THESIS

MWANGI TERESIA NYAMBURA

CROP PRODUTION ENGINEERING

Gödöllő

2023

Hungarian University of Agriculture and Life Science

Szent István Campus

MSc Crop Production Engineering

Thesis Title: **EFFECT OF NITROGEN APPLICATION RATES ON MAIZE YIELDS AND YIELD COMPONENTS.**

Primary Supervisor: Dr. Akos Tarnawa, Professor.

Independent Consultant: Márton Jolánka Professor.

Author: Mwangi Teresia Nyambura

RTW05G

Institute/Department: Crop Production

Gödöllő

2023

ACRONYMS

ANOVA - Analysis of variance

N - Nitrogen

LSD - Least significant difference

GPS - Global Positioning System

C4 - Carbon fixation pathway

FAO - Food and Agriculture Organization

ATP - Adenosine triphosphate

NADH - *Nicotinamide Adenine Dinucleotide Hydrogen*

NADPH - Nicotinamide adenine dinucleotide phosphate

NUE - Nitrogen use efficiency

SPAD – Soil plant analysis devevelopment

NPK - Nitrogen, phosphorus, and potassium

TABLE OF CONTENTS

LIST OF FIGURES

LIST TABLES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

The most significant crop for human nutrition is cereals, which provide 70% of the world's population with food and 75% of their overall calories, and over fifty percent of the protein humans require. The current worldwide problem is to sustain and raise the bar for food production while protecting biodiversity. Corn has a considerable grain and dry matter output, a variety of nutritional benefits in the provision of sugars and culinary oils, and it is particularly significant in the agricultural economies of different nations. Maize (*Zea Mays L*.) is a significant plant cultivated throughout most of the world as an essential food source and fodder crop in various climates. Regarding the land under cultivation and productivity, it ranks third behind rice and wheat (Mousavi & Nagy, 2021).

Maize is widely used in biofuels, animal feed, and various industrial goods, including syrup and maize starch, in addition to being directly consumed in the human diet. The energy density of maize grains is 1.53 MJ per 100 g, with almost 72% being starch, 10% being protein, and 4% being fat. The Poaceae family's C4 crop species, maize, is slightly vulnerable to abiotic challenges such as inadequate nutrients, drought, and water stress (Khaeim et al. 2022). With the increasing world population projected to strike nine billion by 2050 (FAO, 2022) and with global production exceeding two billion metric tonnes, which is likely to increase in the future, placing pressure on the already worst situation, the crop is faced with a myriad of challenges not limited to salt intolerance, heat stress, nutritional deficiency, nutrient inadequacies, and drought impeding optimal global output.

Raising maize productivity for sustained economic and income growth underpinning demand for food for humans and animals alongside other industrial uses can be realized through breeding strategies, biotechnological technologies, and agronomic management practices. Crop breeding and biotechnology require much time and enormous financial investment to achieve the desired results. Agricultural technology, such as inorganic fertilizers, pesticides and farm machinery use, robots, temperature and humidity sensors, aerial photos, and GPS technology, are currently used to increase productivity. This advanced equipment, precise farming and robotic systems enable farmers to be more profitable, efficient, safer, and environmentally friendly. These inputs availability makes are necessary for the use of natural resources and processes to improve agricultural production and reduce costs. Farmers no longer need to apply water, fertilizer, and pesticides evenly across the land. Instead, they can use the least amount and target very specific areas or even treat different plants has been seen as a solution for inorganic fertilizers. Higher yields have been achieved by conducting more intensive cropping with significant fertilizer input. (Raina, 2021).

Low nutrient utilization efficiency, however, is the outcome of the excessive and uneven use of fertilizers, causing a decrease in yield due to physiological factors, toxicity or induced deficiency of other nutrients within the plant or in the soil, and interactions with other elements (Pandey et al. 2021) through biomass accumulation and partitioning interference such as excess N causing lodging, excess nickel (Ni) supplementation displaces magnesium (Mg^{2+}) ions from Rubisco, resulting in a loss of enzyme activity and higher tissue concentrations of zinc (Zn) reduce the uptake of phosphorus (P) and vice-versa (S. B. Mohammed et al. 2021). Therefore, nutrient stress has the largest effect on growth, crop health and yield. According to Bhusal et al. (2021) research, maize output must increase, particularly in emerging countries, to fulfil the rising demand for food for humans and animals. As proper and balanced nutrition improves maize health and its resistance to abiotic stress, studies addressing the impacts of nutritional shortages must receive more attention based on nutrient-enhancing technology.

Nitrogen is the most restrictive nutrient for growth, and its availability in the soils significantly impacts maize development, biomass output, and yield. The application of Nitrogen fertilizer has been realized to be highly effective, significantly impacting the yield and grain quality (Hammad, Chawla, Jawad, Alhuqail, Bakhat, Farhad, Khan, Mubeen, Shah, Liu, Harrison, Fahad, et al. 2022) as maize is more sensitive and more tolerant to Nitrogen fertilizer, counteracting the effect of decreasing fertility of the soil levels due to the low rates and uneven nutrient applications and declining arable land causing nutrient depletion. Excessive N-application is catastrophic to maize growth, such as lodging, due to increased succulency and environmental degradation. Nitrogen is a key requirement in achieving a higher yield of maize. Still, an increase of N-fertilizer to a certain level after that has adverse effects following the law of diminishing returns.

He added that low N supply at the middle growth stage and silking stage causes slow crop growth rate, slowing down reproductive structures growth and thus decline, resulting in lower grain yield (and its components) as well as lesser harvest index and leaf area, reducing dry matter accumulation hence need for optimum supply dose of N at critical stages. This information is lacking in demonstrating how early soil N status in the season affects maize growth and its response to delay N application.

In sub-Saharan Africa (SSA), for instance, unsustainable food production has resulted from insufficient and uneven fertilizer application throughout farm fields and high fertilizer costs are some of the impediments to sustainable food production in the region, with farming practiced mainly by 70–80% resource-poor smallholder farmers (Tamene et al. 2015). In contrast to the industrialized world, which includes China, Europe, and North America, optimal inorganic fertilizer use has resulted in food sufficiency (Bindraban et al. 2015). This unbalanced use of fertilizers requires to be bridged, which renders the intervention profitable.

Due to N losses through leaching and volatilization, an evaluation study has been proposed to understand the optimal quantities of N application mitigating income loss in purchasing N-fertilizer in addition to soil and water pollution. The broad objective of the study targets to contribute towards food and nutritional security and environmental sustainability by identifying and recommending optimal levels of N-fertilizers in maize. The study specifically seeks to determine the optimal levels of Nitrogen for maximum quantity and quality of yield and yield components while maintaining environmental sustainability and to identify the effect of Nitrogen on proximate and minerals biochemical composition of maize derived from the use of different volumes of N-fertilizers use. It was hypothesized that there is no significant difference in the levels of N-fertilizers application on yield, and there are no significant differences in proximate composition and mineral contents of maize under different levels of N-fertilizers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Maize as a crop.

2.1.1. Taxonomy, origin, and diversity of maize.

In terms of the output of cereal crops worldwide, maize (*Zea mays L.*) comes in third place behind rice and wheat. It is extensively cultivated all over the world in a variety of agroecological conditions. Because it is a C4 species, maize effectively uses moisture and sunlight to generate a high yield and total dry matter. As the world's human population continues to grow, there is a growing demand for maize cultivation as a source of food, pasture, oil, and biofuel (Badr et al. 2020). The grown maize plant, commonly known as "corn" in some regions of the world, is a member of the genus *Zea*. It is part of the Andropogoneae tribe of the Poaceae family and subfamily Panicoideae. The same genus has other wild species of maize, but these are wild grasses (known as teosintes) and are not cultivated(O Awata et al. 2019).

About 9000 years ago, in the Balsas area of southwest Mexico, maize was domesticated from the wild grass (Z. mays subsp. *parviglumis*). Teosinte is a general name that refers to any wild taxon from any of the five species of *Zea* (Stitzer and Ross-Ibarra, 2018). These species are widespread throughout most Central America and well suited to their unique local conditions. The tripartite theory went as far as to claim that the parent of maize was an extinct popcorn and that teosinte originated through hybridizations between corn and the closely related species Tripsacum, with further hybridizations leading to the diversity of maize we see today. According to the alternate teosinte hypothesis, maize's primary ancestor was teosinte (Stitzer & Ross-Ibarra, 2018).

Three hypotheses have been put out on the evolutionary genesis of corn. The first claimed that maize was created by Tripsacum being crossed with teosinte. The following claims it originates after a truncated maize variety and that teosinte is a product of Zea and Tripsacum cross-pollination. The tertiary and best well-known explanation states edible corn descended from teosinte. The theory holds that maize descended from extinct popping corn, which had glumes covering each kernel (García-Lara & Serna-Saldivar, 2018). Additionally, it was discovered that Teosinte and Tripsacum couldn't pair up in nature or a laboratory setting.

These two genera's pollen further supported the conclusion that teosinte didn't originate from their hybridization.

The utmost widely recognized hypothesis regarding the ancestry of maize holds that teosinte, due to unlimited and prevalent access, is the ancestor natural hybridization between teosinte and corn. It states the presence of the same number of chromosomes (n=10) with the same structure in both species and several anatomical traits, such as similar morphological pollen characteristics among cultivars (García-Lara & Serna-Saldivar, 2018).

Around 6000 years ago, maize is thought to have been cultivated for use as food. With the discovery of the Americas by European explorers in the fifteenth century, the crop was first introduced there before spreading to Sub-Saharan Africa and the rest of the world. Each area has preserved certain maize cultivars over time that are tailored to its environment (O Awata et al. 2019). Even though substantial impacts made possible by alleles at a small number of genes were crucial, domesticated maize did not develop because of selection only but also on a few genes. The allelic trajectories and phenotypic alterations underlying the events that gave rise to modern maize can be partially understood using genetic and genomic methods, even if we may never be able to fully reconstruct these processes. Hence, the domestication of maize and the contrast with teosinte offer a historical and phenotypic framework for comprehending both the causes and effects of selection (Stitzer & Ross-Ibarra, 2018).

2.1.2 Trends in maize distribution, production, and consumption in Hungary.

Maise and sunflower are the two most significant broad-row crops in Hungary. The most significant feed crop, maize, has been cultivated in an area in Hungary that exceeds 1 million hectares for several decades. After wheat, maize is the crop that is most widely grown in the European Union. Production vastly outpaces consumption, leading to a sizable trade surplus because of the quantity of land and favourable weather. The industry, however, is susceptible to extreme weather events like heat waves and droughts.

The crucial significance of corn in terms of both supply and demand may be supported by numerous aspects. On the contribution side, it is important to draw attention to factors like the good cultivation potential of the arable land in Hungary, the favourable weather, and the presence of farmers with substantial production experience. The vast and different uses of corn are the key component on the demand side. Feed corn is an essential raw material in animal breeding, in addition to the food industry uses such as isosugar, maize mush, canned maize, and feed. The industrial uses, such as the manufacturing of alcohol, should also not be overlooked. Maize is a big agricultural export crop as well since the production level vastly surpasses the need in the local market (Mizik & Rádai, 2021).

Sowing time, row spacing, planting depth, and seed quantity are the primary sowing factors that have a significant impact on the yield. Changes in soil temperature have an impact on when to plant corn since it needs a temperature of 8 to 12 °C to germinate. Recently, because of climate change, the soil warmth reaches 10 °C in the first part of April. As a result, the prior understanding of the ideal sowing period needs to be revised. The best period to plant now is between April 10 and May 2(Tóth & Czakó, 2021). Using a pneumatic seed drill, maize is seeded in rows with a row spacing of 70–76 cm and seeds spaced 16–22 cm apart. The FAO method is used to report hybrid maturities, and FAO group 200 to 600 maturities are the most prevalent range for Hungarian hybrids. A high FAO number means a higher yield, but 500-600 hybrids can only be used in the southern part of Hungary or the Transdanubia region (Bojtor, Mousavi, et al. 2021).

Typically, the sowing depth is 5 to 6 cm. The homogeneity of sowing depth and the invariant stem distance are two aspects of sowing quality. For the possible highest yield, the best sowing conditions, including timing and quality, are essential. In comparison to hybrids with longer growth durations, shorter hybrids have a broader ideal planting time interval. Depending on the hybrid, the ideal plant density ranges from 63,000 to 73, 000 plants per hectare. (Tóth & Czakó, 2021) in their previous research discovered that 70 000 plants per hectare were the ideal density, with the yield drastically reducing with lower or higher densities.

2.1.3 Maize types

It is possible to raise corn of several kinds (flour corn, flint corn, dent corn, sweet corn, popcorn, waxy corn, and amylomaize) and colours (from white to yellow to red to purple). Soft corn, also known as floury corn (*Zea mays var. amylacea*), is a kind of corn that is primarily white in colour with rounded or flat crowns and a little amount of challenging starch. *Zea mays var. indurata*, sometimes referred to as Indian corn or flint corn, is a kind of maize with a hard shell and a soft starch in the middle. Its colour limits are white to red. Dent maize (*Zea mays var. indentata*) has a sunken crown and is either white or yellow in colour.

In comparison to other corn varieties, sweet corn (*Zea mays var. saccharata and var. rugosa*) has a greater sugar content and is eaten in a variety of ways, including simmered, baked, frozen, and tinned. As the endosperm of popcorn (*Zea mays var. everta*) is filled with thick starch, it pops more easily and is mostly utilized for popcorn. Amylopectin makes up 99% of the starch in waxy maize (*Zea mays var. ceratina*), with very low trace levels of amylose. A paste made from waxy cornstarch mimics potato starch in that it has a low tendency to retrograde and a high diffusion. Several foods, like fruit pies, frozen foods, canned foods, and dairy products. and non-food products, such as gummed cassettes, employ waxy cornstarch. White maize is recommended for nixtamalized items like tortillas because it has a white endosperm that has more vitreous endosperm than floury endosperm. The anthocyanins found in blue, purple, and red maize kernels have shown antioxidant and bioactive characteristics (N. Singh et al. 2019).

2.1.4 Importance of maize

Alongside output volume of over one metric billion tons annually, maize has spread far across the world (García-Lara & Serna-Saldivar, 2018), and it is now the most common staple cereal on the planet. According to (Erenstein et al. 2021), the succeeding highest extensively second-largest farmed cereal in the globe is wheat is maize for dry grain, which is planted annually on an estimated 197 M hectares of land worldwide. By 2030, maize is expected to replace wheat as the most extensively produced grain, based on present trends and the relatively stable wheat acreage (Erenstein et al. 2021). In addition to the many conditions, it may thrive in, including the tropics, subtropics, and temperate zones, it is a C4 plant and has great photosynthetic efficiency.

Human feed, livestock, poultry, and industrial usage make up the three categories of maize consumption in Hungary. Since it provides energy for cattle and poultry, maize grain is highly significant. It is also greatly used for gaining weight and utilized in most countries, accounting for around 80% of maize harvests. Maize grain is also utilized in the industrial sector. Several food items, including starch, maize, syrup, and dextrose, can be made by hydrolyzing maize starch. In addition to numerous industrial uses, dry maize starch is utilized in the food industry. As it produces the grain that is used to make ethanol, maize is a prime choice for ethanol production (Nasir Mousavi et al. 2019).

2.1.5 Agronomic requirements

Climatic conditions.

The primary producing zones for corn farming are determined by climate. Although maize is cultivated in a variety of agroclimatic circumstances, some weather elements significantly affect the crop's capacity for yield. Climate variability influences a wide range of management techniques. Temperature and moisture interact and have a direct impact on physiological processes as well as elements of development. There are specified temperature thresholds for the most vulnerable phenological periods, including sowing to emergence, anthesis, and grain filling, as well as for essential physiological processes, including leaf initiation, shoot development, and root growth. In terms of phenological periods and developmental stages, corn reacts to temperature in different ways. Temperatures between 21°C and 32°C, development occurs at the quickest pace. Development is less temperature-sensitive during the reproductive phases than it is during the vegetative phases. Ideal conditions are said to include cool nights, sunny days, and average temperatures. Kernel establishment may be poor because of extreme-heat pressure throughout the pollination phase.

Wetness and the soil's ability to hold water are connected. The amount of soil moisture, the nature of the soil, and the need for water in the atmosphere are all considered when determining the corn plant's accessibility to moisture. The quantity of moisture that is accessible to plants in ideal soil is greater than five centimeters per 30 cm of depth of the soil. Through times of high requirement, water usage might overtake precipitation. The volume of water used by maize varies with the crop stage, and this time frame also includes blooming and pollination. Soil moisture reserves are essential to reducing possible stress.

Soil requirements

As maize is highly susceptible to environmental factors, suitable soils and enough water are expected to provide high yields. The pH range of soils in Hungary is rather wide. According to the research, 13% of soil is very acidic and 43% are slightly acidic. In the last ten years, high-dose fertilization may have contributed to a rise in soil acidity in addition to moist and dry deposition from industrial and household pollutants. The amount of nutrients in soils that are accessible to plants also rises as a response to fertilization. In Hungary, the Luvisols, Chernozems, and Vertisols soil types—which collectively account for 70% of the country's total area—dominate the production of maize(Pepó, 2021).

The main agrotechnical component that alters soil structure by altering its physical characteristics, such as soil moisture content, bulk density, and penetration resistance, is tillage. The emergence of seedlings, plant population density, root dispersion, and crop production are all impacted by changes in soil physical qualities brought about by various tillage techniques. In Hungary, the standard tillage method for maize cultivation has been mould board ploughing. It increases the soil's ability to store water and gives good depth. Nonetheless, this tillage technique has considerable potential for water loss and surface runoff while providing only modest topsoil conservation with crop waste. Minimum tillage entails less disturbance of soil and is becoming popular lately (Bramdeo & Rátonyi, 2020).

Nutrition and water management

Proper irrigation and plant nutrition are two essential crop management techniques. The ability of the soil to hold water per unit depth and the depth at which root developments are advantageous and are the main factors controlling water availability. It is critical to keep in mind that some rainfall is lost to evaporation, runoff, and drainage. The quantity water may be held in stock to augment rainfall during cropping seasonc depends on the soil's capacity to store moisture. Fine-textured soils might have an issue with excess water to the point where drainage becomes a crucial management tool (García-Lara & Serna-Saldivar, 2018).

It is important to understand which nutrients are likely to restrict output when it comes to the key elements for plant nutrition. The characterization of essential elements is those that plants obtain from water and air, such as carbon (C), oxygen (O), and hydrogen (H). The soil is the source of the other elements. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) are the six elements that are utilized most frequently. These substances are known as macronutrients, and major nutrients are N, P, and K and secondary macronutrients are frequently used to categorize Calcium, Magnesium, and Sulphur further. Micronutrients, also known as trace or minor elements, are the nutrients that plants need in very minute amounts. They include molybdenum (Mo), iron (Fe), Zinc (Zn), Boron(B), manganese (Mn), copper (Cu), zinc (Zn), and chlorine (CI) (García-Lara & Serna-Saldivar, 2018). Small crop yields and inadequate fertilizer reactivity in some soils are both consequences of imbalanced soil fertilization. Poor or non-responsive soils are ones with little to no yield improvements following fertilizer usage and hence insignificant economic rewards (Njoroge et al. 2018). The physical, biological, and chemical characteristics of soils have a significant impact on water availability, nutrient storage and release, and plant nutrient uptake. (Burke et al. 2019).

Crop protection of maize.

FAO predicts that by 2050, there will be 9.8 billion people on the planet(“Special Report – FAO Crop and Food Supply Assessment Mission (CSAM) to the Republic of Moldova,” 2022). Grain demand is anticipated to expand by at least 2.2 times from 1970 to 2020 in tandem with this expansion (Nishimoto, 2019). The quantity of cultivated land in the globe was essentially the same in 2018 as it was in 1965, in contrast to the increases in grain demand that are required to keep up with population expansion, and no substantial increases are anticipated going forward. There seems to be a global loss in cultivated area per person, especially when paired with the anticipated population expansion (Nishimoto, 2019).

A significant challenge to grain production is climate change. On one hand, rising temperatures would lengthen the growing season in some places, and there is a possibility that higher carbon dioxide levels might make it easier for some plants to fix carbon dioxide through photosynthetic processes, which might enhance grain output. On the other hand, many other regions are probably going to have reduced grain crop yields because of climate change. In addition, many of the places anticipated to see decreased agricultural yields are already significant grain-producing areas. This indicates that the overall crop yield might be significantly impacted by climate change. Globally, the yield decline from 2000 to 2050 is predicted to be 24% for maize, 11% for rice, and 3% for wheat (Nishimoto, 2019).

The yield of maize is constrained by a wide range of abiotic and biotic stresses, which also contribute to a wide range of diseases and poor crop management. A wide range of diseases harm maize plants, with bacterial and fungal infections being the most significant. In addition to multiple fungi-related illnesses maize is susceptible to a few viruses, bacteria, nematodes, other mycoplasma-like organisms, and higher parasitic plants. According to reports, maize harvests have been severely harmed by numerous bacterial and fungal species (Rehman et al. 2021). Important diseases of maize, especially in Hungary, include maize dwarf mosaic virus, fusarium head blight, leaf blotch, seedling blight and foot rot, leaf blight, common rust, common smut, charcoal rot, and eyespot.

Insects are among the most significant of the many variables that restrict the productivity of maize. Many insect pests that attack corn plants can seriously harm the crop and, in cases when the pest population is considerable, result in yield and quality losses. Stem borers, aphids, and thrips are the most devastating damaging insects for maize (Mahmoud et al. 2021). The harm caused by the insect pest complexity depends on the field's population trends, which in turn depend on how dynamically the physical elements of their immediate surroundings affect them. In addition to helping predict insect losses to the crop, a detailed understanding of the precise link between the change in environmental conditions and those in the pest population may also assist in averting them with some well-timed pest management strategy. The growth of insect pests is greatly influenced by abiotic stresses, including temperature and relative humidity (Mahmoud et al. 2021). Important pests of maize include western corn rootworm, maize leaf weevil, European corn borer, common cockchafer, black beet weevil, turnip moth and cotton bollworm.

Weeds are unwanted plants that invade various crops and reduce agricultural productivity by competing with them for resources like water, light, space, and nutrients. Weed is a known agricultural competitor and a source of several insects, pests, and diseases. To prevent financial loss in agricultural production, weed must be handled effectively. Herbicide spraying was first thought to be the simplest and most cost-effective method of weed management. However, the chemical impacts on the environment and human health have long-lasting detrimental repercussions. The maize crop is extremely sensitive to weed invasion. The output of maize can be reduced by up to 82% to 84% by weed infestation over the whole crop season (Duwadi et al. 2021).

To produce crops, using various weed control tactics is essential. There are numerous different weed control methods, including mechanical, physical, chemical, cultural, and biological ones. The shift in emphasis from pesticide use to non-chemical weed control is motivated by the public's recent increase in environmental consciousness and the issue associated with the harmful effects of herbicides. The non-chemical weed control strategies emphasize the need for sustainable solutions while reducing the use of pesticides. *C. album, Ambrosia artemisiifolia, Echinochloa crus-galli* and *Datura stramonium* are harmful weeds in Hungarian maize fields(Osman et al. 2022).

Post harvest of maize.

To fulfill the rising global need for food, significant resources and efforts have been devoted over the past ten years to raising agricultural productivity and production. However, difficulties in adjusting to climate change as well as limited water and land resources, as well as increasing weather unpredictability provide obstacles to the development of food production. The operations that make up the post-harvest chain for cereals include gathering, shelling, drying, storing, packaging, moving, marketing, and milling. (Chegere, 2018) discovered that considerable grain losses after eight months of storage came from keeping the maize in the field for prolonged durations after it reached physiological maturity. Maize borers were primarily blamed for grain loss. Additionally, he discovered that maize that was harvested early had a larger proportion of mouldy grain, which raised the risk of rotting.

He also discovered that maize post-harvest losses rise with warmth and humidity and fall with greater market access and better storage techniques. A reduction in post-harvest losses of maize is positively correlated with the use of recommended post-harvest activities, such as drying cobs, shelling, drying grains, winnowing, and pesticide treatment. On the other hand, research has shown that pre-harvest strategies like wisely choosing maize hybrids, timely planting, timely harvesting, and efficient pest control minimize post-harvest losses.

2.2 Hindrances to optimal maize production in Hungary.

The world's environmental resources are being severely burdened by rapid population growth, the rising demand for natural resources to meet human requirements, and the negative consequences of climate change. This is also having a harmful effect on the ability of humans to produce enough food. One of the main effects of climate change that has drawn scientists' attention for decades is drought. This is because every year, drought impacts millions of people worldwide, posing serious development issues because of its profound influence on a range of human endeavors, including agricultural methods and social development. The repeated drought events that have plagued Hungary over the past few decades and had an adverse effect on many facets of society making the country sensitive to climate change. Towards the end of the twenty-first century, Hungary is predicted to experience a significant amount of drought (Buzási, 2021). In addition, (Buzási, 2021), predicted that in the next decades, strong drought occurrences will probably become more regular in southern European nations like Hungary, which have already had several severe droughts. According to his studies, by taking quick action to end the drought, its effects might be lessened.

Although rainfall can provide the water needs of crops like maize during the growth period, the effect of the agricultural drought in Hungary has reportedly had a negative influence on crop productivity. According to (S. Mohammed et al. 2022), maize is very drought sensitive. In addition, he discovered that agricultural output is particularly vulnerable to drought occurrences throughout the growing season. He added that the intensity of the drought is closely tied to corn losses. Due to the predominantly rain-based nature of the Hungarian agricultural system, serious crop failure due to a lack of rainfall is a possibility. This puts a strain on food security.

Insect pests, plant diseases (De Groote et al. 2020), and other biotic and abiotic stressors, including heat and drought, are all posing growing threats to maize (Mueller et al. 2020). Distinctly in the northern regions of Europe and at higher altitudes, global warming opens new chances for maize farming. Several insect pests, plant diseases, and other destructive and helpful species will also discover new chances in Europe. Breeding for resistance to current and anticipated future plant diseases and insect pests is one method for reducing the rising biotic hazards in the maize farming process (Miedaner & Juroszek, 2021). Future disease resistance breeding tactics will unavoidably need to be adjusted because of the long-term changes in diseases, which will depend on factors like overall crop health, and pathogen virulence, which includes interactions with insects and the region involved. Moreover, changes in the blooming time will impact diseases like maize ear rots, which are brought on by viruses that infect plants during flowering (Menzel et al. 2020).

Nutrition in maize is crucial for maximum yield. A large pohasn of agricultural fields across the world have an elemental deficit, which affects productivity and product quality. The plant's vascular system, root growth, confectionery transport, carbohydrate combustion, synthesis of nucleic acids, and pollen grain growth are all adversely impacted by an elemental deficit. On the other hand, excessive concentration in the plant destroys and lowers maize fertility and diminishes maize infusion. Chemical fertilizers are necessary for maize to provide high yields. Macronutrients are essential to plant nutrients and are required in high amounts, such as Nitrogen, phosphorus, and potassium. Unlike other critical elements like Sulphur, Potassium, Nitrogen, and Phosphorus, micronutrients are necessary for plant development but are required at much lesser levels. The maize plant cannot absorb additional elements, including zinc, iron, copper, and magnesium, if N and P levels are too high or too low. The generated grains fill is in distorted condition brought on by a deficiency of components. The amount of these elements absorbed into the plant organs per ton of grain falls as yield per hectare increases. Once seed production starts, most of the nutrients are absorbed (Bojtor et al. 2022).

2.3 **Fertilization of Maize in Hungary**

One of the most significant crops for both human and animal consumption is maize. The main objective of cultivation is to increase output and productivity while preserving crop quality. As compared to prior years, there has been no change in the biology of nutrient intake and distribution in maize. Increased plant nutrient absorption and greater use of the soil's nutrient content can be linked to improved yields and biomass output in hybrids with the most recent genetic stock (Bojtor, Illés, et al. 2021).

The sufficient nutrient supply of maize has been evaluated using two distinct ways in agronomy research. The initial one is the examination of the entire plant at its early vegetative stage following the exhaustion of its nutritional stores in the seed. The ear-leaf analysis performed at the tasselling stage is the second one. The early whole plant sample approach enables supplementary nutrient replacement if the analysis reveals nutritional deficits. For nutritional adjustments of the plants during the Vegetative period, the ear-leaf sample is too late. During the ripening stage, nutrient concentrations may be predicted, and these values offer trustworthy information on the intake of each nutrient as well as on the nutritional balance between the various plant organs and between the soil-plant systems (Bojtor, Illés, et al. 2021).

Using fertilizer effectively is essential for raising corn production. Particularly, nitrogen fertilizer is a crucial component since it significantly affects biomass and grain output owing to the growth and toughness of the leaf area. In the process of growing maize, nitrogen fertilizer can be more effective when applied at the right time, in the necessary amount and in the right way. The existing hybrid and the production site's Nitrogen needs to make it feasible to increase maize profitability to the maximum extent conceivable. At maize germination, nitrogen intake is at its lowest level. It then increases steadily until it reaches its maximum during silking. During the process of filling grains, nitrogen absorption and integration are important. The grain is incorporated with 60% of the total nitrogen absorption. (Széles et al. 2019).

According to (Ricardo Carvalho et al. 2016), the administration of N boosts plant height by increasing the space between internodes and the height of internodes, which in turn increases the maize plant features such as the number of leaves per plant. As a result, applying N fertilizer can help increase the length, area of foliage, stem diameter, and wet and dry yields of maize. Nitrogen contributes to several key metabolic processes for plants, including the creation of proteins. It contains molecules like ATP, NADH, NADPH, storage proteins, nucleic acids, enzymes, cytochrome molecules, and chlorophyll. This demonstrates that Nitrogen is closely tied to the growth and production of plants. In addition, he reported that nitrogen fertilizer enhanced grain quality and raised the amount of protein and other nutrients, positively influencing the number of ears per crop and weight of ears as the weight of a thousand seeds grew in accordance with nitrogen dosages.

Basal nitrogen dressing is best done in the spring in Hungary. However, part of the active Nitrogen given prior to sowing may vaporize or percolate into groundwater. This phenomenon occurs because young plants with underdeveloped root systems have a harder time accessing soil supplies. Applying the right quantity of spring basal and top dressing decreases nitrogen deficit, boosts nitrogen supply efficiency, boosts the cost-effectiveness of fertilizer delivery, enhances yield, and improves overall production efficiency(Bojtor et al. 2022). The recommended nutrition for maize fields in Hungary is 28kg/t N, 11kg/t P, 30kg/t K, 8kg/t Calcium, and 3kg/t Magnesium. Organic manure has been reported to have a good effect.

Climate has a big impact on how readily available and absorbed Nitrogen is. The increased nutrient content, more intense nutrient breakdown, and improved root nutrition absorption are all benefits of the hotter soil. The availability of Nitrogen is crucial to plant senescence and has a significant impact on the remobilization of various nutrients from vegetative to generative organs. Several micronutrients, including Fe, Mn, Cu, and Zn, are remobilized, and transported using nicotianamine-based chelates and other organic acids. The control of the synthesis of these nitrogenous chelates can be affected by the excess or lack of Nitrogen, which can be a modifiable component in this process (Bojtor, Illés, et al. 2021). Lack of N results in maize plants that are pale, yellowish green and have wiry stalks. Since Nitrogen is a nutrient that moves everywhere in plants, symptoms start on the older, lower-lying leaves and move up on the crop if the shortage continues. On leaves, symptoms take the form of a V-shaped yellowing that moves from the tip toward the leaf base along the midrib. An optimal and balanced feeding system of maize is critical and must be put in place to increase productivity and yield quality and quantity.

2.4 Effect of Nitrogen on yield and yield components of maize

A versatile crop, maize can grow in a variety of agroclimatic situations. It may be cultivated anywhere in the world, up to 3000 meters above mean sea level. Farmers choose the crop because it has the best potential for producing grains among all cereals, can be used for both food and fodder and can also be grown for income as well as for industrial raw materials(Sah et al. 2020).

As the primary component of plant cells and a key component of the photosynthetic apparatus, optimal nitrogen supply plays a significant role in the growth characteristics of plants. The NUE of maize, which is negatively impacted by fertilizer leaching under the root zone and denitrification, is estimated at 33% globally.

In agricultural productivity, Nitrogen is the most crucial necessary ingredient. Global food security has greatly benefited in recent decades using N fertilizer in the cultivation of cereals. Due to its role in photosynthesis along with other biological processes such xylem movement, vacuole storage, and mineral and water intake, Nitrogen is a vital nutrient for maize and a significant factor in determining grain output. Crop productivity and application of nitrogen rates, however, are not always positively correlated because too much N given to soil prevents plants from using it well, wastes resources, and is harmful to the environment. It is not beneficial for the sustainability of agricultural output to fertilize farmlands with excessive amounts of Nitrogen because this has many adverse consequences on the ecosystem worldwide. The quantity of N that is accessible to plants depends on the balance between the supply and losses of N due to processes such leaching, runoff, ammonia volatilization, extra gaseous N losses, and immobilization. This illustrates the complex interactions between the soil, plant, and atmosphere that control N availability and uptake by plants. The yield of crop plants often varies depending on the species or cultivars they are and the environmental factors to which they are exposed. In terms of these common traits of agricultural plants, the maize plant might not be an exception. When a higher dose of Nitrogen was administered, significantly more cobs per plant, cob length, cob girth, rows per cob, grains per cob, 1000 grain weight, and shelling percentage were produced. (Guo et al. 2022) (Zhai et al. 2019)reported that the production of more assimilates, higher photosynthetic active leaf area and enhanced growth and development of crops were all outcomes of the proper administration of N fertilizer, which was advantageous for chlorophyll synthesis.

(Qi et al. 2020) reported that reported that when the soil's nitrogen content rises, above-ground maize biomass normally grows with it. However, above-ground biomass may decline if there is not enough nitrogen in the soil to meet crop demand. The capacity for maize to absorb N is also influenced by above-ground biomass production. In maize biomass, Nitrogen is divided into grain and Stover, with luxury N intake taking place when N supply is greater than what is necessary to provide the greatest grain yield. The main influencing factors on maize's capacity to absorb nitrogen are the moisture in the soil, the temperature, structure, and bulk density. Thus, sufficient N supply and absorption by maize are required for improvement in above-ground biomass production.

The number of ears per unit area, the number of kernels per ear, and the weight of the kernels all depend on the soil's moisture, temperature, nutrition, and light status. These factors also affect grain production. Reduced N fertilizer usage resulted in a considerable reduction in the quantity and weight of maize kernels (Ran et al. 2016). The greater nutrient availability in the soil system is what causes the ear length to rise in response to nitrogen rates, allowing the maize plant to express its full yield potential and produce the longest ear under high nitrogen rates(Begizew, 2020).

According to (Begizew, 2020), The increase in the number of kernels per ear in response to Nitrogen application rates may be explained by increased N availability in the soil, which plants need in large quantities both directly for growth and indirectly to make other nutrients necessary for seed germination and development, like phosphorus and potassium, available. Additionally, they noted that higher nutrient availability in the soil may be responsible for the rise in the number of kernels in response to nitrogen rates. This would allow plants to develop aggressively and produce totally viable huge ears with a lot of kernel rows on them.

In addition, he observed that the thousand-grain weight is quantitatively growing with an increase in the N rate. Increased N application rates may have a favourable effect on maize development by raising the leaf area index and lengthening the grain-filling phase, which enables the grains to accumulate more photosynthetic assimilates.

CHAPTER THREE

3.0 MATERIALS AND METHODS.

3.1 Experimental site

In 2022, a field experiment was performed in experimental plot owned by the Department of Agronomy, The Hungarian University of Agriculture and Life Sciences, Hungary, to examine the impact of Nitrogen levels on maize yield and yield components. This test location is 242 meters above sea level (47046' N, 19021' E) in a mountainous region of the nation, in a climate zone with a near-average climate, with chernozem sandy loam and brown forest soil. The pH of the soil is acidic. The estimated annual precipitation in Hungary is between 400 and 500 mm; the western regions are moderately moist than the eastern. Moisture distribution at planting was 100mm. The temperature was 20 at planting.

Figure 1: Experimental site

3.2 Treatments

Mouldboard plough was used to prepare the land and seedbed preparation was done with a combinator. With a density of 70,000 plants per ha1, the hybrid maize seed variety Margitta FAO 280 was sowed on May 5, 2022, using a Wintersteiger Plotman maize planter machine.

A row distance of 75cm of maize was maintained during planting. Four inspection layouts with Ammonium nitrate as the source of Nitrogen were set at levels of T1 (0 kg/ha), T2 (80 kg/ha), T3 (160 kg/ha), and T4 (240 kg/ha), each with a net area of 3M by 4M. Four replications with ten plants each made up each treatment. A randomized block design was used to administer the treatments. The treatments were subjected to the same standard agronomic procedures.

3.3 Measurements

At physiological maturity, the tagged plants were used to take measurements. Plant height, number of leaves, plant girth, leaf area index was measured and SPAD-502 was used to measure leaf chlorophyll concentration. The maximum number of cobs that could be harvested from each plot was noted at harvest. After threshing, cleaning, and sun-drying, seeds from tagged plants were collected per replication. Cob weight, the number of rows per cob, the number of grains per cob, and the grain yields per plot were computed. Data on grain quality, including moisture content, oil, protein, and starch contents, were collected using the Mininfra Grain Analyzer.

Figure 2: Maize at experimentation stage

3.4 Data Analysis

The influence of Nitrogen fertilization on grain production of corn and its components was investigated using one-way ANOVA of with a probability threshold of $P \leq 0.05$. Using Post Hoc Comparison tests with the Least Significant Difference (LSD) at $P \leq 0.05$, differences between treatment means were examined.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Effect of Nitrogen on plant height

Data analysis showed that nitrogen levels had no significant impact on plant height in the groups of different nitrogen treatments, that is, 0 kg/ha, 80 kg/ha, 160 kg/ha, and 240 kg/ha. Although the highest application of Nitrogen had the tallest plants, no significant difference was recorded.

Table 1: ANOVA table showing the effect of Nitrogen on plant height.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3757.4	3	1252.47	3.33398	0.02575	2.76943
Within Groups	21037.33333	56	375.667			
Total	24794.73333	59				

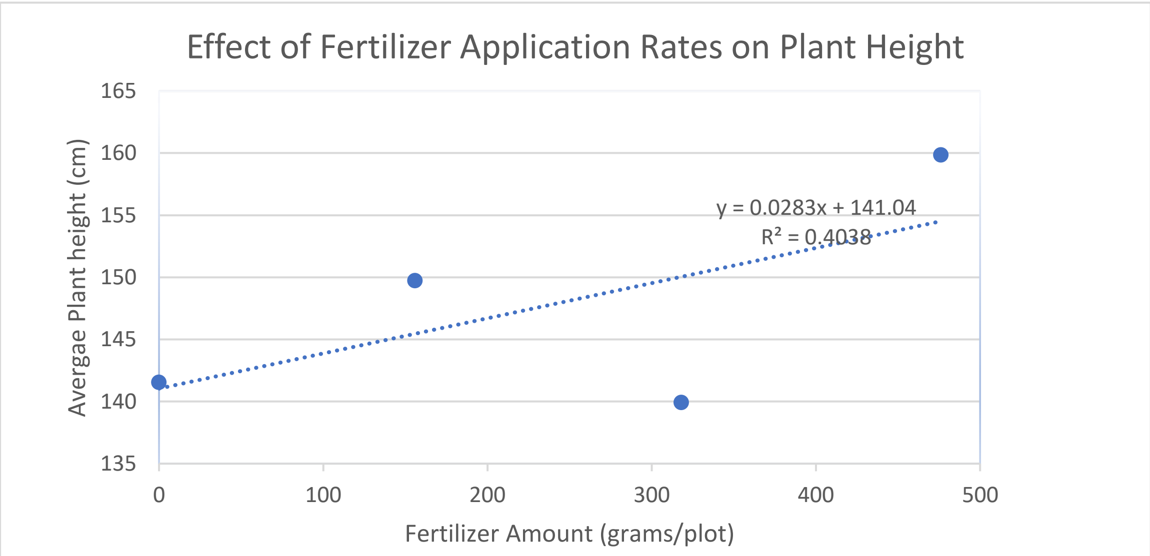

Figure 3: Graph showing the effect of fertilizer application rates on plant height.

4.2 Effect of Nitrogen on the number of leaves

Data analysis revealed that nitrogen levels significantly differed in the number of leaves. Averages in the data showed that increased nitrogen levels on the treatment increased the number of leaves. The plot with the highest amount of Nitrogen, 240 kg/ha, had the highest number of leaves, while the control recorded the lowest number of leaves. The plot with the highest nitrogen level recorded a mean of 12.53, while the control recorded 11.93.

Table 2: ANOVA table showing the effect of Nitrogen on plant height.

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.38333	3	1.12778	1.00566	0.39714	2.76943
Within Groups	62.8	56	1.12143			
Total	66.1833	59				

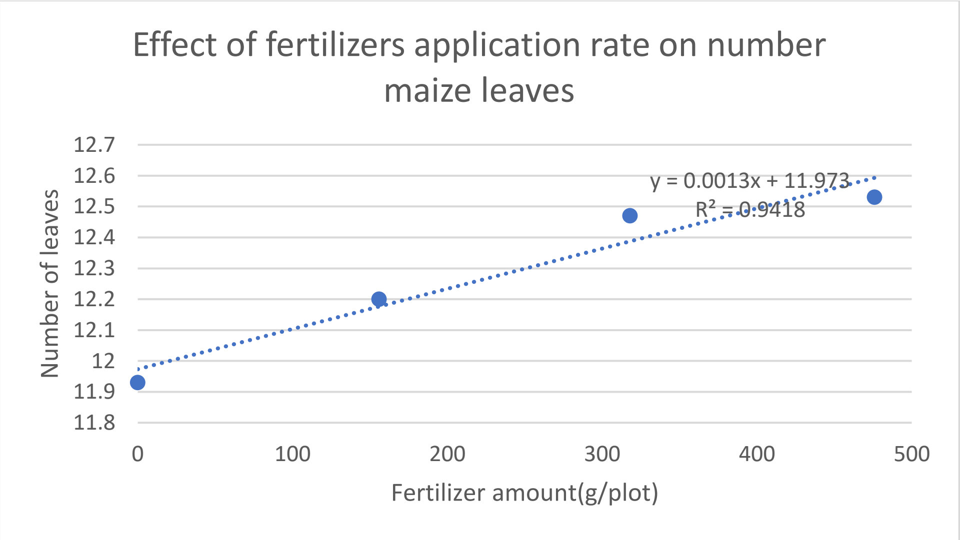

Figure 4: Graph showing the effect of fertilizers on the number of leaves.

A crucial factor in the growth of maize leaves is the number of leaves per plant, which is greatly influenced by the supply of nutrients, particularly Nitrogen. Statistical analysis showed that Nitrogen significantly differed in the number of leaves. Leaves are the primary photosynthesis factories and directly impact a plant's growth and development; thus, the amount of foliage per plant is a crucial measure of plant growth. Similar results were reported by Tiwari et al. (2022), who said that application of 120 kg of Nitrogen per hectare may have boosted the interception, absorption, and use of radiant energy, which in turn, boosted photosynthesis and, ultimately, raised plant height and the number of leaves per plant. Comparable effects were also attained regarding the growth features of maize increased nitrogen and zinc application rate by (J. Singh et al. 2021), which showed that higher nitrogen availability promotes the maximal vegetative development of plants and produces more leaves. Nitrogen need for cell division explains how N supply affects leaf development (Liu et al. 2023). In the leaf growth zone, the control of N on cell replication and extension is connected to multiple metabolisms, producing additional leaves.

4.3 Effect of Nitrogen on plant girth.

Statistical analysis of plant girth data revealed that Nitrogen had significant differences in the diameter of maize plants. Application of Nitrogen at 240 kg/ha recorded the same mean as the control plot; however, 80 kg/ha and 16 0kg/ha recorded the highest diameter. This brought up the significant difference in plant girth and the mean was at par. Control and 240 kg/ha recorded a diameter of 1.7cm, while 80 kg/ha recorded a mean diameter of 1.8cm.

Table 3: ANOVA table showing the effect of Nitrogen on plant girth.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.2045	3	0.06817	1.19841	0.31879	2.76943
Within Groups	3.18533	56	0.05688			
Total	3.38983	59				

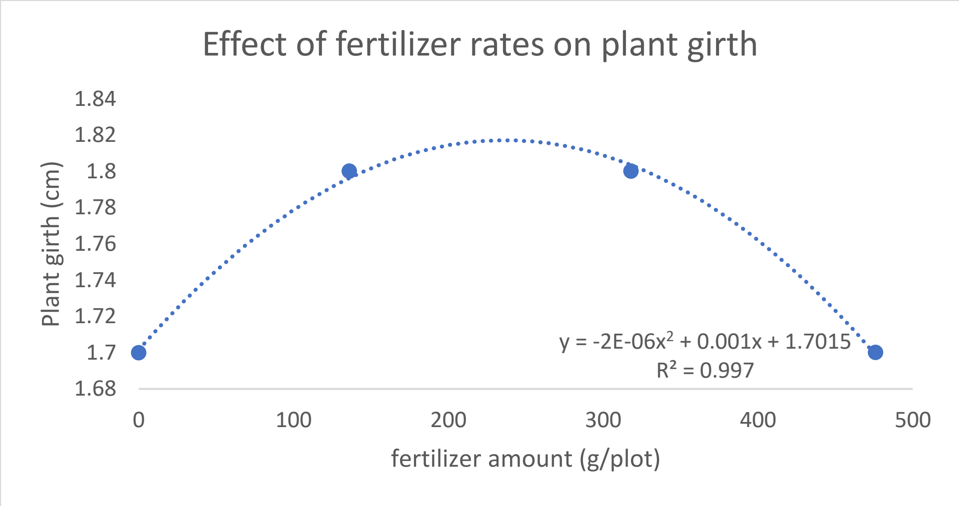

Figure 5: Graph showing the effect of fertilizer rates on plant girth.

Statistical analysis of maize plant girth showed that Nitrogen significantly differed in the plants' diameter. Steady growth in stem diameter may have been caused by cell division caused by an increase in the nitrogen supply. The concept that Nitrogen encourages plant development may account for the rise in stem diameter by nitrogen treatment. These results align with (Ali and Anjum, n.d.), who reported that nitrogen levels significantly affected the stem diameter of maize. Similarly, increased plant growth, stem diameter, and dry matter output significantly increased with greater nitrogen treatment levels. (Rino et al. 2020) indicated that Nitrogen was noticeably better than other treatments in terms of stem girth. It is attributed to fertilizer being used efficiently, giving the plant the right amount and timing of nutrients. (Iqbal et al. 2015) noticed that the diameter of the maize stems expanded along with the maize crop's enhanced growth and development when Nitrogen levels were increased.

4.4 Effect of Nitrogen levels on SPAD value

Data regarding SPAD values revealed significant differences in different levels of Nitrogen applied to maize plants. The highest value was recorded when Nitrogen was applied at 160 kg/ha. Control treatment recorded a moderately high mean of 27.4 chlorophyll level compared to the treatment with the highest nitrogen level, 240 kg/ha, which recorded a mean of 26.7 chlorophyll level and was the same with treatment with 80 kg/ha N application.

Table 4: ANOVA table showing the effect of Nitrogen on SPAD value.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	44.5556	3	14.8519	1.09675	0.36473	2.90112
Within Groups	433.333	32	13.5417			
Total	477.889	35				

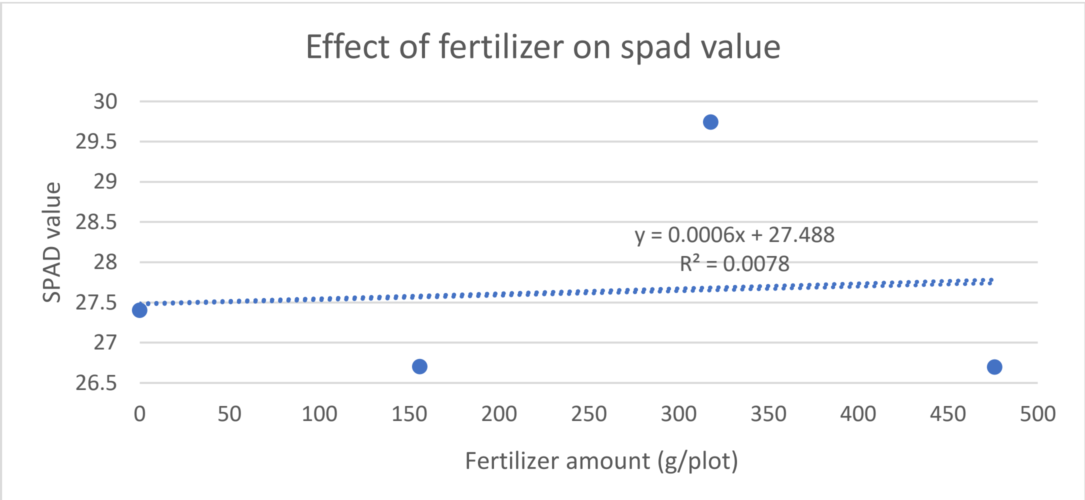

Figure 6: Graph showing the effect of fertilizer rates on SPAD values.

Data analysis showed that Nitrogen significantly affected SPAD values used to record chlorophyll content. As recorded, the increase in nitrogen content increased the leaves' chlorophyll levels, leading to high chlorophyll values. In agreement (Chen et al. 2023) demonstrated that raising the Nitrogen and photosynthetic levels of the leaves was beneficial for enhancing the activities of structural proteins involved in electron transfer and enhancing the absorption and transmission of additional radiation by chlorophyll molecules. This physiological alteration results from a simultaneous rise in crops' maximal and real photochemical efficiencies. (Wu et al. 2021) noted that during proper fertilization (15 cm), SPAD values were greater, probably because this depth encouraged roots to absorb more Nitrogen. (Fu et al. 2020) documented that SPAD value of the various varieties of stay-green maize leaves initially rose and subsequently declined with the development of crops.

Although SPAD rose as the nitrogen application rate improved, it did not significantly increase after it exceeded 180 kg N/ha.

4.5 Effect of nitrogen levels on leaf area index

Nitrogen levels significantly affected the leaf area of maize plants, according to data analysis on the leaf area index. The data showed that increased nitrogen levels increased the leaf area index in maize plants. The treatment with the highest nitrogen application (240 kg/ha) recorded the highest mean value of 1.63 of the leaf area index. The control treatment recorded a relatively low mean, as observed in the data analysis.

Table 5: ANOVA table showing the effect of fertilizer rates on leaf area index.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.64569	3	2.54856	33.3948	1.64781	2.76943
Within Groups	4.27371	56	0.07632			
Total	11.9194	59				

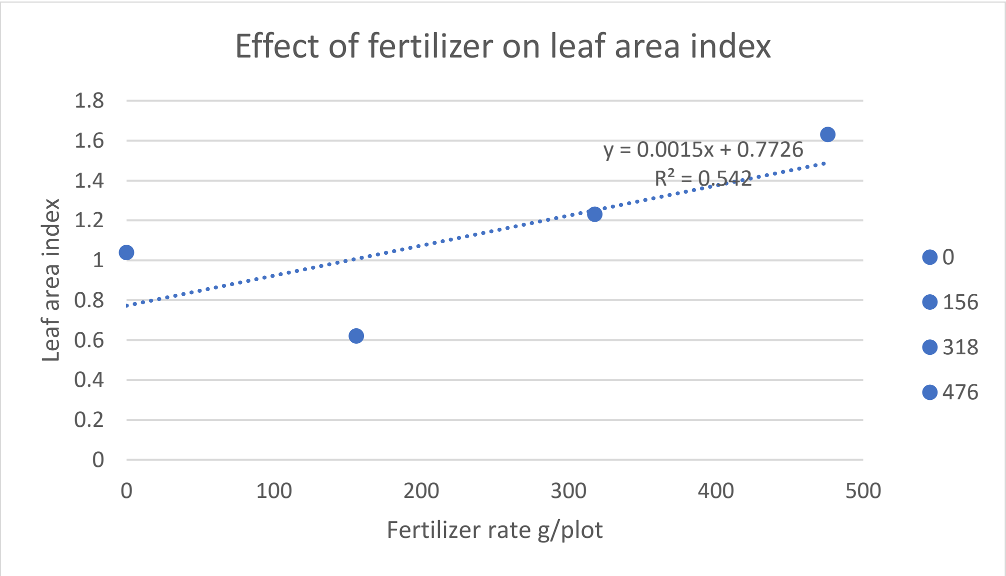

Figure 7: Graph showing the effect of fertilizer rates on leaf area index.

Treatments with fertilizer substantially impacted maize's leaf area index (P>0.05). Treatment with the highest nitrogen level recorded the greatest leaf area in maize plants. These results align with (Atnafu et al. 2021), who indicated that high levels of fertilizer treatment increase leaf area. He argued that after the administration of balanced and increased NPK fertilizer, the crop grew quickly, and the length and breadth of the leaves both rose significantly. Similar results were reported by (Gaire et al. 2020), who indicated that high Nitrogen levels cause plants' chlorophyll content to rise, impacting the proliferation of cells and tissues. (Ochieng' et al. 2021) Suggested that the leaf area index grows as the nitrogen treatment rate increases because Nitrogen increases leaf area and the effectiveness of photosynthetic processes. The primary factor in boosting crop output is the leaf area index. The formation of greater above-ground biomass with larger leaves generated by Nitrogen may cause an increase in the leaf area index.

4.6 Effect of Nitrogen on yield and its components

Data analysis on row number per cob and grain number per row showed significant treatment differences. On row number per cob, treatment with 80 kg/ha recorded the highest mean of 22.6, followed by treatment with 240 kg/ha recording a mean of 19.8, 160 kg/ha recorded a mean of 18.8, with control recording the lowest standard of 17.7. Although the sequence did not follow from the highest level recording the highest mean, there were significant differences. The grain number per row recorded the same trend as the row number per cob. Treatment with 80kg/ha recorded the highest mean of 15.8, followed by 240 kg/ha with a mean 13.9 and 160 kg/ha recording a mean of 13.1. Control recorded the lowest mean of 13.

Table 6: ANOVA table showing the effect of nitrogen rates on grain number/row.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	44.5556	3	14.8519	1.09675	0.36473	2.90112
Within Groups	433.333	32	13.5417			
Total	477.889	35				

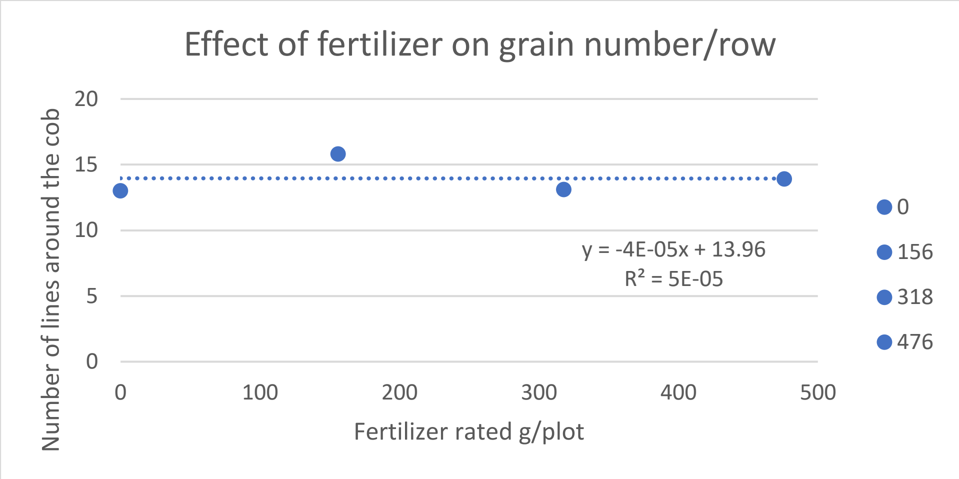

Figure 8: Graph showing the effect of fertilizer on grain number/row.

Data analysis showed that nitrogen levels significantly affected grain number per row. It is attributed to the increase in sinks provided by adequate Nitrogen during the growth of maize. Higher nitrogen levels result in more grains per row since there is less competition for nutrients, which allows the plants to build more biomass and have a greater potential to turn more products of photosynthesis into sink. Similar results were reported by (Shahid et al. 2016), who stated that increasing the number of grains per row may result from the Nitrogen being provided at the right do is crucial for cell division, tissue development, tissue development, and plant growth. During the early phases of crop growth, adding Nitrogen increased the number of cells and the volume per leaf, increased chlorophyll production, and increased plant biomass. The number of ears rose due to the rapid growth, enhancing yield(Hammad, Chawla, Jawad, Alhuqail, Bakhat, Farhad, Khan, Mubeen, Shah, Liu, Harrison, Saud, et al. 2022). (Rahman & Paul, 2016) agrees with the present study and indicates that the increase in grains per row could be because nitrogen fertilizer properly translocated starch and sugar in the grain.

Table 7: ANOVA table showing the effect of nitrogen rates on row number/cob.

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	118.306	3	39.4352	1.57872	0.21371	2.90112
Within Groups	799.333	32	24.9792			
Total	917.639	35				

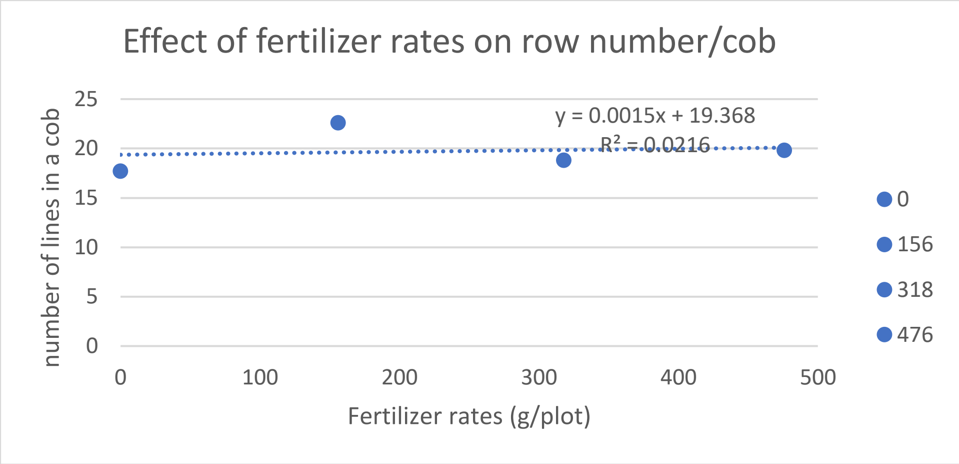

Figure 9: Graph showing effects of fertilizer rates on row number/cob.

Statistical analysis revealed that nitrogen fertilizer positively interacted with the number of rows per cob. Nitrogen fertilizers increased the photosynthetic assimilates to the cobs, thus increasing the number of rows. These results align with (Adhikari et al. 2021), who discovered that the number of rows of grain per cob increased as Nitrogen levels rose. These results are in unison with (Dhital et al. 2022) who observed that as the nitrogen level increased from 0 kg/ha to 70 kg/ha, the number of kernels per cob also increased. (Muhammad Arif, 2015) Found that a considerable increase in Nitrogen boosted crop yield.

4.7 Effect of Nitrogen levels on the chemical composition of maize

The findings show that nitrogen levels significantly influence grain moisture, starch, oil, and protein content. 80 kg/ha recorded the highest moisture and protein content and oil and starch content.

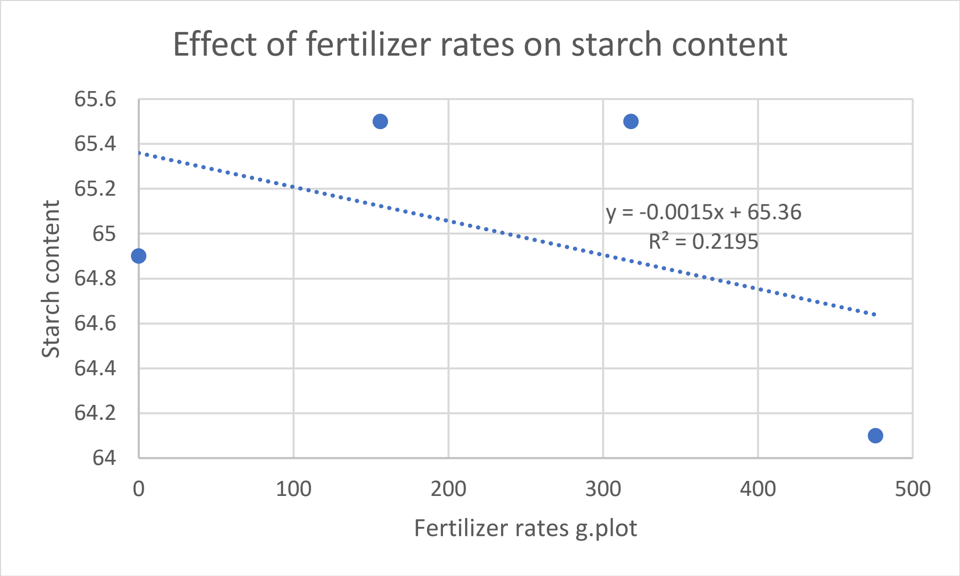

Figure 10: Graph showing the effect of fertilizer rates on starch content.

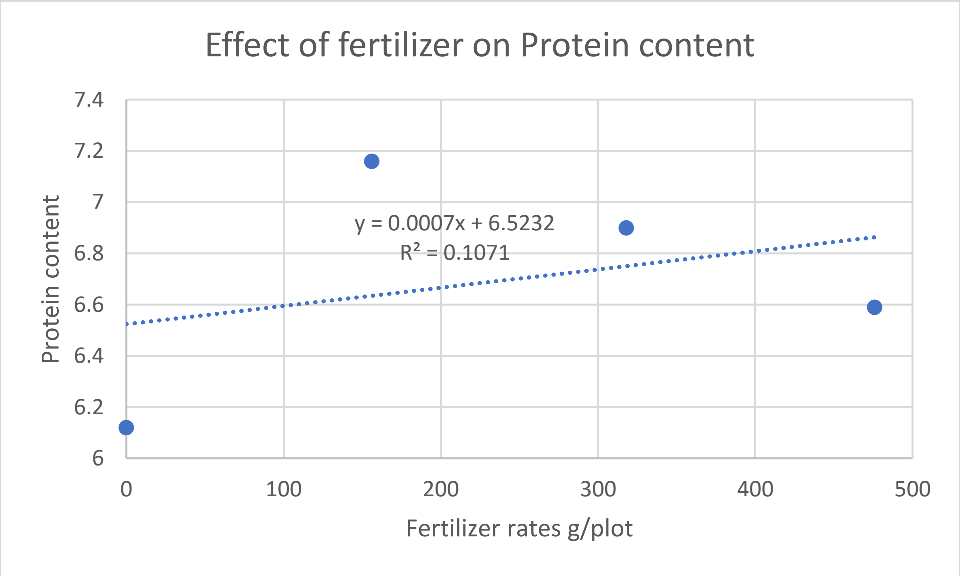

Figure 11: Graph showing the effect of fertilizer rates on protein content.

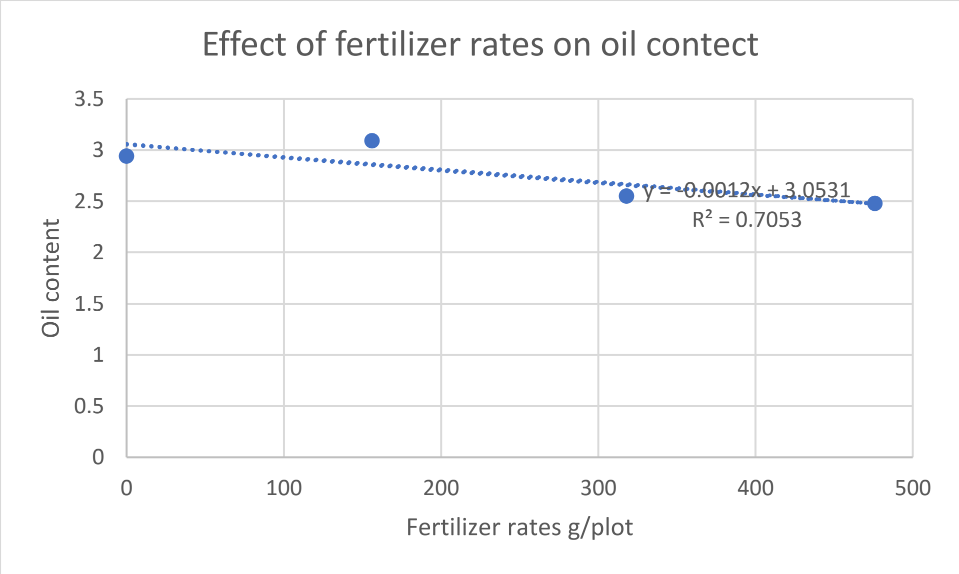

Figure 12: Graph showing the effect of fertilizer rates on oil content.

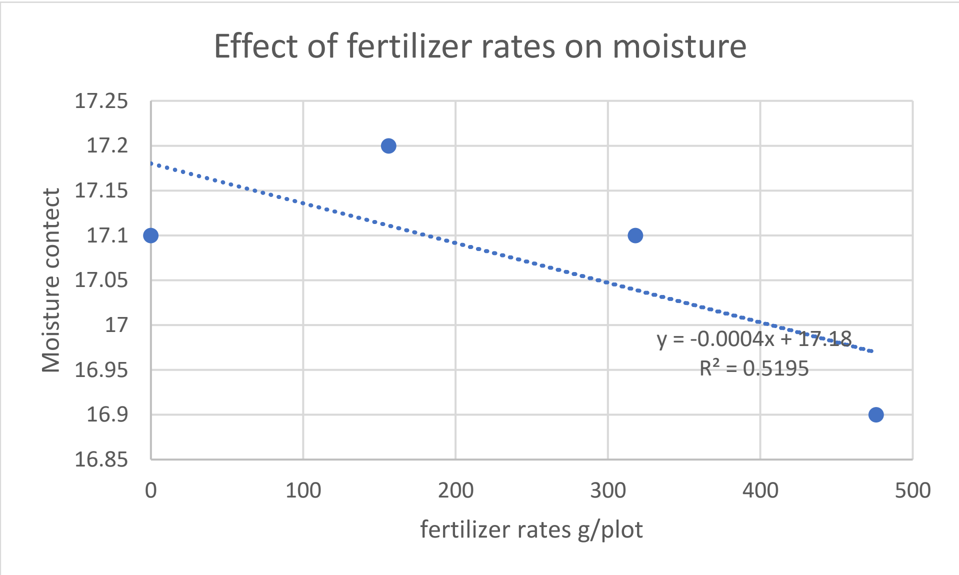

Figure 13: Graph showing the effect of fertilizer rates on moisture content.

N frequently causes maize crops to produce more grain, and this reaction is closely related to grain quality, such as the quantity of moisture, oil, protein, and starch in the grain. The current results contrast with this statement. However, the results align with (Omar et al. 2022); the maximum oil content was produced by N treatment at 150 kg/ha. Studies have shown that higher N levels will raise maize's seed protein content. On the contrary, low N environments limit grain yield and quality, including moisture and protein concentrations.

CHAPTER FIVE

5.0 CONCLUSION

The effect of N fertilization on maize yield and quality was assessed in this study. The findings demonstrated that increased nitrogen application had little to no impact on the grain's quality, including the levels of moisture, oil, protein, and starch. However, there were notable effects on yield indicators. The best N application, between 80 and 160 kg/ha, out of the four used, may potentially boost the yield, showing that N treatment can generate better grain yields and higher protein and starch contents. Having the best nitrogen fertilizer rate will increase starch, protein, and oil content for the best nutritional value of maize. In addition, having the best fertilizer rates will reduce the negative impacts of nitrogen fertilizers such as leaching and affecting underground water. Recently there are Nitrogen designated zones in Europe which affect Hungary as well. The correct application of fertilizers will reduce more areas to be marked as nitrate-vulnerable zones thus increasing production while maintaining good environmental conditions. More research and analysis are needed to fully understand the effects of N application on maize production and quality; the findings will benefit both researchers and agricultural producers to apply the correct amount for high productivity with environmental sustainability.

SUMMARY

Thesis title: EFFECT OF NITROGEN APPLICATION RATES ON MAIZE YIELDS AND YIELD COMPONENTS.

Author: Mwangi Teresia Nyambura

Course: MSC Crop Production Engineering

Institute/Department: Crop Production

1. Primary thesis adviser: Dr. Akos Tarnawa, Professor, Institute of Crop Production Sciences.

2. Independent consultant: Dr. Márton Jolankai, Professor, Institute of Crop Production Sciences.

Maize is an important crop in human nutrition, livestock feeding, biofuels and industrial uses. One of Hungary's main crops is maize. It is primarily utilized for human consumption, animal nutrition, and the manufacturing of ethanol, which is a fuel additive. With the increasing world population projected to strike nine billion by 2050 and with global production exceeding 2B metric tons, which is likely to increase in the future, placing pressure on the already worst situation, the crop is faced with a myriad of challenges not limited to salt intolerance, heat stress, nutritional deficiency, nutrient inadequacies, and drought impeding optimal global output. Nitrogen is one of the elements with the greatest impact on maize production and quality. Nitrogen's function in photosynthesis and other biochemical processes, including mineral and water uptake, vacuole storage, and xylem movement, make it a crucial factor in determining grain production.

In this research work, we aimed to investigate the effect of different levels of nitrogen fertilizers on yield and yield components of maize. To do this, a field experiment was conducted using ammonium nitrate as the source of Nitrogen with four different levels. The study was conducted at the agricultural experimental field Department of Agronomy of the Hungarian University of Agriculture and Life Sciences. Nitrogen was set at levels of T1 (0 kg/ha), T2 (80 kg/ha), T3 (160 kg/ha), and T4 (240 kg/ha). Maize was planted on May 5th

2022, with 3m by 4m plots. Treatments were set up in a randomized block design. The treatments were subjected to the same standard agronomic procedures.

Plant height, number of leaves, plant girth and leaf area index, were measured in the field. Cob weight, the number of rows per cob, the number of grains per cob, and the grain yields per plot were computed. One-way ANOVA was used to analyze the data, and LSD was used to separate the means.

The results showed that different levels of Nitrogen significantly affected the yield and yield components of maize. Averages in the data showed that an increase in nitrogen levels on the treatment increased the number of leaves. The plot with the highest amount of Nitrogen, that is, 240 kg/ha, had the highest number of leaves, while the control recorded the lowest number of leaves. Application of Nitrogen at 240 kg/ha recorded the same mean as of the control plot; however, 80 kg/ha and 160 kg/ha recorded the highest diameter. SPAD values showed that statistically, there were significant differences in different levels of Nitrogen applied to maize plants, Although the highest value was recorded when Nitrogen was applied at 160kg/ha. The results showed that an increase in nitrogen levels increased the leaf area index in maize plants. The treatment with the highest nitrogen application (240kg/ha) recorded the highest mean value. There was a significant difference recorded in yield components of maize that is on row number per cob and grain number per row. Treatment with 80kg/ha recorded the highest mean in both. The findings show that grain moisture content, starch content, oil content and protein content are significantly influenced by nitrogen levels. 80kg/ha recorded the highest moisture content and protein content, as well as oil content and starch content.

Based on the findings we found out that the the best N application, between 80 and 160 kg/ha, out of the four used, may potentially boost the yield, showing that N treatment can generate better grain yields and higher protein and starch contents. Having the best nitrogen fertilizer rate will boost starch content, protein content and oil content for the best nutritional value of maize. To maximize the effects of N application on maize production and quality, more investigation and evaluation are required; the results will be helpful to both researchers and agricultural producers.

ACKNOWLEDGEMENT

First and foremost, I wish to thank the Almighty God for His care and good health during my studies. I would like to thank the Hungarian University of Agriculture and Life Sciences for this opportunity to undertake my degree studies. I will always be proud of being one of the alumni of the MATE community.

My sincere gratitude goes to my supervisors, Dr. Akos Tarnawa and Prof. Marton Jolankai, for their guidance and support during this work. I am also greatly indebted to the technicians in the Department of Agronomy who worked hand in hand with me. This journey wouldn't have been successful without you.

To my mother, Margaret Mwangi, many thanks and may you have strength in the Lord and live to count your blessings. I salute you. I wish to thank Stipendium Hungarian and the Ministry of Education Kenya for giving me chance to study this course To my fellow classmates, it was fulfilling walking with you throughout my studies and may God bless you.

REFERENCES

Adhikari, K., Bhandari, S., Aryal, K., Mahato, M., & Shrestha, J. (2021). Effect of different levels of Nitrogen on growth and yield of hybrid maize (Zea mays L.) varieties. *Journal of Agriculture and Natural Resources*, *4*(2), 48–62. https://doi.org/10.3126/janr.v4i2.33656

Ali, N., & Anjum, M. M. (n.d.). Effect of Different Nitrogen Rates on Growth, Yield and Quality of Maize. *Middle East Journal of Agriculture Research*.

Ariraman, R., Selvakumar, S., Sowmya, S., David, M., Mansingh, I., & Prabhaharan, J. (2020). Effect of nitrogen levels on growth parameters, yield parameters, yield, quality and economics of maize: A review. *~ 1558 ~ Journal of Pharmacognosy and Phytochemistry*, *9*(6). https://doi.org/10.22271/phyto.2020.v9.i6w.13169

Atnafu, O., Balemi, T., & Regassa, A. (2021). Effect of Nutrient Omission on Grain Yield and Yield Components of Maize (Zea mays L.) at Kersa District, Jimma Zone, Southwestern Ethiopia. *Agriculture, Forestry and Fisheries*, *10*(1), 7. https://doi.org/10.11648/j.aff.20211001.12

Badr, A., El-Shazly, H. H., Tarawneh, R. A., & Börner, A. (2020). Screening for drought tolerance in maize (Zea mays l.) germplasm using germination and seedling traits under simulated drought conditions. *Plants*, *9*(5). https://doi.org/10.3390/plants9050565

Begizew, G. (2020). Role of integrated nutrient management for enhancing nitrogen use efficiency in crop. *Open Journal of Plant Science*, 001–012. https://doi.org/10.17352/ojps.000017

Bindraban, P. S., Dimkpa, C., Nagarajan, L., Roy, A., & Rabbinge, R. (2015). Revisiting fertilizers and fertilization strategies for improved nutrient uptake by plants. *Bioligical Fertile Soils*, *51*, 897–911. https://doi.org/10.1007/s00374-015-1039-7

Bojtor, C., Illés, Á., Nasir Mousavi, S. M., Széles, A., Tóth, B., Nagy, J., & Marton, C. L. (2021). Evaluation of the nutrient composition of maize in different NPK fertilizer levels based on multivariate method analysis. *International Journal of Agronomy*, *2021*. https://doi.org/10.1155/2021/5537549

Bojtor, C., Mousavi, S. M. N., Illés, Á., Golzardi, F., Széles, A., Szabó, A., Nagy, J., & Marton, C. L. (2022). Nutrient Composition Analysis of Maize Hybrids Affected by Different Nitrogen Fertilisation Systems. *Plants*, *11*(12). https://doi.org/10.3390/plants11121593

Bojtor, C., Mousavi, S. M. N., Illés, Á., Széles, A., Nagy, J., & Marton, C. L. (2021). Stability and adaptability of maize hybrids for precision crop production in a long-term field experiment in hungary. *Agronomy*, *11*(11). https://doi.org/10.3390/agronomy11112167

Bramdeo, K., & Rátonyi, T. (2020). Effect of tillage and fertilizer treatments on yield of maize (Zea mays L.) hybrids. *Columella : Journal of Agricultural and Environmental Sciences*, *7*(1), 57–65. https://doi.org/10.18380/szie.colum.2020.7.1.57

Burke, W. J., Frossard, E., Kabwe, S., & Jayne, T. S. (2019). Understanding fertilizer adoption and effectiveness on maize in Zambia. *Food Policy*, *86*. https://doi.org/10.1016/j.foodpol.2019.05.004

Buzási, A. (2021). Climate vulnerability and adaptation challenges in szekszárd wine region, Hungary. *Climate*, *9*(2), 1–17. https://doi.org/10.3390/cli9020025

Chegere, M. J. (2018). Post-harvest losses reduction by small-scale maize farmers: The role of handling practices. *Food Policy*, *77*, 103–115. https://doi.org/10.1016/j.foodpol.2018.05.001

Chen, G., Wu, P., Wang, J., Zhou, Y., Ren, L., Cai, T., Zhang, P., & Jia, Z. (2023). How do different fertilization depths affect the growth, yield, and nitrogen use efficiency in rain-fed summer maize? *Field Crops Research*, *290*. https://doi.org/10.1016/j.fcr.2022.108759

De Groote, H., Kimenju, S. C., Munyua, B., Palmas, S., Kassie, M., & Bruce, A. (2020). Spread and impact of fall armyworm (Spodoptera frugiperda J.E. Smith) in maize production areas of Kenya. *Agriculture, Ecosystems and Environment*, *292*. https://doi.org/10.1016/j.agee.2019.106804

Dhital, G., Marahatta, S., Karki, T. B., & Basnet, K. B. (2022). Response of Different Levels of Nitrogen and Plant Population to Grain Yield of Winter Hybrid Maize in

Chitwan Valley. *Agronomy Journal of Nepal*, 59–68. https://doi.org/10.3126/ajn.v6i1.47938

Duwadi, A., Acharya, A., & Gautam, S. (2021). A REVIEW ON NON-CHEMICAL WEED MANAGEMENT IN MAIZE (ZEA MAYS L.). *Food and Agri Economics Review*, *1*(1), 46–51. https://doi.org/10.26480/faer.01.2021.46.51

Erenstein, O., Chamberlin, J., & Sonder, K. (2021). Estimating the global number and distribution of maize and wheat farms. *Global Food Security*, *30*. https://doi.org/10.1016/j.gfs.2021.100558

FAO. (2022). Special Report – 2021 FAO/WFP Crop and Food Security Assessment Mission (CFSAM) to the Republic of Tajikistan. In *Special Report – 2021 FAO/WFP Crop and Food Security Assessment Mission (CFSAM) to the Republic of Tajikistan* (Issue May). https://doi.org/https://doi.org/10.4060/cb9996en

Fu, W., Wang, Y., Ye, Y., Zhen, S., Zhou, B., Wang, Y., Hu, Y., Zhao, Y., & Huang, Y. (2020). Grain yields and nitrogen use efficiencies in different types of stay-green maize in response to nitrogen fertilizer. *Plants*, *9*(4). https://doi.org/10.3390/plants9040474

Gaire, R., Pant, C., Sapkota, N., Dhamaniya, R., & Bhusal, T. N. (2020). Effect of Spacing and Nitrogen Level on Growth and Yield of Maize (Zea mays L.) in Mid hill of Nepal. *Malaysian Journal of Halal Research*, *3*(2), 50–55. https://doi.org/10.2478/mjhr-2020-0009

García-Lara, S., & Serna-Saldivar, S. O. (2018). Corn History and Culture. In *Corn: Chemistry and Technology, Third Edition* (pp. 1–18). Elsevier. https://doi.org/10.1016/B978-0-12-811971-6.00001-2

Guo, J., Fan, J., Xiang, Y., Zhang, F., Yan, S., Zhang, X., Zheng, J., Hou, X., Tang, Z., & Li, Z. (2022). Maize leaf functional responses to blending urea and slow-release nitrogen fertilizer under various drip irrigation regimes. *Agricultural Water Management*, *262*. https://doi.org/10.1016/j.agwat.2021.107396

Hammad, H. M., Chawla, M. S., Jawad, R., Alhuqail, A., Bakhat, H. F., Farhad, W., Khan, F., Mubeen, M., Shah, A. N., Liu, K., Harrison, M. T., Fahad, S., & Saud, S. (2022). Evaluating the Impact of Nitrogen Application on Growth and Productivity of Maize Under Control Conditions. *Frontiers in Plant Science*, *13*(885479), 1–11. https://doi.org/10.3389/fpls.2022.885479

Hammad, H. M., Chawla, M. S., Jawad, R., Alhuqail, A., Bakhat, H. F., Farhad, W., Khan, F., Mubeen, M., Shah, A. N., Liu, K., Harrison, M. T., Saud, S., & Fahad, S. (2022). Evaluating the Impact of Nitrogen Application on Growth and Productivity of Maize Under Control Conditions. *Frontiers in Plant Science*, *13*. https://doi.org/10.3389/fpls.2022.885479

Iqbal, M. A., Maqsood, Q., Ahmad, Z., Afzal, S., & Ahmad, M. M. (2015). *Optimizing Nitrogen Level to Improve Growth and Grain Yield of Spring Planted Irrigated Maize (Zea mays L.)*. https://www.researchgate.net/publication/278019892

Khaeim, H., Kende, Z., Jolánkai, M., Kovács, G. P., Gyuricza, C., & Tarnawa, Á. (2022). Impact of Temperature and Water on Seed Germination and Seedling Growth of Maize (Zea mays L.). *Agronomy*, *12*(2). https://doi.org/10.3390/agronomy12020397

Liu, Z., Gao, J., Zhao, S., Sha, Y., Huang, Y., Hao, Z., Ke, L., Chen, F., Yuan, L., & Mi, G. (2023). Nitrogen responsiveness of leaf growth, radiation use efficiency and grain yield of maize (Zea mays L.) in Northeast China. *Field Crops Research*, *291*. https://doi.org/10.1016/j.fcr.2022.108806

Mahmoud, H. H., Abd El-Rahman, S. F., Abd El-Moez Mahbob, M., & Ahmed, S. S. (2021). Seasonal abundance of the most important insect pests of maize and their natural enemies in Egypt. *Polish Journal of Entomology*, *90*(1), 27–40. https://doi.org/10.5604/01.3001.0014.8151

Menzel, A., Yuan, Y., Matiu, M., Sparks, T., Scheifinger, H., Gehrig, R., & Estrella, N. (2020). Climate change fingerprints in recent European plant phenology. *Global Change Biology*, *26*(4), 2599–2612. https://doi.org/10.1111/gcb.15000

Miedaner, T., & Juroszek, P. (2021). Global warming and increasing maize cultivation demand comprehensive efforts in disease and insect resistance breeding in north-western Europe. In *Plant Pathology* (Vol. 70, Issue 5, pp. 1032–1046). Blackwell Publishing Ltd. https://doi.org/10.1111/ppa.13365

Mizik, T., & Rádai, Z. M. (2021). The Significance of the Hungarian Wheat Production in Relation to the Common Agricultural Policy. *Review on Agriculture and Rural Development*, *10*(1–2), 44–51. https://doi.org/10.14232/rard.2021.1-2.44-51

Mohammed, S., Alsafadi, K., Enaruvbe, G. O., Bashir, B., Elbeltagi, A., Széles, A., Alsalman, A., & Harsanyi, E. (2022). Assessing the impacts of agricultural drought (SPI/SPEI) on maize and wheat yields across Hungary. *Scientific Reports*, *12*(1). https://doi.org/10.1038/s41598-022-12799-w

Mohammed, S. B., Dzidzienyo, D. K., Yahaya, A., Umar, M. L., Ishiyaku, M. F., Tongoona, P. B., & Gracen, V. (2021). High Soil Phosphorus Application Significantly Increased Grain Yield , Phosphorus Content but Not Zinc Content of Cowpea Grains. *Agronomy*, *11*(802), 1–18.

Mousavi, S. M. N., & Nagy, J. (2021). Evaluation of plant characteristics related to grain yield of FAO410 and FAO340 hybrids using regression models. *Cereal Research Communications*, *49*(1), 161–169. https://doi.org/10.1007/s42976-020-00076-3

Mueller, D. S., Wise, K. A., Sisson, A. J., Allen, T. W., Bergstrom, G. C., Bissonnette, K. M., Bradley, C. A., Byamukama, E., Chilvers, M. I., Collins, A. A., Esker, P. D., Faske, T. R., Friskop, A. J., Hagan, A. K., Heiniger, R. W., Hollier, C. A., Isakeit, T., Jackson-Ziems, T. A., Jardine, D. J., … Wiebold, W. J. (2020). Corn yield loss estimates due to diseases in the United States and Ontario, Canada, from 2016 to 2019. *Plant Health Progress*, *21*, 238–247. https://doi.org/10.1094/PHP-05-20-0038-RS

Muhammad Arif, S. I. (2015). Effect of Nitrogen Levels and Plant Population on Yield and Yield Components of Maize. *Advances in Crop Science and Technology*, *03*(02). https://doi.org/10.4172/2329-8863.1000170

Nasir Mousavi, S. M., Bodnár, K. B., & Nagy, J. (2019). Studying the effects of traits in the genotype of three maize hybrids in Hungary. *Acta Agraria Debreceniensis*, *1*, 97–101. https://doi.org/10.34101/actaagrar/1/2378

Nishimoto, R. (2019). Global trends in the crop protection industry. In *Journal of Pesticide Science* (Vol. 44, Issue 3, pp. 141–147). Pesticide Science Society of Japan. https://doi.org/10.1584/jpestics.D19-101

Njoroge, R., Otinga, A. N., Okalebo, J. R., Pepela, M., & Merckx, R. (2018). Maize (Zea mays L.) Response to secondary and micronutrients for profitable n, p and k fertilizer use in poorly responsive soils. *Agronomy*, *8*(4). https://doi.org/10.3390/agronomy8040049

O Awata, L. A., Tongoona, P., Danquah, E., Ifie, B. E., Suresh, L. M., Jumbo, M. B., Marchelo-D, P. W., & Sitonik, at. (2019). Understanding tropical maize (Zea mays L.): The major monocot in modernization and sustainability of agriculture in sub-Saharan Africa. *IJAAR*, *7*, 32–77. https://doi.org/10.33500/ijaar.2019.07.004

Ochieng', I. O., Gitari, H. I., Mochoge, B., Rezaei-Chiyaneh, E., & Gweyi-Onyango, J. P. (2021). *Optimizing Maize Yield, Nitrogen Efficacy and Grain Protein Content under Different N Forms and Rates*. https://doi.org/10.1007/s42729-021-00486-0/Published

Osman, M. G. A., Szalai, M., Zalai, M., Dorner, Z., & Kiss, J. (2022). Measurement of post-dispersal invertebrate seed predation of some relevant weed species in maize fields in Hungary: An ecosystem service provided in crop fields contributing to weed management. *Plant Protection Science*, *58*(4), 351–359. https://doi.org/10.17221/159/2021-PPS

Pandey, R., Vengavasi, K., & Hawkesford, M. J. (2021). Plant adaptation to nutrient stress. *Plant Physiology Reports*, *26*(4), 583–586. https://doi.org/10.1007/s40502-021-00636-7

Pepó, P. (2021). Effect of agrotechnical factors on soil chemical traits and maize yield on chernozem in the long-term experiment. *Plant, Soil and Environment*, *67*(8), 453–459. https://doi.org/10.17221/115/2021-PSE

Qi, D. L., Hu, T. T., & Song, X. (2020). Effects of nitrogen supply methods on fate of Nitrogen in maize under alternate partial root-zone irrigation. *International Journal of Agricultural and Biological Engineering*, *13*(3), 129–135. https://doi.org/10.25165/j.ijabe.20201303.5287

Rahman, M. M., & Paul, S. K. (2016). Effects of spacing and nitrogen levels on yield and yield contributing characters of maize. *J. Bangladesh Agril. Univ*, *14*(1), 43–48.

Raina, S. K. (2021). Importance and Advancement in Agriculture Technology Agrotechnology. *Agrotechnology*, *10*(5), 1–2.

Rehman, F. U., Adnan, M., Kalsoom, M., Naz, N., Husnain, M. G., Ilahi, H., Ilyas, M. A., Yousaf, G., Tahir, R., & Ahmad, U. (2021). Seed-Borne Fungal Diseases of Maize (Zea mays L.): A Review. *Agrinula : Jurnal Agroteknologi Dan Perkebunan*, *4*(1), 43–60. https://doi.org/10.36490/agri.v4i1.123

Ricardo Carvalho, I., Nardino, M., Jardel Szareski, V., Corazza da Rosa, T., Henrique Demari, G., Jardel Simone Morgan Dellagostin, V., Nicolau Follmann, D., Andrade Monteiro, M., José Basso, C., Pedó, T., & Zanatta Aumonde, T. (2016). *IMPORTANCE OF NITROGEN IN MAIZE PRODUCTION Experimentação agrícola e Biometria View project IMPORTANCE OF NITROGEN IN MAIZE PRODUCTION*. https://www.researchgate.net/publication/308443580

Rino, K., Singh, P. L., & Singh, A. P. (2020). Annals of Plant and Soil Effect of plant population and sources of Nitrogen on growth and yield of baby corn (Zea mays L.). In *Research* (Vol. 22, Issue 2).

Sah, R. P., Chakraborty, M., Prasad, K., Pandit, M., Tudu, V. K., Chakravarty, M. K., Narayan, S. C., Rana, M., & Moharana, D. (2020). Impact of water deficit stress in maize: Phenology and yield components. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-59689-7

Shahid, M. N., Zamir, M. S. I., Haq, I.-U., Khan, M. K., Hussain, M., Afzal, U., Asim, M., & Ali, I. (2016). Evaluating the Impact of Different Tillage Regimes and Nitrogen Levels on Yield and Yield Components of Maize (<i>Zea mays</i> L.). *American Journal of Plant Sciences*, *07*(06), 789–797. https://doi.org/10.4236/ajps.2016.76073

Singh, J., Partap, R., Singh, A., Kumar, N., & -, K. (2021). Effect of Nitrogen and Zinc on Growth and Yield of Maize (Zea mays L.). *International Journal of Bio-Resource and Stress Management*, *12*(3), 179–185. https://doi.org/10.23910/1.2021.2212

Singh, N., Singh, S., & Shevkani, K. (2019). Maize: Composition, bioactive constituents, and unleavened bread. In *Flour and Breads and Their Fortification in*

Health and Disease Prevention (pp. 111–121). Elsevier. https://doi.org/10.1016/B978-0-12-814639-2.00009-5

Special report – FAO Crop and Food Supply Assessment Mission (CSAM) to the Republic of Moldova. (2022). In *Special report – FAO Crop and Food Supply Assessment Mission (CSAM) to the Republic of Moldova*. FAO. https://doi.org/10.4060/cc3043en

Stitzer, M. C., & Ross-Ibarra, J. (2018). Maize domestication and gene interaction. In *New Phytologist* (Vol. 220, Issue 2, pp. 395–408). Blackwell Publishing Ltd. https://doi.org/10.1111/nph.15350

Széles, A., Kovács, K., & Ferencsik, S. (2019). The effect of crop years and nitrogen basal and top dressing on the yield of different maize genotypes and marginal revenue. *Idojaras*, *123*(3), 265–278. https://doi.org/10.28974/idojaras.2019.3.1

Tamene, L., Mponela, P., Ndengu, G., & Kihara, J. (2015). Assessment of maize yield gap and major determinant factors between smallholder farmers in the Dedza district of Malawi. *Nutrient Cycling in Agroecosystems*, *15*, 1–18. https://doi.org/10.1007/s10705-015-9692-7

Tiwari, D. K., Singh, T., & Chaturvedi, D. P. (2022). Effect of nitrogen and sulphur levels on growth, yield and quality of maize (Zea mays L.). *~ 418 ~ The Pharma Innovation Journal*, *11*(1), 418–422. http://www.thepharmajournal.com

Tóth, G., & Czakó, I. (2021). THE EFFECT OF INCREASED SOWING SPEED ON SOWING EFFICIENCY AND YIELD LOSS IN MAIZE AND SUNFLOWER IN HUNGARY. *EPRA International Journal of Agriculture and Rural Economic Research (ARER)-Peer-Reviewed Journal*. https://doi.org/10.36713/epra0813

Wu, P., Liu, F., Li, H., Cai, T., Zhang, P., & Jia, Z. (2021). Suitable fertilizer application depth can increase nitrogen use efficiency and maize yield by reducing gaseous nitrogen losses. *Science of the Total Environment*, *781*. https://doi.org/10.1016/j.scitotenv.2021.146787

Zhai, L., Xu, P., Zhang, Z., Wei, B., Jia, X., & Zhang, L. (2019). Improvements in grain yield and nitrogen use efficiency of summer maize by optimizing tillage practice and nitrogen application rate. *Agronomy Journal*, *111*(2), 666–676. https://doi.org/10.2134/agronj2018.05.0347

APPENDICES

Post Hoc Test	
Groups	Pvalue/Ttest
Average plant Girth plot 1 VS plot 2	0.18763361
Average plant Girth plot 1 VS plot 3	0.273140597
Average plant Girth plot 1 VS plot 4	0.94321214
Average plant Girth plot 2 VS plot 3	1
Average plant Girth plot 2 VS plot 4	0.097165353
Average plant Girth plot 3 VS plot 4	0.193887836

Appendix 1: Post Hoc Test comparing means group means of plots plant girth.

Post Hoc Test	
Groups	Pvalue/Ttest
Average spad value 1 and 2	0.810401191
Average spad value1 and 3	0.160742055
Average spad value1 and 4	0.567261682
Average spad value2 and 3	0.229759777
Average spad value2 and 4	0.922841414
Average spad value3 and 4	0.057081699

Appendix 2: Post Hoc Test comparing group means of plots SPAD value.

Post Hoc Test	
Groups	Pvalue/Ttest
Average plant height plot 1 VS plot 2	0.315875357
Average plant height plot 1 VS plot 3	0.858483
Average plant height plot 1 VS plot 4	0.02689345
Average plant height plot 2 VS plot 3	0.125806513
Average plant height plot 2 VS plot 4	0.035865219
Average plant height plot 3 VS plot 4	0.002409324

Appendix 3: Post Hoc Test of comparing group means of plots plant height.

Post Hoc Test	
Groups	P value/Ttest
Average leaf area index plot 1 VS plot 2	0.00014125
Average leaf area index plot 1 VS plot 3	0.045484061
Average leaf area index plot 1 VS plot 4	7.32563E-06
Average leaf area index plot 2 VS plot 3	3.68901E-07
Average leaf area index plot 2 VS plot 4	2.46248E-11
Average leaf area index plot 3 VS plot 4	0.003049102

Appendix 4: Post Hoc Test comparing groups means of pots leaf area index.

STUDENT DECLARATION

Signed below, Mwangi Teresia Nyambura, student of the Szent István Campus of the Hungarian University of Agriculture and Life Science, at the MSc Course of Crop Production Engineering declare that the present Thesis is my own work and I have used the cited and quoted literature in accordance with the relevant legal and ethical rules. I understand that the one-page-summary of my thesis will be uploaded on the website of the Campus/Institute/Course and my Thesis will be available at the Host Department/Institute and in the repository of the University in accordance with the relevant legal and ethical rules.

Confidential data are presented in the thesis: yes no*

Date: 2023 05 02

Student

SUPERVISOR'S DECLARATION

As primary supervisor of the author of this thesis, I hereby declare that review of the thesis was done thoroughly; student was informed and guided on the method of citing literature sources in the dissertation, attention was drawn on the importance of using literature data in accordance with the relevant legal and ethical rules.

Confidential data are presented in the thesis: yes no *

Approval of thesis for oral defense on Final Examination: approved not approved *

Date: 2023 05 02

signature