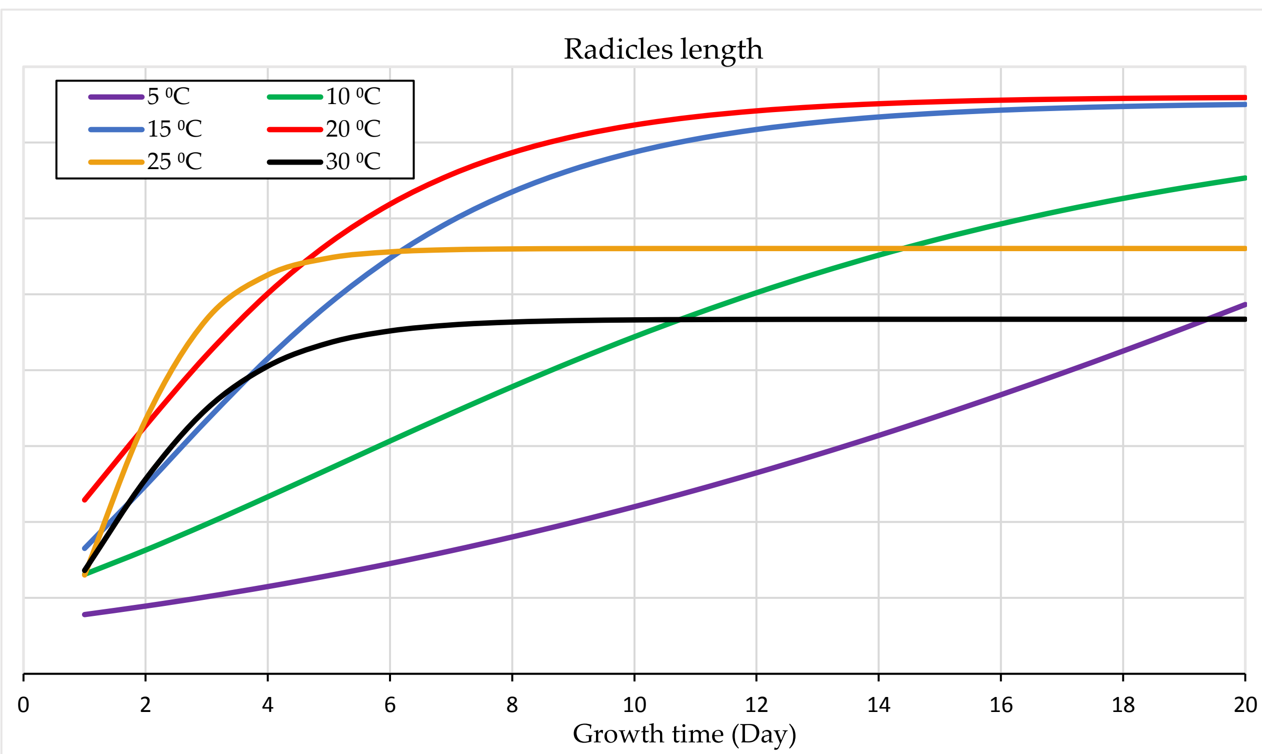


Figure B.5. 4. Patterns of wheat radicles development in response to temperature-induced.

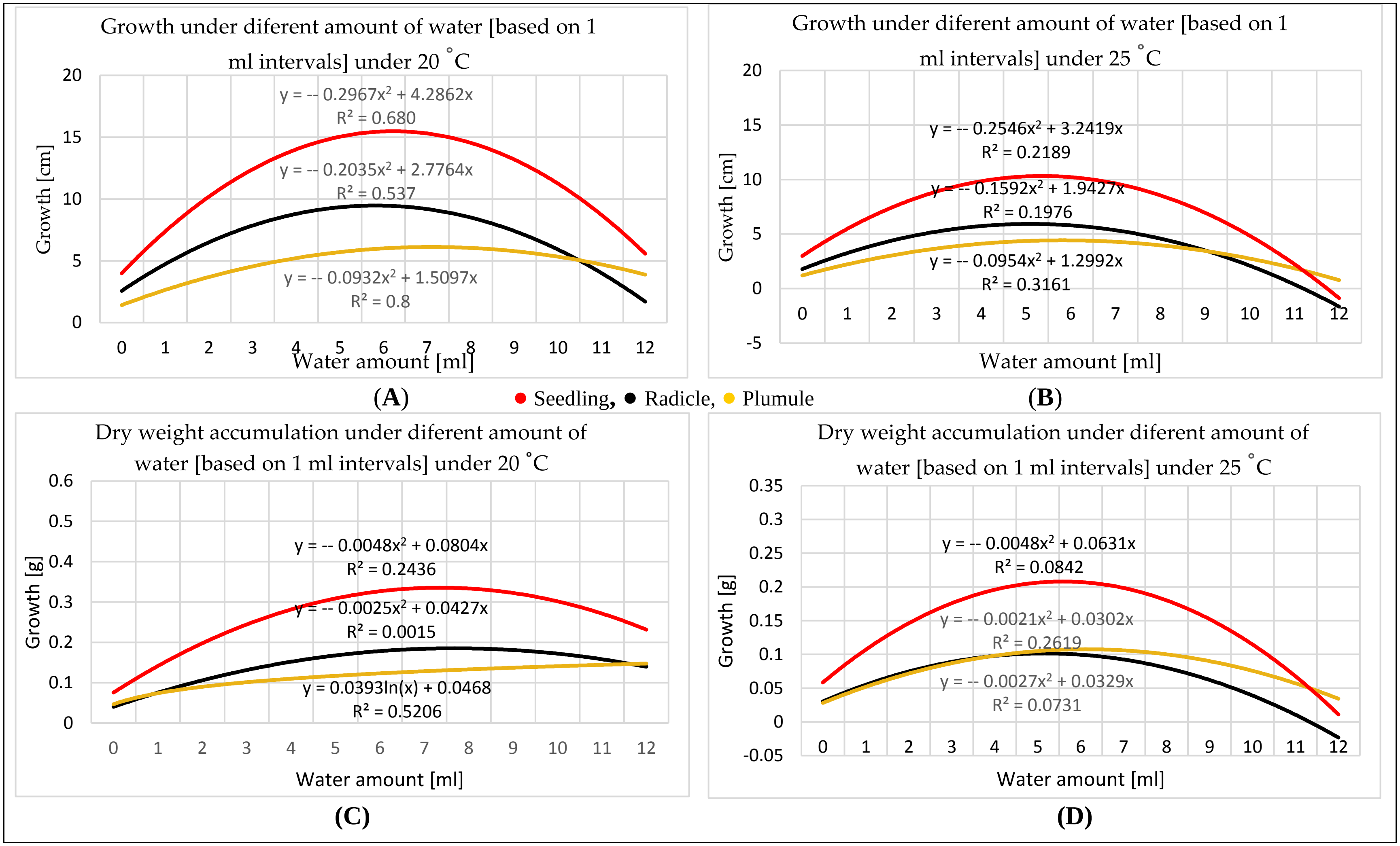


Figure B.5. 5. Seedlings, shoot, and radicle response to the different amounts of water at 2 temperature levels, 20 and 25 °C.

(A) Growth using different amounts of water based on 1 ml intervals (1–12) at 20 °C. (B) Growth using different amounts of water based on 1 ml intervals (1–12) at 25 °C. (C) Dry weight accumulation using different amounts of water based on 1 ml intervals (1–12) at 20 °C. (D) Dry weight accumulation using different amounts of water based on 1 ml intervals (1–12) at 25 °C.

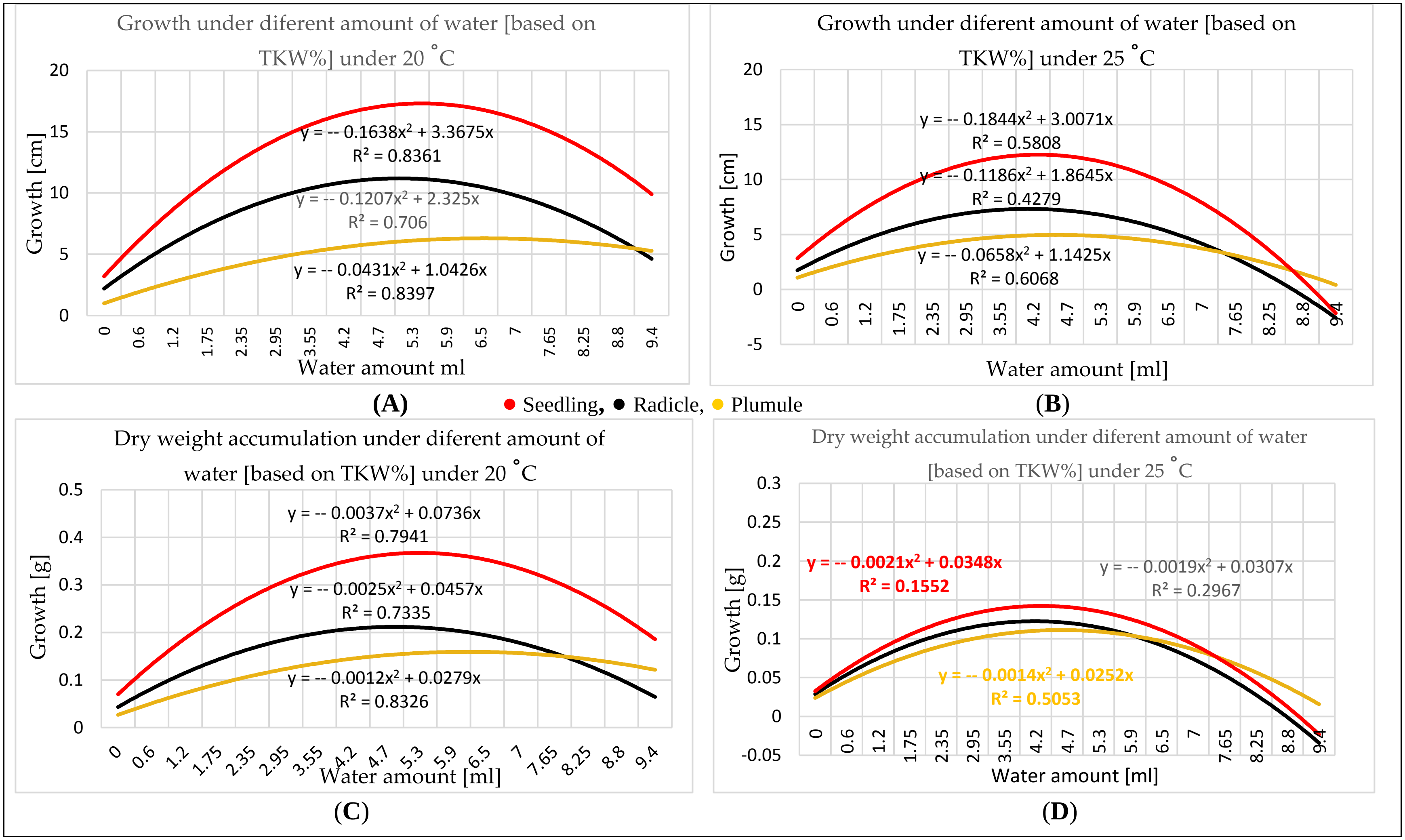


Figure B.5. 6. Seedlings, shoot, and radicle response to the different amounts of water at 2 temperature levels, 20 and 25 °C. (A) Growth using different amounts of water based on TKW% at 20 °C. (B) Growth using different amounts of water based on TKW% at 25 °C. (C) Dry weight accumulation using different amounts of water based on TKW% at 20 °C. (D) dry weight accumulation using different amounts of water based on TKW% at 25 °C.

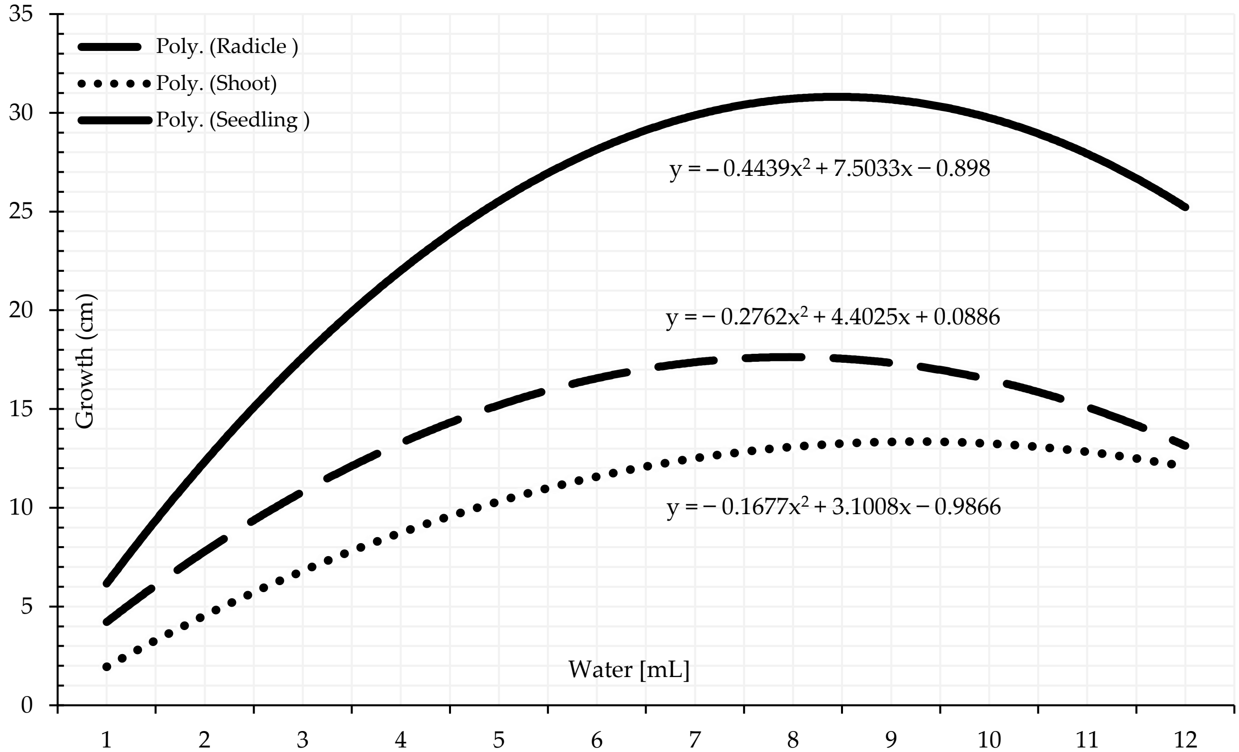


Figure B.5. 7. Seedling growth of wheat in response to water amount based on 1 ml intervals.

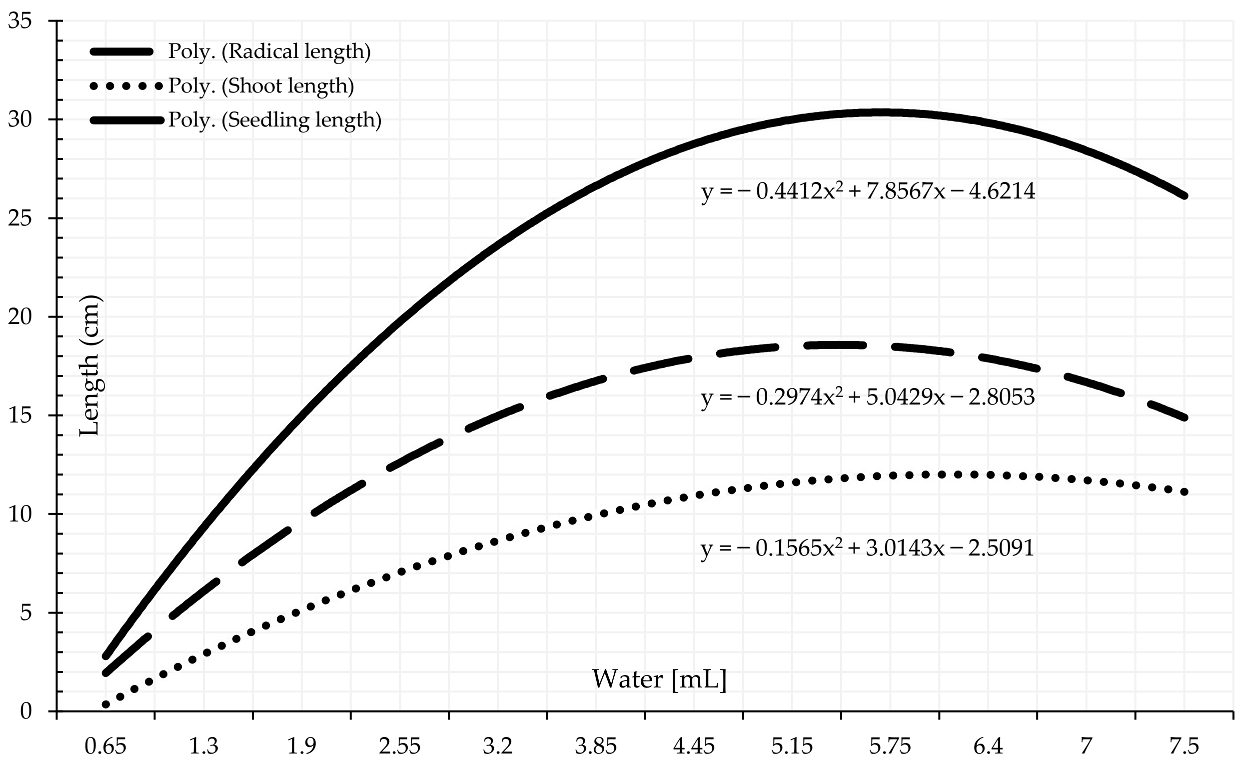


Figure B.5. 8. Seedling growth of wheat in response to the water amount based on TKW.

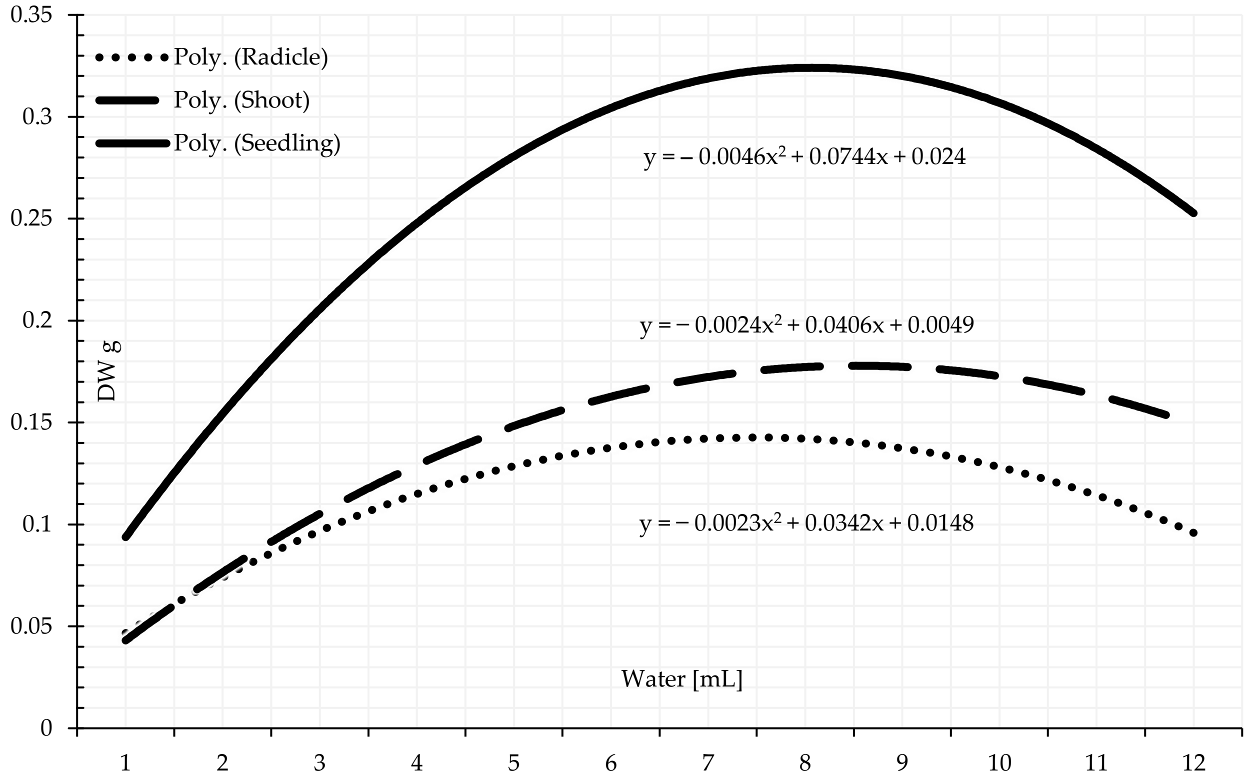


Figure B.5. 9. Seedling growth of wheat based on dry matter in response to the water amount based on 1 ml intervals.

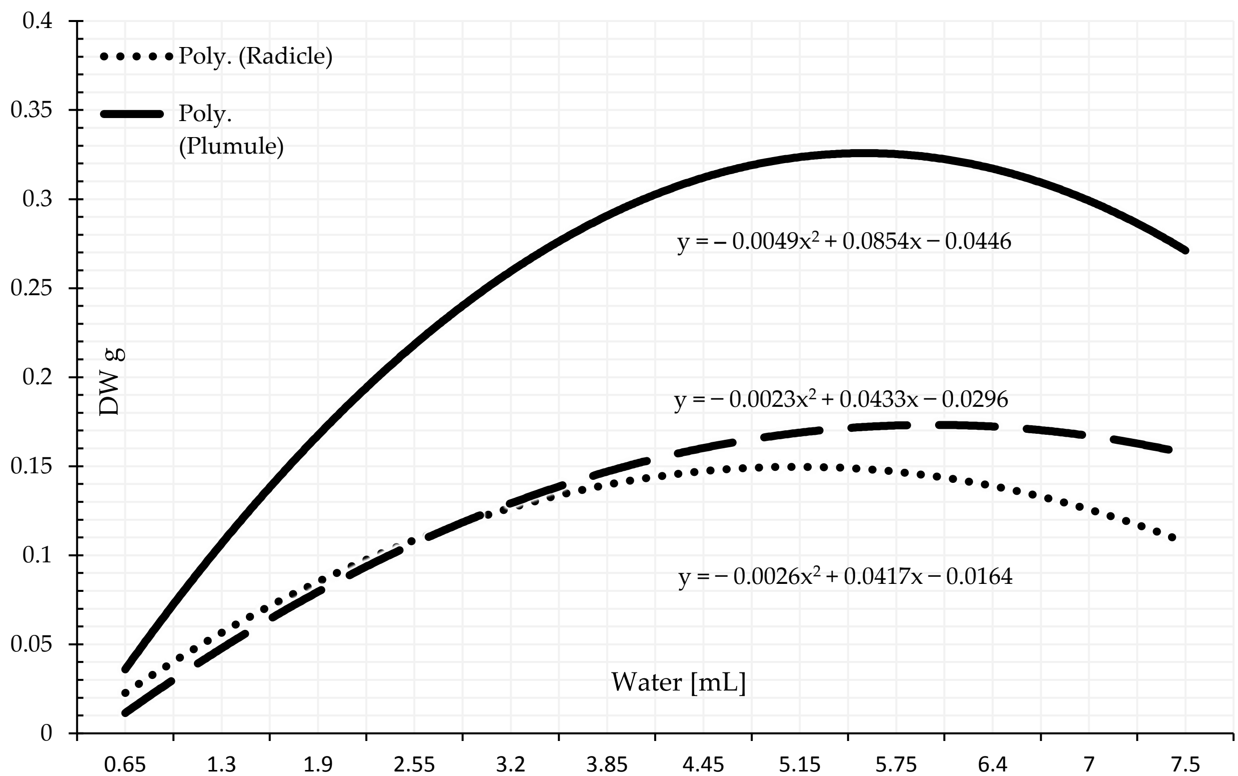
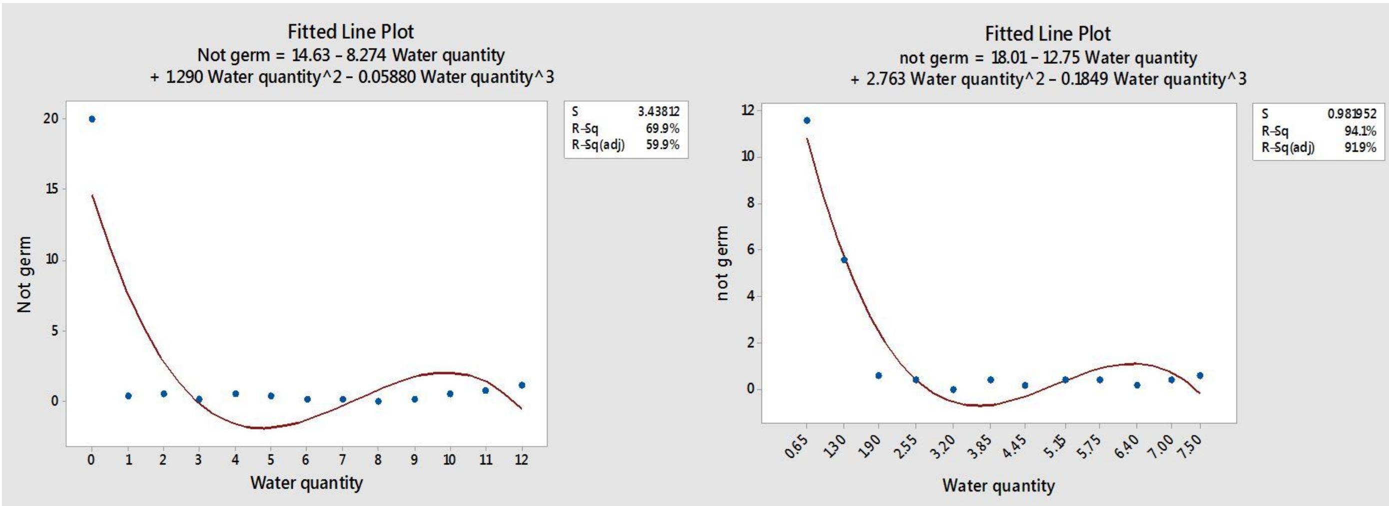


Figure B.5. 10. Seedling growth of wheat based on dry matter in response to water amount based on TKW.



(**A**) (**B**)

Figure B.5. 11. Wheat seeds germination ability under different water quantities.

25 seeds 20 seeds 15 seeds

Figure B.5. 12. Petri dish density of 25, 20, and 15 seedlings in a 9 cm Petri dish.
The 25 seeds in the Petri dish show the intensive density and growth pattern. The 20 seeds in the Petri dish show a high density and growth pattern. The 15 seeds in the Petri dish show the density and growth pattern.

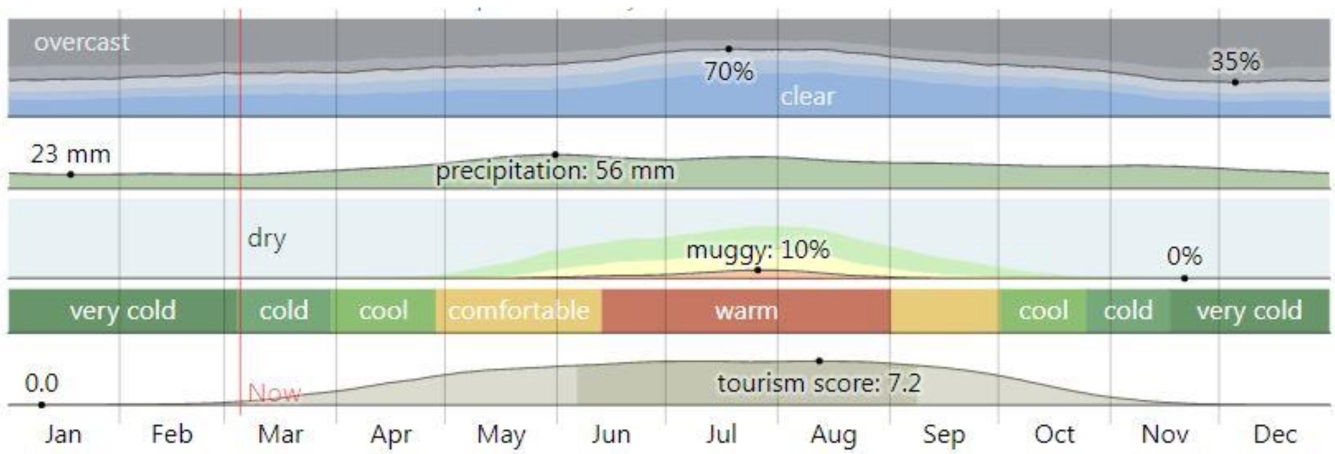
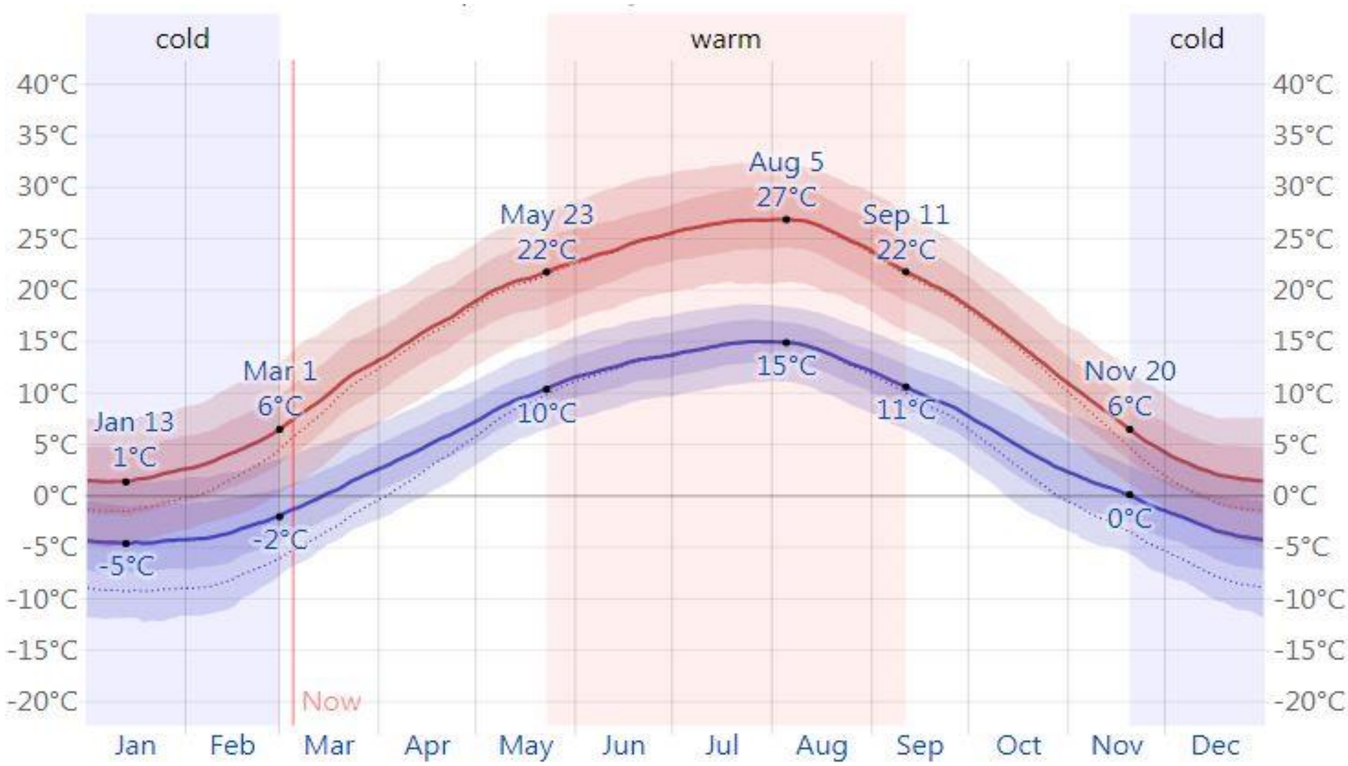


Figure B.5. 13. Average climate in Gödöllő, Hungary, Gödöllő weather by month. Source: https://weatherspark.com/



The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	2°C	4°C	10°C	16°C	21°C	24°C	26°C	26°C	21°C	15°C	7°C	2°C
Temp.	-1°C	0°C	5°C	11°C	16°C	19°C	21°C	20°C	16°C	10°C	4°C	-0°C
Low	-4°C	-3°C	0°C	5°C	10°C	13°C	15°C	14°C	10°C	5°C	0°C	-3°C

Figure B.5. 14. Average High and Low Temperature in Gödöllő. Source: https://weatherspark.com/

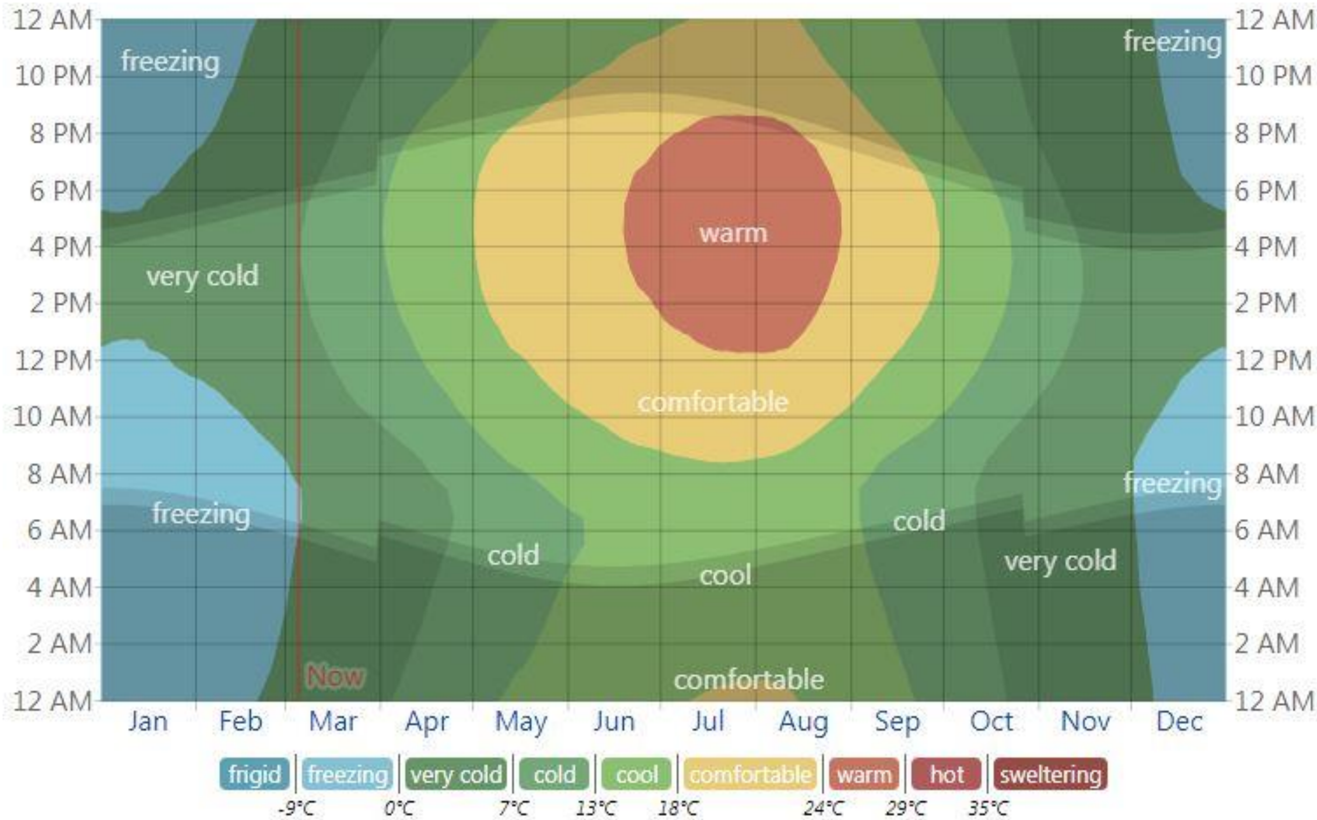
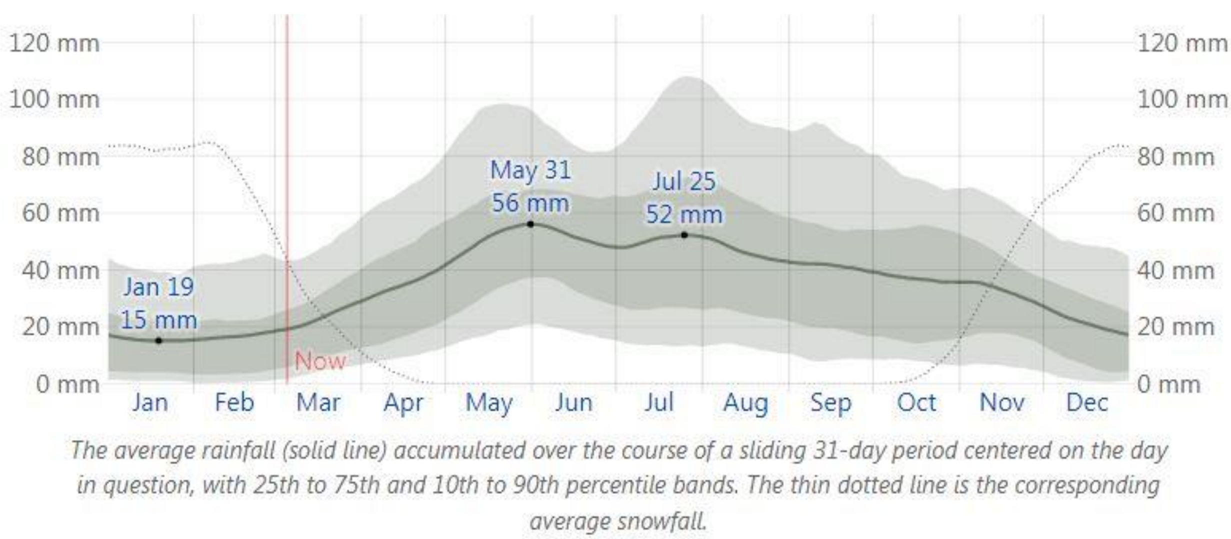


Figure B.5. 15. The average hourly temperature, color coded into bands. The shaded overlays indicate night and civil twilight. Source: https://weatherspark.com/



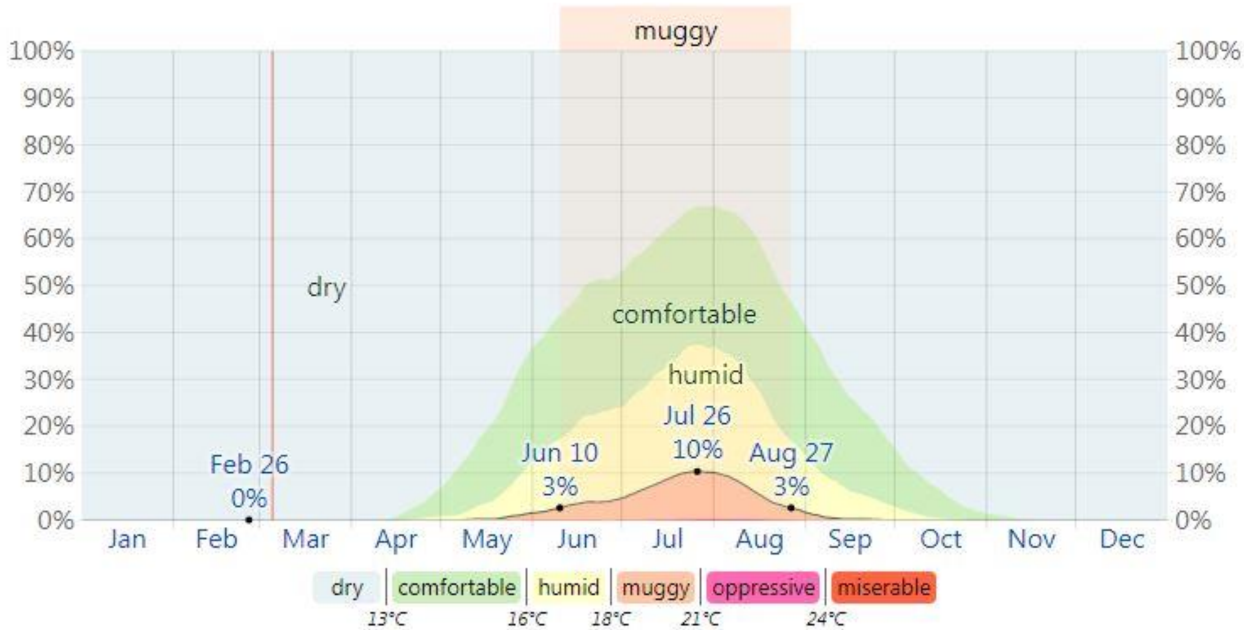
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	15.2mm	16.5mm	22.7mm	34.5mm	51.7mm	51.8mm	51.3mm	45.9mm	41.8mm	36.8mm	33.2mm	21.1mm

Figure B.5. 16. Average Monthly Rainfall in Gödöllő. Source: https://weatherspark.com/

The percentage of days in which various types of precipitation are observed, excluding trace quantities: rain alone, snow alone, and mixed (both rain and snow fell in the same day).

Days of	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rain	2.5d	2.8d	4.4d	6.2d	8.9d	8.2d	7.7d	6.9d	5.9d	5.3d	4.7d	3.1d
Mixed	0.9d	0.7d	0.5d	0.1d	0.0d	0.0d	0.0d	0.0d	0.0d	0.1d	0.5d	0.9d
Snow	1.3d	1.2d	0.4d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.0d	0.6d	1.2d
Any	4.7d	4.7d	5.2d	6.3d	8.9d	8.2d	7.7d	6.9d	5.9d	5.4d	5.7d	5.2d

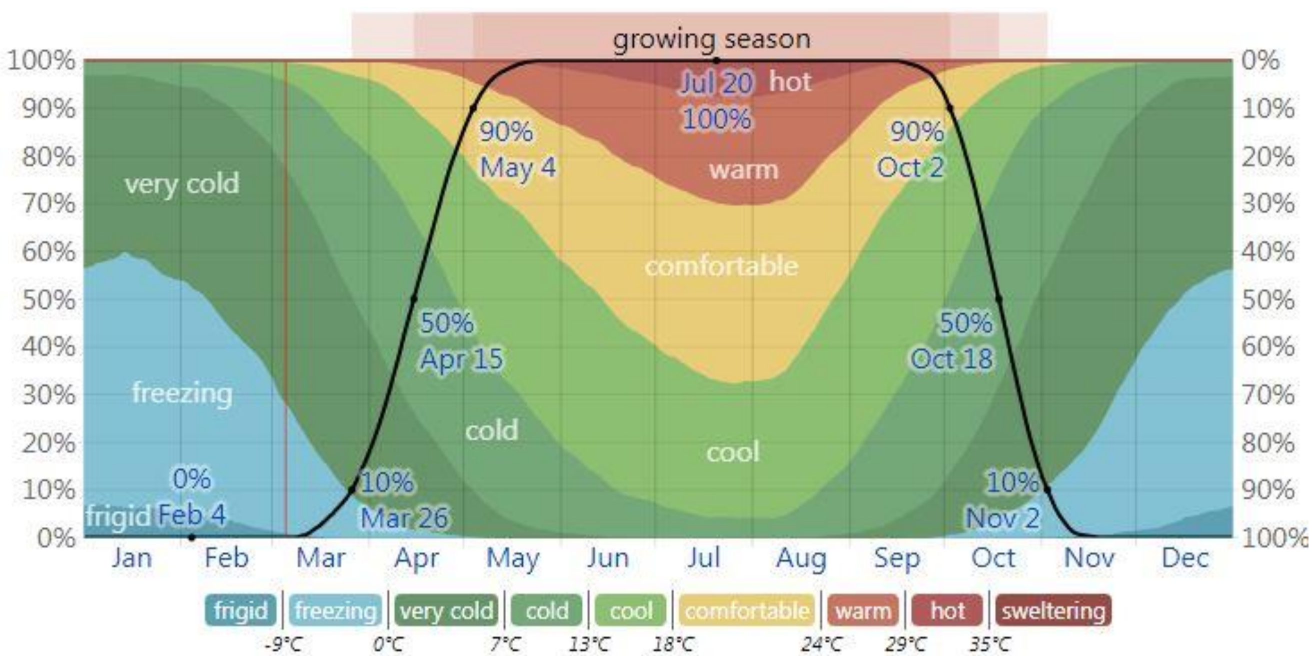
Figure B.5. 17. Daily Chance of Precipitation in Gödöllő. Source: https://weatherspark.com/



The percentage of time spent at various humidity comfort levels, categorized by dew point.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Muggy days	0.0d	0.0d	0.0d	0.0d	0.1d	0.9d	2.6d	1.8d	0.1d	0.0d	0.0d	0.0d

Figure B.5. 18. Humidity Comfort Levels in Gödöllő. Source: https://weatherspark.com/



The percentage of time spent in various temperature bands. The black line is the percentage chance that a given day is within the growing season.

Figure B.5. 19. Time Spent in Various Temperature Bands and the Growing Season in Gödöllő.
Source: https://weatherspark.com/

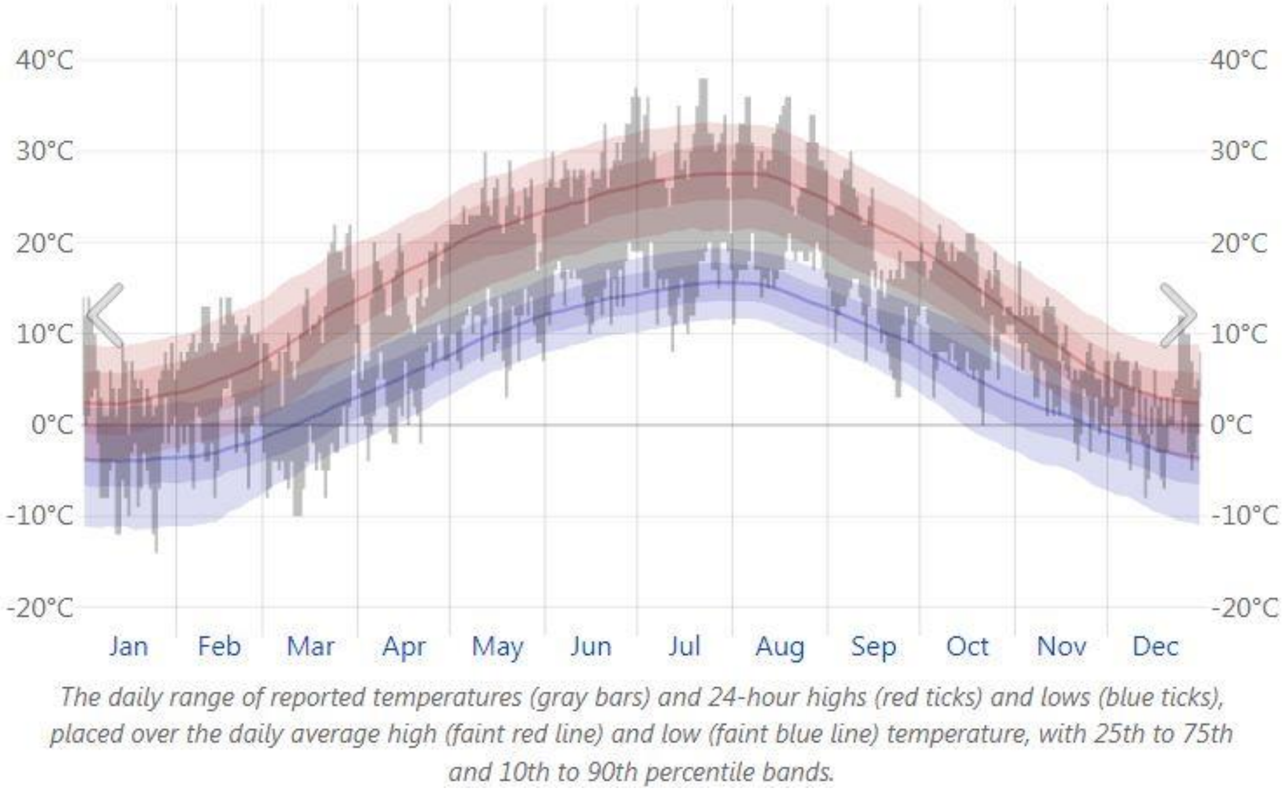


Figure B.5. 20. Gödöllő Temperature History 2022. Source: https://weatherspark.com/

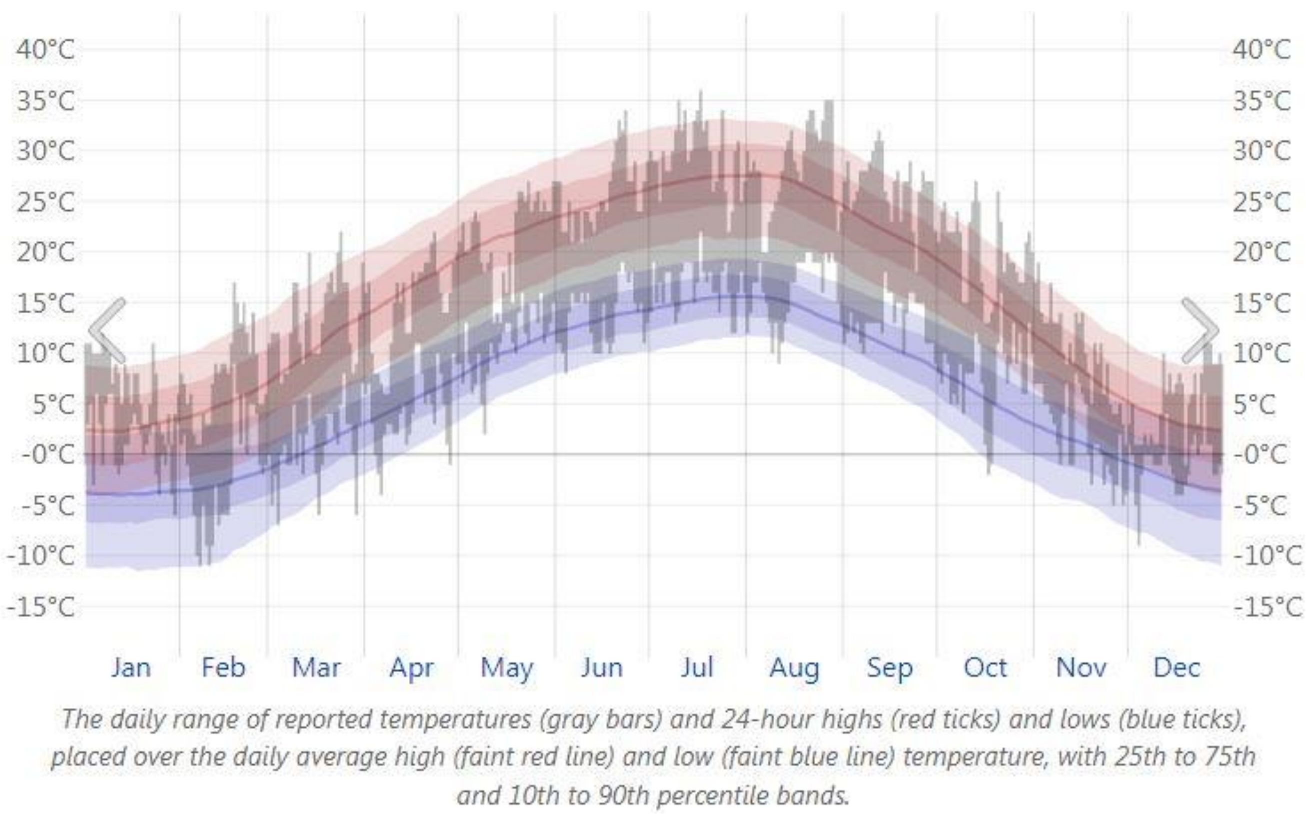
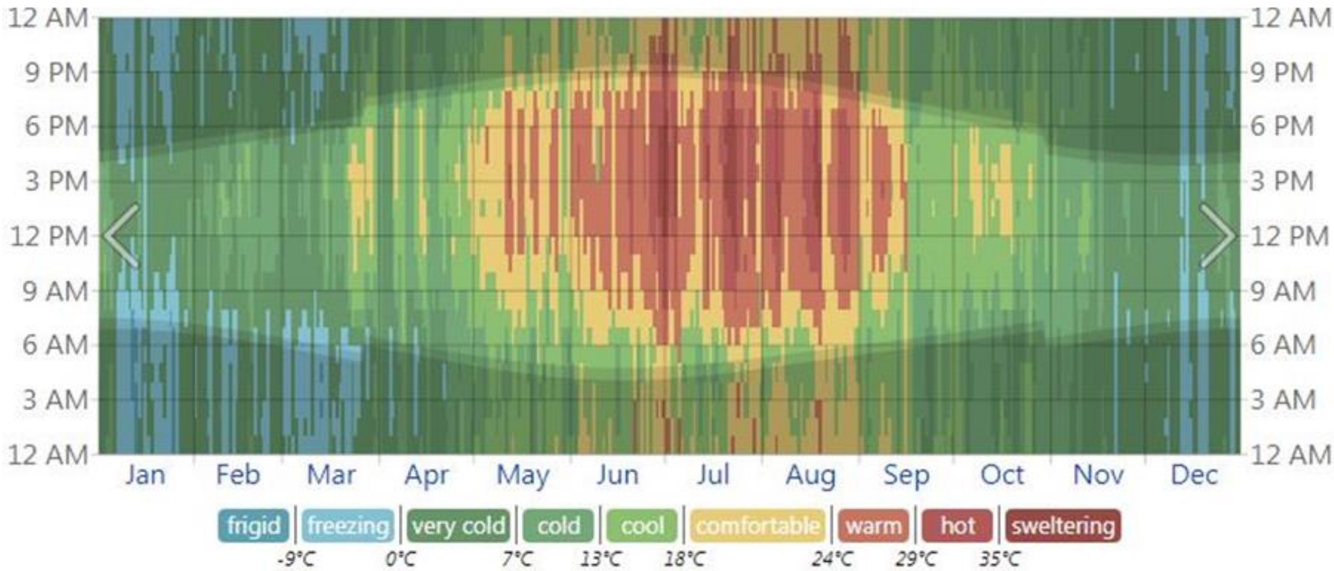
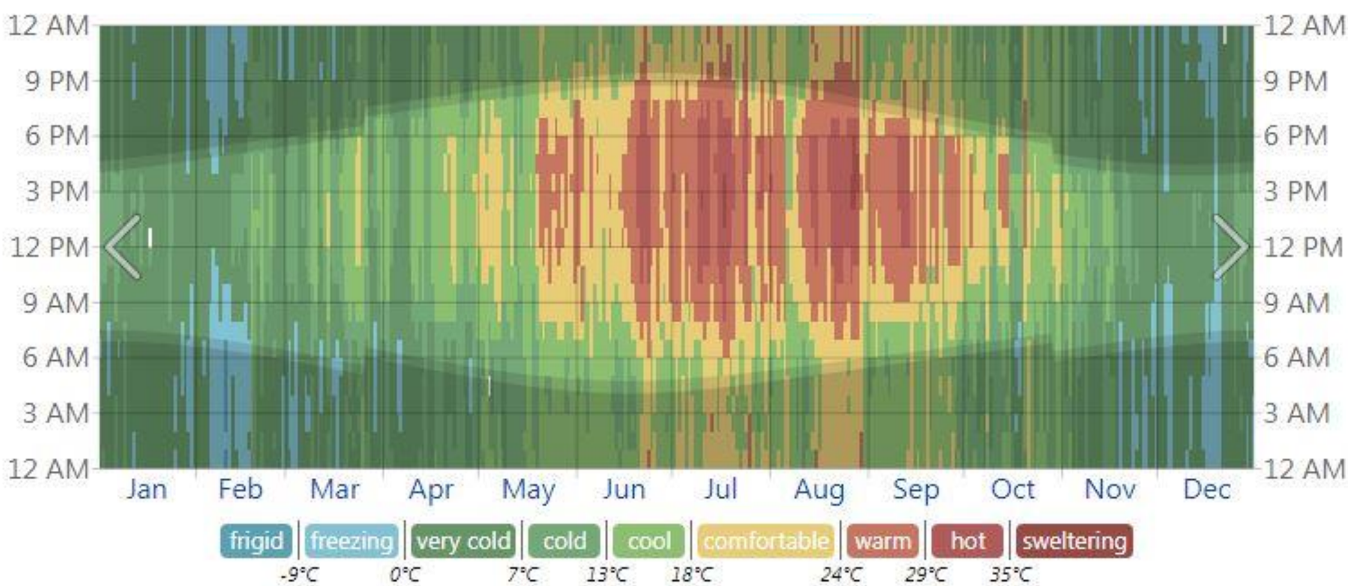


Figure B.5. 21. Gödöllő Temperature History 2023. Source: https://weatherspark.com/



The hourly reported temperature, color coded into bands. The shaded overlays indicate night and civil twilight.

Figure B.5. 22. Hourly Temperature in 2022 at Gödöllő. Source: https://weatherspark.com/



The hourly reported temperature, color coded into bands. The shaded overlays indicate night and civil twilight.

Figure B.5. 23. Hourly Temperature in 2023 at Gödöllő. Source: https://weatherspark.com/

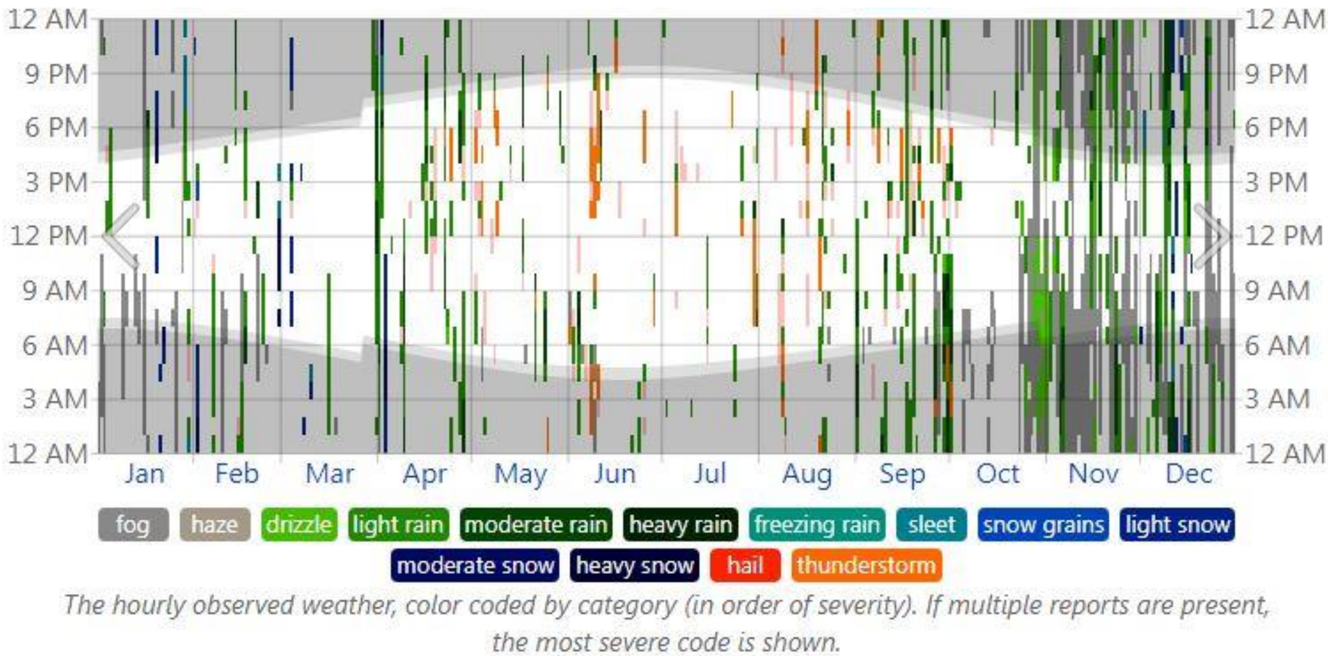


Figure B.5. 24. Observed Weather in 2022 at Gödöllő. Source: https://weatherspark.com/

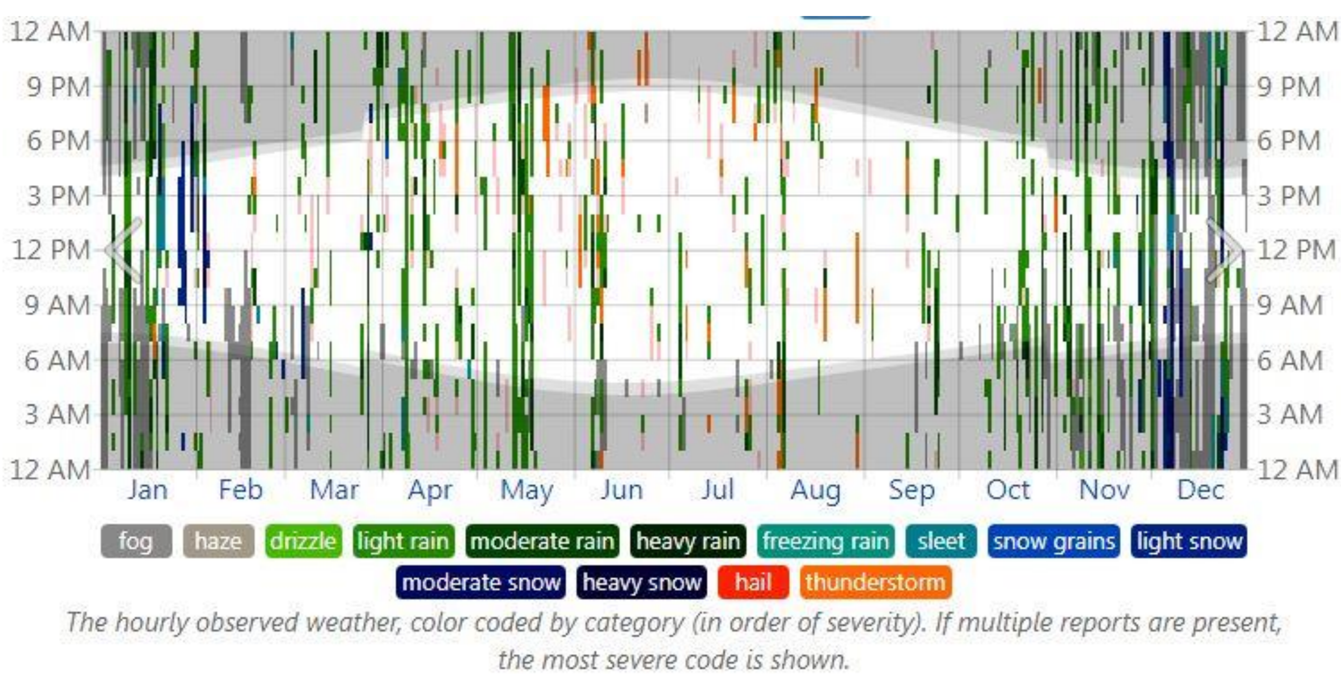


Figure B.5. 25. Observed Weather in 2023 at Gödöllő. Source: https://weatherspark.com/

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