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Effect of Different Irrigation Levels on Growth and Yield of Maize

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Table of Content

List of Figures

List of Tables

List of Abbreviations

UAA: Utilized agricultural area

EU: European Union

HCSO: Hungarian Central Statistical Office

UN: United Nations

V: Vegetative stage

T: Silking stage

P: Phosphorus

N: Nitrogen

K: Potassium

VT: Tasseling stage

R: Silk Stage

VE: Emergence

FAO: Food and Agriculture Organization

Mha: Million hectares

AI: Aerated irrigation

WUE: Effectiveness of water use

DI: Deficit irrigation

L: Litre

mm/h: Millimeter per hour

m^2: Meter square

mm: Millimeter

kg m^{-3}: Kilogram per cubic meter

NaCl: Sodium chloride

ANOVA: Analysis of variance

I Introduction

Since the beginning of time, mankind have cultivated and consumed maize (*Zea mays*) as one of their main crops in all of its various stages of development. Numerous studies on maize plants have been carried out to increase our understanding of the production of maize. Maize is essential among the grains that has been discovered globally. It can thrive in tropical, subtropical, and temperate conditions and can therefore be grown practically anywhere, with the exception of Antarctica. Due to its increased yield potential, rapid growth cycle, high nutritional value as food, forage, and feed for livestock and poultry, as well as its cheaper cost as origin of fresh ingredient for farming-based industry, maize (*Zea mays*) is becoming more significant in the agricultural system. It has superior nutritional value, containing a concentration of 72% carbohydrate, 10% protein, 8% fiber, 4% oil, 3% sugar, and 17% ash (Tahir *et al.* 2008).

Maize is the most significant field crop in Croatia, Serbia, Hungary, and Bosnia-Herzegovina. In Hungary, maize occupied 1,149,410 hectares (about 25% of arable lands) between 2006 and 2010, while in Serbia, Croatia, and Bosnia and Herzegovina (B&H), it occupied 1,216,786 ha (37%), 1,216,786 ha (34%), 298,697 ha (34%), and 189,613 ha (19 percent). 30% of the arable land in the aforementioned countries is normally cultivated with maize. Maize yields averaged 6.17 tons per hectare, 4.86 tons per hectare, 6.76 tons per hectare, and 4.56 tons per hectare in Hungary, Serbia, Croatia, and Bosnia and Herzegovina throughout the research, individually. Additionally, from 2006 to 2010, annual maize yields in Bosnia and Herzegovina, Serbia, Croatia, and Hungary varied from 3.6 to 7.5 tons per hectare, 4.9 to 8.0 tons per hectare, and 3.2 to 5.1 tons per hectare, respectively. Climate change is the key reason for variations in maize production throughout time (Kovačević *et al.* 2013).

Corn is a vital crop in Nigeria. It makes up between 50 and 70 percent of the ingredients in cattle feed and is mostly used for human consumption. Nigeria produced one million tons of maize in 1975 and a significant amount is imported each year to offset local production declines. It is impossible to overstate the nutritional significance of maize in the diet of Nigerians; in most African nations, maize, millet, sorghum, rice, and other grains make up roughly 70% of the total caloric intake. After the testa is removed from processed maize using a mechanical or indigenous method, maize flour is obtained and used to make dough, pap, bread, and biscuits (Sowunmi 2010).

With maize included, abiotic factors—which are greatly influenced by climatic changes—remain one of the primary factors affecting agricultural productivity worldwide. The Intergovernmental

Panel on Climate Change's definition of climate change is expected to have an impact on agricultural development and production in light of this.

Climate change is predicted to surge the frequency of droughts and decrease mean rainfall in many places. These changes would significantly harm crops when coupled with rising temperatures (Schlenker & Lobell, 2010). This will harm crops because the condition cannot be balanced in the absence of enough soil water, therefore, the increased vapor pressure deficit and evapotranspiration need brought on by a rise in temperature would have a detrimental effect on plant growth. As a result, the plant is under stress. Less precipitation and more frequent warming are predicted for the future, which will result in extended dry spells (Field & Barros, 2014).

Due to the diminishing availability and rising expense of water supplies, it is advantageous to utilize these few resources wisely for the highest potential field output. Tahir et al. (2008) investigated how irrigation maize's yield responded to water restrictions. They discovered that the seasonal water requirement for irrigation was 400 millimeter, the grain yields ranged from 9.5 to 10.9 tons per hectare, and the seasonal water use efficiencies were 1.3 to 1.5 kilogram per cubic meter. In order to get fair outcomes, crop production requires the use of proper irrigation management because both an excessive and inadequate water supply to crops can be damaging (Mahal *et al.* 2000).

Problem Statement

- With the current climate change realities, which has contributed to the scarcity of water as an important maize production factor. It is therefore necessary to determine the how this important limited resource can be managed and its effective utilization for optimum production of maize.

Hypotheses

- Different levels of irrigation will significantly affect the growth and yield of the maize plant, with higher level of irrigation resulting in higher growth and yield. However, a point is reached after continuous water application where increase in water application does not lead to any significant increase in maize production. This is because excess water causes a waterlogged condition, which damages roots by reducing available oxygen. Also, essential nutrients are leached as a result of the flood condition. The theory can be examined by taking measurements of the maize crops' growth and yield in response to various irrigation levels.

In light of the information previously provided, the following objectives were sought in this study:

- Examining how varying irrigation levels affect the productivity and growth characteristics of maize.
- The ideal irrigation amount for maize to thrive and yield at its best.

II Review of the Literature

II-1 Origin of Maize

The origin of maize, a significant cereal crop on a global scale, has been a subject of scientific inquiry for many years. It is widely believed that maize was first domesticated in Mexico, but some evidence suggests that the crop may have also been independently domesticated in other regions.

Corn and maize are synonymous terms in the Western world. This is because maize was the most widely traded grain in early British and American trade, the term "corn" was still used to describe maize and all other grains. It's unclear where the word "maize" came from, although it's generally accepted that it was used by the Arawac tribes of Caribbean natives. Based on this common name (*Zea mays L.*), Linnaeus assigned the name as a species epithet to the botanical classification Zea (Ranum *et al.* 2014).

In the 1990s, genetic studies on maize helped to further clarify its origins. One study conducted by Doebley *et al.* (1990) used molecular markers to trace the ancestry of maize and found that it had been domesticated from teosinte in southern Mexico. However, subsequent studies have suggested that there may have been multiple domestication events in different parts of the Americas (Matsuoka *et al.* 2002; van Heerwaarden *et al.* 2011).

Furthermore, evidence confirming Peruvian origin of maize came from studies of plant remains at archaeological sites in the region. The study showed evidence of domestication of maize and other domesticated plants, suggesting that maize was being cultivated as far back as the millennium (Perry *et al.* 2006).

Despite these archeological discoveries, genetic research has indicated that teosinte, the natural parent of maize, is exclusively found in Mexico and certain regions of Central America. According to Matsuoka *et al.* (2002), this indicates that maize was probably domesticated in this area before eventually spreading to other regions of the Americas.

Corn had to be domesticated in order to adapt to temperate and other various environmental circumstances from its tropical origins, which resulted in a considerable morphological change to the plant and the inflorescence design. Landraces of maize were created because of the spread of the primitive and early modified varieties over North and South America. Landraces are dynamic populations with genetic diversity and no organized crop improvement.

With the advent of Europeans in America, corn was spread over numerous continents via various patterns of adaptation and breeding, including Europe, Africa, and Asia. By using self-pollination, more advanced breeding techniques have made it possible to create high-yielding inbred corn lines from landraces, from which hybrids or commercial types have been created. Teosinte, landraces, and inbred-lines—all terms that are widely used to describe the current germplasm of corn—are significant genetically varied assets for crop improvement and food sustenance.

II-2 Global Production and consumption of maize

Even though yields vary greatly, maize is grown all over the world (Table 1). The Food and Agriculture Organization of the United Nations' agricultural production indices (FAO, 2012) include items that are regarded as edible and nutrient-rich, and they show the relative level of the total volume of agricultural production for each year in comparison to the base period 1999-2001. Estimates indicate that in the year 2012, the US, Brazil, and China collectively gathered 31 percentage, 24 percentage, and 8 percentage of the world's total maize crop, respectively. Estimates place the global production of maize in that year at 875,226,630 tons.

Table 1. Corn production in 2012 by country, FAOSTAT

Country	Maize production in 2011 (million MT/year)
United States of America	274
China	208
Brazil	71
Mexico	22
Argentina	21
India	21
Ukraine	21
Indonesia	19
France	16
Canada	12
South Africa	12

A significant amount of the maize crop is utilized to make ethanol fuel, which produces the same kind of alcohol as alcoholic beverages. Usually, it serves as an additive when added to gasoline, particularly as a motor fuel. The primary source of the raw materials used to make ethanol is maize.

The rising demand for ethanol production has led to more incentives to expand maize acreage and higher maize prices. The development and use of biofuels raises a number of social, economic, environmental, and technological challenges, such as the impact on oil prices and the "food versus fuel" argument (Koizumi, 2015). According to Taylor & Tanumihardjo (2010), In comparison to rice and wheat, maize has about 70-74 percentage more carbohydrates, 8-10 percentage fewer proteins, and 2-6 percentage fewer fat calories per 100 grams of food (2010). Similar to this, it was emphasized by (Ranum *et al.* 2014) that while maize is a strong source of fiber, it is deficient in other nutrients including vitamin B12 and vitamin C and is generally a poor origin of iron, calcium, and folate. A few B vitamins and important minerals are present in maize, nevertheless. Vegetables, tea (for example, oxalates), coffee (for example, polyphenols), eggs (for example, phosvitin), milk, and other foods may all interfere with the absorption of iron, especially the nonheme iron present in maize. Fortifying maize flour and cornmeal with iron and other vitamins and minerals has been used to increase micronutrient consumption and prevent iron insufficiency, according to Ranum *et al.* (2014), in places where anemia and iron deficiency are viewed as moderate to severe public health issues. About 25 developing countries, mostly in Africa and Latin America, where animal protein is both scarce and expensive and therefore out of reach for a large portion of the population, rely on maize grain for between 15 and 56 percent of their daily calorie intake.

II-3 Maize production in Nigeria

Maize, often known as corn, is a key staple, source of fodder, energy, and a model plant in sub-Saharan Africa, particularly in Nigeria (FAO, 2003). After rice, sorghum, and millet, it was initially planted in Nigeria in the sixteenth century and later rose to become the fourth most widely consumed grain (FAOSTAT, 2012). In Nigeria, maize has long been considered a staple grain and is used to make a number of regional specialties, including pap, cornmeal, and tuwo. It is also a vital component in the creation of several foods, such as pasta, bread, and biscuits.

Maize is useful for producing medications and raw materials for industry in addition to food. In a study by Abdulrahaman and Kolawole (2008), 28 different food products or cuisines were assessed along with six medical benefits of maize. These include cooked and roasted maize, popcorn, ajepasi, aadun, kokoro, elekute, dambu alubosa, donkunnu, maasa, cous cous, Akple, Ukejuka, Gwate, Nakia, and Dambu alubosa, maize medicinal functions were proven and its importance as a valuable agro-industrial materials was further established. In Nigeria, maize has grown into a substantial crop throughout time, taking up farmland previously occupied by more established crops like millet and sorghum. With a total output of 10.2 million tons of maize from 4.8 million hectares in 2018, Nigeria was the top producer in Africa (FAOSTAT, 2018). According to Sadiq et al. (2013), Nigeria's maize consumption is rising more quickly each day. The Federal Government of Nigeria's restrictions on the importation of maize and other grains have resulted in an increase in demand for locally grown maize because it is an important staple food for many families and a raw material for the production of a variety of goods, including beer, poultry feed, forage, baked goods, and pharmaceuticals (Ogunniyi, 2011).

The key to a significant gain in maize production in Nigeria was expanded cultivated areas rather than higher yields. Between 1986 and 2000, maize harvesting in Nigeria expanded from 2.8 to 3 million hectares to more than 6 million hectares in 2011 (Olaniyan, 2015). In 2017, corn was grown on more than 56,139,729 hectares of land in Nigeria, accounting for almost 61 percent of all the country's cultivated land (FAO, 2017b). Additionally, one of the many technologies created as a result of the research carried out by breeders and agronomists is the breeding of high yielding varieties that are resistant to disease, low nitrogen, and Striga infestation (Kamara *et al.* 2014). The Nigerian savannas still have low yields despite the existence of these cultivars.

II-4 Maize Production in Hungary

A valuable part of Hungarian agriculture is the cultivation of maize. According to the condition of crop rotation, Hungary's corn producing area, which ranges from 1.1 million to 1.3 million hectares, is the fourth-largest in the European Union (EU), (Eurostat, 2020). The national average yield of maize in Hungary varies between 4 to 7 tons per hectare, this is dependent on the year and the extent of production (Pepó *et al.* 2008). Maize plays a large part in the Hungarian cereal industry. It is also supported by its significant portion of the utilized agricultural area (UAA), where maize has the 22% of the cultivated agricultural area in Hungary (HCSO, 2021a). A combination of climatic, industrial, and demographic factors have increased the need for corn in Europe. Based on the average production from 2007 to 2015 (UN Comtrade, 2020), Hungary is the second-largest corn exporter after France, with a mean capacity of 3.7 million tons annually. The amount and distribution of rainfall during maize vegetation are unfavorable under Hungarian conditions. There has been evidence of positive correlation between kernel abortion and the frequency of drought (Hegyi *et al.* 2008).

Many factors might support the significance of maize in terms of both supply and demand. On the supply side, it is important to point out, for instance, that the arable land in Hungary is great for cultivation, the weather is suitable, and the farmers have knowledge and extensive production experience. The most significant factor affecting demand is the numerous and varied uses of maize, which include uses in the food sector (such as isosugar, maize mush, canned corn, etc.), feed for livestock, and industrial uses (such as ethanol and distiller's grains with solubles as a byproduct). According to Gnansounou, *et a*l. (2010) maize is also an important ingredient in traditional Hungarian cuisine, particularly in dishes such as stuffed cabbage and lángos (a type of fried dough). In addition, maize is used in the production of ethanol, a biofuel that is blended with gasoline to reduce greenhouse gas emissions.

In conclusion, maize is a crucial crop in Hungary, contributing significantly to the country's economy and food security. Sustainable farming practices and increasing use of maize in the food industry offer opportunities for further development in the sector, while also addressing challenges such as climate change and environmental degradation.

II-5 Types of Corn

There are several varieties of maize grown throughout the world, but the main difference is in their color. Maize kernels come in a variety of colors, including black, white, yellow, red, and others. While white type of maize is more prevalent in Africa, Southern and Central USA, yellow maize is widely grown throughout the country. For reasons related to social standing, Africans dislike yellow maize; they think that only the poor consume it and that it is connected to food-aid programs. In addition, yellow corn is mostly used in the feed industry to produce feed for livestock. However, tradition plays a major role in the widespread adoration of white maize; people are accustomed to consuming white goods, and the whiter the better. Yellow and orange maize, which have higher quantities of precursors to vitamin A known as carotene and cryptoxanthin, will probably be ingested at lower levels as a result of this preference (Ranum *et al.* 2014).

The desire for higher extraction rate meal and flour, another blatant example of it was entire-grain products, which, despite being whiter, have lower fiber, vitamin, and mineral content. White maize quality is important because it influences product grading, milling effectiveness, and yield of premium items. The following artificial kernel kinds of maize are distinguished based on the endosperm size and composition, for example: flint, dent, waxy, flour, pop, Indian, pod, and sweet maize. Another identifying or classifying feature is the sweetness or amount of sugar. The kind and period of field harvest affect the quantity of residual sugar in maize. Sweet corn must be consumed straight soon, kept in a container, or frozen to avoid the kernels shrinking, getting rough, and turning starchy. In sweet variants, there is no fortification (Ranum *et al.* 2014).

II-6 Climate and Soil Needed for the Production of Maize

Maize is grown as an annual crop in areas with correct amount of precipitation. In surroundings with temperatures between 10°C and 40°C, with 30°C being the ideal, maize flourishes, according to GEOFIN, (2016). At temperatures of 8°C or above, or roughly 40°C, plant growth often comes to an end. Rainfall determines whether commercial maize crops are cultivated on dry land with high or poor yields. Additionally, he mentioned that during the flowering stage, when yield is determined, maize is particularly susceptible to moisture stressful situations. Maize needs lots of sunlight and low humidity to survive; otherwise, it would grow sickly and receive insufficient pollination. According to him, the ideal soil for growing maize is frequently thought to be deep, medium-textured, rich in organic matter, well-drained, and capable of giving the plant all the nutrients it needs at the rates the crop need as it grows.

Maize also grows well in soils with a pH range of 5.5 (acidic) to 8.0, according to GEOFIN, (2016). (Slightly simple.) He reported why sandy soils are unsuitable for growing maize, unless they have been properly manured, this is because they have propensity to dry out quickly and typically have low fertility. Clay soils cannot produce the greatest maize because they are frequently overly compacted and inadequately drained. He then concluded that the easiest type of soil to work with and greatest overall for growing farm crops is loamy soil. Less clay and more sand make the surface more malleable for construction (Park).

According to Onasanya *et al.* (2009), fertilizers, particularly nitrogen, phosphate, and potassium, are highly necessary for maize production whether it is done on a large or small scale. They classified maize as an aggressive feeder that rapidly depletes the nitrogen, phosphate, and potassium content of the soil. The micronutrients molybdenum and zinc, which depend on the kind of soil, are also significant for its production (Adhikary, 2010).

II-7 Development Stages of Maize

Throughout the growing season, maize develops and grows at varying rates. Young maize plants gain weight gradually, but as more leaves develop, the rate of dry-matter accumulation increases. Environmental factors including nutrient deficit, water, temperature, and air quality affect how quickly plants develop. Additional factors, such as disease and insect infestations, may stress corn plants and limit development and productivity, according to Lee, (2011). These issues can badly injure the plant and hinder its absorption of nutrients and water, which will lower yield. In addition to having negative effects on corn development, weeds directly compete with maize for nutrients, light, and water.

A number of classification strategies can be used to determine the growth stage of a maize plant. The Iowa State categorization system is the mechanism that is most frequently employed (Lee, 2011). According to the following definition, this method divides maize development and growth into reproductive (R) stages and vegetative (V);

II-7-1 Emergence

The growing tip and the entire stem of maize are positioned between 25 and 40 mm underneath the soil after sprouting, as stated by GEOFIN (2016). In warm, moist environments, seedlings can begin to grow in as short as 6 to 10 days, whereas they may take two weeks or longer in cool, dry environments. 60 percent of the soil's maximum capacity and temperatures between 20 and 30 degrees Celsius are ideal for germination.

II-7-2 Stages of Vegetation

The vegetative phase of plant development refers to the period of growth that occurs between germination and flowering. Plants actively participate in photosynthesis while they are in the vegetative stage to build up the resources they will need for flowering and reproduction. The vegetative phase is one of the most important stages in the development of the maize plant because it establishes the "factory" of the plant, which is necessary in the future stages of development. Leaf collars are one method for staging corn during the vegetative stage, among others. The number of easily visible leaf collars reveals the stages of vegetative growth. The number of collared leaves that are visible before the tassel emerges (VT) is represented by the number n, and the vegetative stages that follow emergence are denoted by the letter V1, V2 and Vn.

This demonstrate the location of the leaf's actual separation from its stem and sheath, the number of visible leaf collars defines the vegetative growth phases. The whorl excludes undeveloped leaves and leaves without a recognizable leaf collar. It should be noted that depending on the type of corn hybrid and the local climate, the number of leaves varies. If it is early season, reproductive development can begin at the V12 stage (maturity rating less than 95 days).

It should be noted that depending on the type of corn hybrid and the local climate, the number of leaves varies. If it is early season, reproductive development can begin at the V12 stage (maturity rating less than 95 days). The plant loses its small lower leaves around the V6 stage as a result of the development of nodal roots and stalks. When assessing the vegetative stage, it is important to account for the loss of lower leaves. Silking (R1), the first stage of reproduction, is followed by ripeness, or the "black layer" (R6).

Maize will sprout within 4 to 6 days of seeding in warm, humid circumstances. At this stage, the soil must have the proper temperature and moisture content. When soil water is scarce, germination and emergence are delayed because the seed needs water to germinate. On the other hand, too much water slows down root emergence and growth. If the soil is coated in residue or the air temperature in spring is low, germination may be slow due to the cool soil temperature. Low temperatures (below 50°F) may inhibit the germination of seeds. Corn should be planted between 3.8 and 5 cm deep. While planting shallowly (3.8 cm) in warmer soil can hasten emergence, it may lead to insufficient root development. If seeds are sown deeper than 5 cm into the soil, the initial leaves may emerge below the earth's surface.

In the leaf world, the coleoptile, sometimes known as a "spike," is followed by the development of true leaves aboveground. Warmth, moisture, and proper air circulation are prerequisites for the soil's ability to support healthy growth and development. At one "growing point" at the stem's apex, new leaves begin to appear. The "growing tip" can remain underground after planting for a maximum of four (4) weeks. When the growing point lies below the surface of the soil, the crop frequently survives minor hail and light frost. However, maize plants are particularly vulnerable to water damage at this point, and flooding could result in significant output decline.

The roots of maize do not initially penetrate much soil, but as the plant becomes older, they do so quickly. There are nodal and seminal roots in maize. Seminal roots appear quickly after germination, cease to develop at veraison 3, but continue to serve their purposes throughout the plant's life. Nodal roots start to form when the first node (V1) forms, and this process continues until kernel blister. By the V6 development stage, nodal roots are now the primary source of nutrients and water. When the soil is cold and wet early in the growing season, nutrient deficiencies, particularly those linked to phosphorus (P), are common. Starter fertilizer is usually effective at avoiding this problem. Early season nutritional deficits typically disappear and have little effect on yield if fertility levels are satisfactory. Weed scouting during the initial phases of growth is crucial (Lee, 2011). Six Leaves (V6) to Seven Leaves Transition Stage (V7)

At the V6 stage, the stem expands swiftly and ear shoots begin to develop. Every three days, new leaves emerge, and at this time, lower leaves start to degrade. Since the developing point of plants is on the surface of the soil, frost or hail could cause them considerable injury. The root system is formed and evenly dispersed throughout the soil, which improves the plant's capacity to absorb nutrients. Scouting is crucial during the V6 growth stage to determine whether extra fertilizer is required. According to studies, the optimal moment to side dress nitrogen (N) is between V6 and V8. It's also crucial to look for insects that cut roots, such maize rootworms. As there are few other means of controlling these insects, it is best to use plant resistance or genetically modified hybrids (Lee, 2011).

II-7-3 Eight-Leaf (V8) through Eleven-Leaf (V11)

There are a lot of ear shoots (possible ears) present at this stage. Only one or two of the top shoots develop into usable ears in the end. The corn hybrid determines how many ears form, with prodigious hybrids producing several ears when planted in sparse plant populations. At this point, deficits in macro- and micronutrients may show up. Nutrient deficits can severely impede leaf growth if left unattended. By V10, the plant had grown quickly and was producing new leaves every two to three days. To keep growing at this rate, the plant needs a lot of water and nutrients. Pests, high temperatures, an absence of nutrients, and/or a shortage of moisture can all limit growth (Lee, 2011).

II-7-4 Above 12-Leaf (V12)

A plant's number of leaves depends on its maturity level and the type of maize it produces. In comparison to grain corn, silage corn could have more leaves. As maturity rating rises, so does the quantity of leaves. Ear size and potential kernel production are decided at the V12 growth stage. How quickly maize plants grow during the V12 stage depends on the hybrid maturity. Early-maturing hybrids pass through these stages faster and grow smaller ears than later-maturing hybrids. Yield discrepancies between early and late hybrids can be balanced if water and fertilizer availability permits a larger plant density or population.

During the V12 stage, stress may cause the number of kernels and ear size to decrease. At this point in its growth cycle, when water consumption is at its peak, the plant can use up to a 0.6 cm^3 of water every day. At this stage, the maize plant uses a substantial amount of nitrogen, phosphate, and potassium. Hailstorms that snap tassels and pull leaves from plants can cause crop loss.

II-7-5 Tasseling (VT)

The tasseling stage is finished two to three days before to silking. The ear shoot's silks have not yet begun to appear, despite the fact that the plant has reached its maximum height and the terminal branch of the tassel is now visible. Depending on the corn hybrid and external factors, the time it takes to advance from VT to R1 (the silk stage) differs. Pollen often spreads between the late morning and early evening. Since all of the corn's leaves have grown by this time in its development, the impact of hail can be much greater than it would be at any other stage. Very little or no grain development may result from harm or loss to the tassels.

II-7-6 Silk Stage (R1)

During the first phase of the reproductive cycle (R1), silk first manifests itself. On an ear, each ovule (potential kernel) produces its own silk. Immediately following the V12 stage, the silks begin to lengthen. Silks begin to form at the R1 stage and catch pollen that is released by the tassel. Within 24 hours, Ovules located on the cob are fertilized by pollen that the silks capture, causing kernel development. Early to midmorning is prime time for pollen discharge given that moisture and temperature conditions are ideal. Environmental conditions that are not favorable might significantly reduce yield during this important reproductive stage. When exposed plants are in dry (low moisture) and hot circumstances, fertilization is negatively impacted due to the desiccating of the silks and lost pollen.

Ears stay unfertilized without fertilization. Each day, about 3.8 cm of silk are added. Silks grow up until pollen is collected and starts to germinate; at that point, they start to fall apart. For instance, the strain of a drought might prevent silk from lengthening and becoming visible. In general, silks remain pollen sensitive for the maximum time of 10 days after silk appearance, but they don't actually begin to deteriorate until days later. Pollen-shed and silk emergence happen concurrently in an ideal climate, making silk receptivity unimportant. The breakdown of silk by insect pests like maize rootworm results in lower yields. To minimize losses, fields should be checked for corn rootworm beetles at silking (R1) and treated if populations rise above a certain level. Potassium (K) uptake is finished at silking, although nitrogen (N) and phosphorus (P) uptake are still occurring. The plant will try to make up for a lack of N and P by transferring nutrients from lower to upper leaves or by producing grain. Lower leaves exhibit symptoms of N and P deficiency at this stage. Sadly, adding additional nutrients now or later in the development phase won't make up for these deficiencies (Lee, 2011).

II-7-7 Stage of Kernel Blisters (R2)

Starting about 22 days after silking, the kernel milk stage begins. At this point, the exterior layer of the kernels is primarily yellow, starch accumulation is rapid, the fluid inside the kernels is milky white, and endosperm cell division is whole. Maize kernel growth is primarily influenced by cell development and starch buildup; excessive tension can result in abortion of the kernel. The kernel moisture level is around 80 percent, and the physiological maturation period is 880 GDD. (days growing in degrees). At this stage, stress may cause a decrease in kernel size and weight, but it is less important than at the R1 growth stage (Lee, 2011).

II-7-8 Age of Kernel Milk (R3)

The kernel milk stage begins at 22 days after silking. Starch accumulation is quickening, the fluid inside the kernels is milky white, and endosperm cell division is finished at this stage. The outside of the kernels are mainly yellow. Significant stress can cause kernel abortion, while cell multiplication and starch accumulation are the key factors in observable kernel growth. The kernel moisture level and physiological maturity remains the same as R2. Despite not being as serious as the R1 stage, but at this point, stress may result in the kernel being smaller and heavier. (Lee, 2011).

II-7-9 Stage of Kernel Dough (R4)

The kernels' consistency switches from milky to soft and sticky when they reach the dough (R4) stage. At R4, the cob is a light red to pink color, and the kernels are almost half their mature weight. Four embryonic leaves have grown, and the moisture level of the kernel is currently around 70%. Kernel weight may decline because of poor climatic conditions (Lee, 2011).

II-7-9-1 Stage of Kernel Dents (R5)

The moisture level is around 55%, most of the kernel crowns are denting at the R5 growth stage, and the milky line, a distinct horizontal line separating the yellow (starch solid) and white (milky-liquid) regions of the kernel, is visible. The length of this line eventually extends to the kernel's tip as the starch matures and solidifies. A severe cold at R5 could damage the plant, limiting output and kernel growth. The amount of maize plants that are killed at this time have a low test weight and rate of maturity. These risks can be reduced by choosing a hybrid that is mature two to three weeks before the first fall frost. If an early frost damages the crop, one alternative is to harvest it and ensile it as high-moisture grain for animal feed (Lee, 2011).

II-7-9-2 Physical Development (R6)

After silking, the maize plant matures physiologically 55 to 65 days later (R6). The starch line has reached the tip of the kernel, the moisture content is between 30 and 35 percent, and the starch line has also reached the base of the mature kernels. A dark layer has also formed at the base of the ripe kernels due to the moisture content. The kernels turn black from the tips to the basal kernels. At this point, severe stress has no impact on grain production until a disease like stalk rots or insect feeding damages the stalk or ear integrity. Currently, drying costs are lower when the crop is allowed to dry in the field.

Corn must be dried to 12% moisture content before long-term storage in order to prevent spoiling. In terms of growth and development, hybrids vary slightly (in terms of the number of leaves, ears, maturity, dry-down, and other features). Early harvesting is rarely possible because of the cost of drying or dockage. If the stalks are sturdy, ear drop is not a problem, and there is little chance of ear and kernel rots, corn can be left in the field during hot, dry conditions. In farms where the European corn borer or Western bean cutworm is present, harvest loss due to lodging and ear drop can be substantial. In these situations, the cost of drying should be weighed against the benefits of early harvesting to prevent harvest losses. Checking for grain moisture, ear rots, ear retention, and stalk condition is essential (Lee, 2011).

Table 2: Summary of Growth and Development Stages in Maize (Lee, 2011)

Vegetative Stages	**Reproductive Stages**
Emergence (VE)	Silking: the presence of silks outside of the husks (R1)
First leaf collar (V1)	Blister - The white kernels look like blisters. (R2)
Second leaf collar (V2)	Milk: The exterior part of the kernels are yellowish, and the interior fluid is milky (R3)
Third leaf collar (V3)	Internal milky fluid in dough thickens (R4)
(V(n)) nth collared leaves are evident	Almost all kernels develop a dent (R5)
Tasseling: The final branch is clearly apparent (VT)	Black abscission layer production indicates physiological maturity (R6)

II-8-1 Irrigation

Water is added to soil during irrigation, which is primarily done to satisfy the thirst of developing plants. The water is pumped or flows naturally through ditches, canals, pipes, or even natural streams after being drawn from rivers, lakes, reservoirs, or aquifers. Field irrigation improves crop quality, productivity, and dependability. The irrigated agriculture sector is the largest water user in the world, requiring roughly 80–90% of the available freshwater, while having a poor water usage efficiency of just 45% of the applied amount consumed on average (Mário C., 2017). According to the Food and Agriculture Organization of the United Nations, irrigation accounts for 20% of the agricultural production area worldwide and nearly 40% of the world's total food production (Bjorneberg, 2013). According to GEOFIN, (2016), irrigation also minimizes the risk of soil piping, cools soil temperature, washes off or dilutes soil salts, and softens the tillage pan. All of these elements support healthy plant growth.

To provide irrigation for particular crops in particular places, many irrigation techniques have been developed over time. Drip/micro, sprinkler, and surface irrigation are the three main forms. Surface irrigation is the method used to water the soil. By spraying or sprinkling water from permanent or mobile equipment, sprinkler irrigation irrigates soil. Only a small portion of the soil surface in the field is dampened by micro-irrigation, which makes numerous tiny applications by bubbling, trickling, or spraying. A fourth minor irrigation technique called subirrigation uses ditches or subsurface drains to increase or maintain the water table close to the plant root zone.

More than 324 million hectares were accessible for irrigation in 2012, of which 275 million hectares, or over 85%, were used for irrigated agriculture (FAO, 2016). India and China currently have nearly the same amount of irrigated land as the rest of the globe, with 69.4 and 66.7 million hectares of irrigated land, respectively (FAO, 2016). In China and India, on the other hand, surface irrigation covers almost 95% of the irrigated land. Each country has about 20 million hectares of irrigated land. Each of the other nations has fewer than 10 million hectares (Mha) of irrigated land. The percentages of sprinkler and micro-irrigation used in irrigated agriculture in the United States are higher than those used in the other three countries, and they have been rising over the past 20 years. The 22 Mha of irrigated agriculture in the United States receives 54 percent of their irrigation via sprinklers, compared to 7 percent from micro-irrigation (Bjorneberg, 2013).

II-8-2 Effective Utilization of Irrigation Water

The world's increasing population, expanding irrigated agricultural lands, and economic development are some of the factors contributing to the need for water. Although the world's surface water resources (lakes, rivers, and reservoirs) have enough water to meet this demand, regional variations are large and cause water stress in many parts of the world. Water stress is a persistent issue in countries like the Sahel, South Africa, Central America, Australia, India, Pakistan, and North East China, to name just a few. More than 2 billion people, or 35% of the world's population, are estimated to endure acute water stress (Wada *et al.* 2010). 4 billion people globally are impacted by water scarcity, according to the same report (Du *et al.* 2018).

The long-term viability of irrigation farming is still threatened by water stress. To deal with the limited irrigation water supply, appropriate irrigation techniques and water-saving irrigation technology must be created. This is because crop production areas cannot be expanded, it is believed that the ability to increase water usage efficiency is the most crucial tool for increasing crop production while protecting water and the environment. In particular, in regions with limited water supplies, an efficient irrigation schedule is essential to assisting farmers in increasing crop yields while conserving water. Crop biomass is expected to increase as applied water volume approaches the plant's potential transpiration rate, according to Ityel *et al.* (2014).

Aerated irrigation (AI) is one irrigation technology that has been used, according to Abuarab *et al.* (2013), to increase the effectiveness of water use (WUE). Additionally, it was demonstrated that using oxygenated subsurface drip irrigation water could significantly improve crop yields, water use efficiency, and salinity tolerance, particularly for crops grown on hard clay soils (Abuarab *et al.* 2013). According to research by Ityel *et al.* (2014), subsurface drip irrigation provided substantial aeration for a number of crops (either by air or by H_2O_2 injection). The rate of oxygen diffusion was dramatically reduced as a result of the airways being more convoluted due to increased soil moisture content surrounding the root zone (Du *et al.* 2020).

A lack of oxygen in the root zone may have a negative impact on plant root and shoot growth, soil respiration, stomata conductance, and nutrient uptake, according to Du *et al.* (2020). Additionally, irrigation leaves the rhizosphere near-saturated for several hours after, significantly lowering air permeability and oxygen levels in the root zone, as shown by (Du *et al.* 2018). It has been shown that a lack of oxygen in the root zone prevents root growth, which reduces the root system's capacity to absorb water, increases water volume drainage and leakage, and results in a drop in WUE (Guo *et al.* 2008). Aerated irrigation (AI) has been suggested as a way to improve soil aeration. Air is infused through subsurface drip irrigation cables to accomplish this (Du *et al.* 2018). The ability of AI to deliver aerated water to the root zone, which also promotes plant water and nutrient uptake, may help to alleviate anoxic or hypoxic situations.

The main benefits of this method are affordability and simplicity, especially when irrigation and air injection are applied via the same drip lines (Du *et al.* 2020). According to certain studies, artificial irrigation (AI) significantly increases crop productivity, ranging from 20 to 150 percent, which is necessary to save scarce water resources while maintaining enhanced crop yield (Du *et al.* 2018). According to studies, oxygenation improves soybean water usage efficiency (WUE) for treatments using hydrogen peroxide and air injection through a venturi valve by 54 and 70%, respectively, and boosts pod yield by 82 and 96% for both treatments (Abuarab et al. 2013). As a result of AI, bell pepper biomass and fruit yield increased by 16% and 18%, respectively (Ityel *et al.* 2014). The optimum rates of plant growth and development occur when water consumption efficiency (WUE) is raised.

Another way to make the most of few water resources is to use more water when plants are more susceptible to water shortages and less water when they are more resistant to them (Tari, 2016). Deficit irrigation (DI) offers a viable option for switching crops or using rotating fallow when there is not enough water to satisfy the entire crop's water requirements. Deficit irrigation (DI) was defined by Comas et al. (2019) as the application of water below the full crop-water requirement, which can be purposefully applied during significant crop growth stages to conserve water and reduce production losses while decreasing the yield gap compared to fully watered crops (Mario *et al.* 2017).

Deficit irrigation may increase a farm's net profitability, according to the findings of numerous research (Hayashi, 2002; Fang *et al.* 2018). Improved irrigation effectiveness, lower irrigation expenses, and the potential to lower water expenditures are three benefits of deficit irrigation (Tari, 2016). Deficit irrigation, or purposeful under-irrigation of the crop, can occasionally be used to increase the output from an irrigated field. Economic theory and the results of prior research back up this assertion (Tari, 2016). He emphasized further that the effect of a lack of soil moisture on crop output depends on the crop's phenological stage, which differs from region to region.

Due to regional differences in agronomic and environmental practices, information specific to a location is required to construct and improve limited irrigation strategies. It is important to consider how crops respond to water stress at various growth stages when planning irrigation schedules. Previous research found that the sensitivity of wheat to water stress varied with growth stage (Tari, 2016). Particularly during booting and heading, certain stages of wheat development are more susceptible to moisture stress, according to the literature.

Despite high input, excessive irrigation will lead to a low yield, according to (GEOFIN, 2016). Appropriate irrigation not only meets the crop's need for normal growth but also stops water losses while supplying the crop with an adequate water supply. Effective watering will help with the initial stages of growth and yield, including seedbed preparation, germination, root growth, nutrient use, plant growth and regrowth, yield, and quality (Oke, 2016). A number of crops, including maize, mature in between 100 and 120 days. Reaching physiological maturity normally requires 100 days of irrigation, though this can vary per variety. The best way to cultivate maize with the highest yield possible is to do it stress-free throughout the full growing season (GEOFIN, 2016).

II-9-2 Irrigation Methods

II-9-2-1Surface Irrigation

One of the most widely used field irrigation techniques worldwide, surface irrigation accounts for around 80 percent of the world's irrigated land and more than 90% in Asia, according to Li *et al.* (2020). Approximately 90 percent of China's irrigated land is currently covered by it, with application efficiency ranging from 39 percent to 91 percent. (On average, 60%). The effectiveness of using surface techniques can vary between 40 percent and 80 percent, according (Sable *et al.* 2019). Since infiltration rates vary from year to year as a result of fluctuations in cropping patterns, cultivation methods, weather conditions, and a variety of other factors, it does not produce high levels of performance. This makes determining the effectiveness of surface irrigation for irrigation difficult. Surface irrigation performance must be improved due to the rise in competing water needs. Surface irrigation can be improved by adopting the best management practices and models that are calibrated using measured field data like as inflow, furrow cross-section, slope, and field length (Moravejalahkami, 2020). During irrigation, water is either allowed to pool on the soil or is continuously pumped over it. Typically, water is moved by gravity through canals, pipes, or ditches from a water source to the field. However, there are times when it may be essential to pump water up to a field farther away from the source.

II-9-2-2 Unchecked Flooding

When water is simply allowed to fall onto a surface without any effort to regulate or standardize the application, it is said to be "uncontrolled flooding." The application is not in any manner controlled or uniformed. The application of water to crops without any prior soil preparation or the use of a barrier to direct or control the flow of water onto the field is another aspect of the term. Water is moved to field ditches and then introduced at one end of the field in order to stop the field from flooding uncontrollably. When there is a surplus of water, the terrain is uneven, and the crop being grown is unaffected by a surplus of water, this method is appropriate. The advantage of uncontrolled flooding is that it requires little upfront land preparation. This disadvantage is offset by increased water loss from deep percolation and surface runoff (Sable *et al.* 2019).

II-9-2-3 Irrigation in Furrows

According to Moravejalahkami (2020), the bulk of the world's surface irrigation methods use furrow irrigation. Furrow irrigation's hydraulic behavior is affected by infiltration changes, making it a crucial factor in the design, assessment, and management of this technique. It is possible to make little channels along the water's main course, known as "furrows," "creases," or "corrugation," and allow the water to flow through them instead of flooding the entire ground surface. Small canals known as "furrows" have a nearly constant slope in the irrigation direction. When using furrow irrigation, water flows in corrugates or ridges that are typically 0.1-0.3 m wide and evenly spaced on fields with slopes of 0.1-3 percent. Irrigations typically last 12 to 24 hours, while shorter or longer intervals may be used depending on the length of the furrow, the qualities of the soil, and water management issues. Depending on the soil, slope, size of the field, and management concerns, individual furrow input rates can range from 10 to 100 L per minute. In around 25% of the overall irrigation period, the field must get an equal distribution of water. For fields with higher slopes (slopes larger than 1%), it is crucial to carefully control the flow rate since soil erosion rises with field slope and inflow rate. On soils with poor infiltration rates, low input rates, and lengthy irrigation times, it might be necessary to apply the appropriate amount of water during an irrigation. However, in order for water to flow over a field and evenly irrigate both the upper and lower sections of the field, fields with low slopes and/or high infiltration rates typically require higher inflow rates (Bjorneberg, 2013).

Water from a ditch or a gated pipe (concrete or earthen) can be used to irrigate a field. Siphon tubes are often used to move and control the water flow from ditches to specific furrows. As long as the tube's exit is lower than the water's height in the ditch, water will flow through it, over the ditch's bank, and into the furrow. How much water flows into the furrow depends on the tube's diameter and the elevation difference between the water level in the ditch and the tube's output. Water is sent to furrows through outlets on the pipe that are evenly spaced apart. It is possible to irrigate a field using water from a ditch or a gated pipe (earthen or concrete). Siphon tubes are widely used to move and control the water flow from ditches to specific furrow. As long as the tube's exit is lower than the water's height in the ditch, water will flow through it, over the ditch's bank, and into the furrow. How much water flows into the furrow depends on the tube's diameter and the elevation difference between the water level in the ditch and the tube's output. Water is sent to furrows through outlets on the pipe that are evenly spaced apart. The gated pipe's exit aperture and water pressure control how much water flows into the furrow. Individual earthen ditch furrows or a smaller feed ditch that feeds water to multiple furrows are irrigated by a breach or other break in the ditch bank. Flow restriction is much more challenging with an earthen ditch breach than with siphon tubes or pipe gates.

Furrow irrigation is more labor-intensive, less expensive, and technically sophisticated than the majority of other irrigation methods. Since water flows in furrows, field irrigation is possible without grading or leveling the ground. Because each irrigation in each furrow requires a different water flow rate, furrow irrigation is not a viable option for automation (Bjorneberg, 2013).

11-9-2-4 Border and Basin Irrigation

Systems of irrigation that use basins and borders provide the ground with an even layer of water. Basin irrigation is defined by Khanna and Malano (2006) as the application of water to a region that is normally leveled to a slope of zero and bordered by dykes or check banks to prevent runoff. Low bunds encircle flat areas of land to prevent water from flowing into neighboring fields. On-farm surface irrigation that achieves high water application consistency is known as basin irrigation. Basin irrigation is often used to grow rice on flat land or in terraced slopes.

Additionally, pastures (Lucerne, clover), trees (Citrus, Banana), and broadcast crops can be planted in basins (cereals). The basin method is suitable for crops that are mostly unaffected by prolonged standing in water. Crops that can't endure prolonged damp or wet conditions are frequently ineligible for basin irrigation. Usually, these are root and tuber crops, such potatoes, cassava, beets, and carrots, which need a soil that is loose and well drained. A flat area with uniform soil texture is necessary for effective basin irrigation, as is a water supply that can swiftly and evenly cover the basin. In an uneven basin, higher elevation locations will receive less water than lower elevation parts. If the basin's input rate is insufficient, water will move slowly, resulting in discernible disparities in how long an infiltration opportunity lasts inside the basin.

Basins are a form of irrigation that includes drain-back level basins. A drain-back level basin is made up of a series of parallel basins connected by a thin ditch that is 5–10 meters wide. A gate opens to start filling the nearby, lower-elevation basin after the first basin is full. Water flows to the second basin and then drains back into the inflow ditch near the inflow end of the first basin. Continue doing this until all basins have been irrigated. The drain-back phase improves uniformity by reducing the amount of water that infiltrates near the inflow end and initially increasing the inflow rate to the next basin, which boosts the advance rate. Because water travels across dikes rather than ponding within basins, border irrigation systems are more efficient for sloping fields than basin irrigation systems. The size of the irrigated areas between the dikes ranges from 3 to 30 meters in width and up to 400 meters in length. If the field slope between the dikes is about level, water should flow down the field uniformly (perpendicular to the flow direction). Even though border systems usually have slopes of no more than 0.5 percent, the slope along the dikes can occasionally resemble furrow irrigation (Bjorneberg, 2013).

In addition to open ditches with gates, breaches, or siphon tubes, borders and basins may also receive water through above- or below-ground pipelines. According to Bjorneberg (2013), inflow rates typically range from 10 to 100 L per second but can vary greatly depending on the size of the basin or border, the soil's texture, and the slope. Border and basin irrigation requires less manual labor than furrow irrigation since water is dispersed over a broader region with a single outlet.

11-9-2-5 Irrigation with Sprinklers

Sprinkler irrigation hydrates soil by sprinkling or spraying water over its surface from above. The irrigation system's mainline pipe pushes and distributes water; it is occasionally buried to avoid obstructing farming operations.

Sprinkler irrigation systems are divided into three categories: moving, set-move, and solid-set. Sprinkler irrigation is used to water many different types of plants, including pastures, orchards, grass, and field crops. Sprinkler systems are furthermore installed to apply sewage, protect plants from frost, and manage dust in enclosed animal activities.

Solid-set systems can be set up for a single season or indefinitely for lawns, orchards, or perennial crops. Set-move system types are manually or automatically shifted to another area of the field when the irrigation set at the current location is finished. Moving devices like center pivots and traveling cannons are used to spray water around the field. Due to the possibility of more exact control over water application, sprinkler irrigation frequently outperforms surface irrigation. Conversely, in windy and/or hot regions, sprinkler watering could result in substantial water losses as a result of evaporation and wind movement. Sprinkler irrigation systems also require maintenance because clogged nozzles and leaky pipe connections reduce system efficiency and application uniformity.

II-9-2-6 Sprinkler System with Solid Set

Solid-set sprinkler irrigation systems are made to spray water infrequently, every 1 to 5 days, to satisfy the needs of plants. Water application rates for field crops could range from 4 to 6 mm/h to 5 to 30 mm/h for turf treatments. Since sprinklers and pipe need to be put throughout the whole irrigation area, solid-set sprinkler systems have higher overhead costs than conventional sprinkler systems. Conversely, systems that are permanently installed can be automated to save time and enable irrigation to happen at any moment of day, decreasing the risk of plant stress.

Solid-set systems have excellent application consistency when built properly. Solid-set systems can also be utilized with specific high-value annual crops that have a little acceptance for water shortage, but they are more typically used with grass, landscape, and permanent crops. 20 m^2 can be irrigated by tiny sprinklers, whereas 50 m can separate two enormous sprinklers that resemble guns. Plastic pipe is frequently used in underground irrigation systems in addition to some above-ground ones. For field crops, aluminum tubing (diameter 50-100 mm) is typically utilized when the system is set up after planting and taken down before harvest. Since most irrigation systems are zoned, only a small area is irrigated at a time. On the other hand, equipment for preventing solid-set frost needs to be built to concurrently irrigate the entire area (Bjorneberg, 2013).

II-9-2-7 Sprinklers that are set to move

These irrigation systems are made to slowly apply water (e.g., 4-6 mm per hour) throughout the irrigation set, which usually lasts between 8 and 24 hours. The sprinkler irrigation system is relocated to a neighboring field for the subsequent set of irrigation after the irrigation set. In order to meet crop water needs up until the irrigation system returns to the area, which typically takes 7 to 10 days, a suitable volume of water should be applied during an irrigation set. Manual and side-roll irrigation systems are the most popular types of set-move irrigation systems. A single sprinkler or a line of sprinklers can make up a hand-move sprinkler system. A handline, often referred to as a hand-move sprinkler line, is typically made up of sprinkler-attached sections of aluminum pipe that are 9 or 12 meters long and 75 or 100 millimeters in diameter. An irrigation line is made up of separate pipes connected together and is often no longer than 400 meters.

After the irrigation set is finished, each component is manually moved 10 to 20 meters to the following irrigation set. The connection is then severed. The sprinkler pipes are connected in these less common systems in a certain method that makes it possible for a tractor to drag the irrigation line to the next set of sprinklers. Wheel lines, which are also called side-roll systems, function similarly to handlines in that the sprinkler is elevated by an enormous diameter wheel (1.5 to 3 meters diameter) that is positioned in the middle or at the ends of individual length of aluminum pipe (100 to 125 mm diameter). Sprinklers are used with self-leveling sprinklers so that they don't need to be put perfectly in order for them to work (Bjorneberg, 2013).

II-9-2-8 Sprinkler Systems that Move

Moving irrigation systems can move linearly, rotate at a fixed point, or employ traveling guns. A large capacity sprinkler mounted on a cart and propelled across the field by a cable or water supply pipe is referred to as a "moving gun." These systems irrigate a 400 m length by 50 to 100 meter wide region. Due to the fact that irrigation is set as the cart travels through the field and is then moved to a new spot for the subsequent irrigation set, a traveling gun is a mobile set-and-move irrigation system. In cable tow systems, a winch on the cart winds the cable, towing the cart and a soft hose across the field.

The cart is pulled by a hose reel system, in which a polyethylene solid plastic hose is looped around a reel on a trailer affixed at the run conclusion. Reel or winch power comes from an engine or water turbine. Sports fields, teeny-tiny pastures, and arenas can all be irrigated using smaller-sized traveling guns. Other times, a 20 to 60 m-long irrigation boom with numerous sprinklers, similar to those on center pivot systems, is used in place of the one enormous sprinkler. Systems using a center pivot and linear movement have comparable visuals and layouts. The sprinkler pipe spans that make up these systems—which may be one or more—are supported by "A-frame" towers. Between 30 and 65 meters are used as the span length. Sprinkler pipes are elevated 2-4 meters above the ground by hydraulic or electric-powered towers (Bjorneberg, 2013).

II-9-3 Impact of irrigation on Maize Production

In many countries, maize is grown in areas that receive between 300 and 500 mm of precipitation annually, which is close to or below the minimum amount required to generate a good yield (Sah *et al.* 2020). There are a lot of reports available about how water affects maize performance. When fertilizers and water are not in short supply, maize is a crop with a high water requirement that can produce 10–12 milligram of grain per hectare of land (Mário, 2017). It is, nevertheless, very susceptible to nutrient and water stress. For example, it has been shown that a single irrigation skip during a crucial growth stage, such as just prior to anthesis, tasseling, or silking and grain filling, reduces final grain yield (by 30–40%), plant height, dry matter accumulation leaf area index, and root growth in a maize crop that requires 400 to 450 mm for maximum yield. He went on to say that the two weeks before and two weeks after pollination are when maize needs the greatest water (Bondesio *et al.* 2016). Maize appears to be less responsive to water stress during the early vegetative growth phases because crop evapotranspiration is relatively low. If there is not enough water available during the reproductive periods, there could be significant yield losses (Abdelraouf & Ragab, 2018).

Improving irrigation is one way to increase crop yields in water-stressed areas while simultaneously boosting the resilience of the agricultural system to climate unpredictability (Jägermeyr *et al.* 2017). Irrigation boosts maize yield and thousand-grain weight across all soil types, according to studies (Fang & Su, 2019).

A lack of water, on the other hand, has minimal effect on yield during the early and mature stages. The biggest yield reduction occurred when the crop was stressed by a deficiency of 75% over the duration of the growing season. Crop water consumption efficiency throughout the course of the entire growing season ranged from 1.7 kilogram per cubic meters under ideal irrigation water application to 2.9 kg m-3 under stress caused by a 75 percent shortage. The vegetative, silking (flowering), and ear phases of maize growth can all be affected by water stress, which can lead to yield decreases of up to 25 percent, 50 percent, and 21 percent, individually (Sah *et al.* 2020). The maize plant is moderately sensitive to salt.

Acosta-Motos *et al.* (2017) stated that the bulk of investigations on this crop have identified salinity as one of the major factors contributing to plant stress. By using the biphasic model of salinity-induced growth reduction, it was determined that the first phase of the decreased growth in cereals is caused by osmotic stress and the second phase is related to ion toxicity (Farooq *et al.* 2015). Also discovered was a connection between maize susceptibility to salt and increased Na^+ accretion in the leaves. Salt concentrations more than 0.25 M of NaCl cause maize plants to suffer from stunted development and severe wilting. The most detrimental ion that hinders potassium from being adequately absorbed is sodium because it disrupts stomata undulations and causes considerable water loss and necrosis in maize. Additionally, he claimed that salt stress causes maize to produce more reactive oxygen species, which causes oxidative damage to plant cells. Similar to this, (Farooq *et al.* 2015) confirmed that maize grown in saline water initially grew more slowly, with dark green leaves but no signs of toxicity.

II-9-4 Importance of Irrigation on Maize Growth and Yield

A very significant global production-limiting factor for maize is water (Dordas *et al.* 2018), The optimal distribution of precipitation during the vegetative phenophases determines yield stability, it was further explained that grain may vary due to climate condition (Jolankai *et al.* 2016), Water causes considerable economic losses in the cultivation of corn; due to this fact, one of the most serious difficulties facing maize breeders today is breeding for drought tolerance (Payero *et al.* 2009). Moreover, maize has significant water requirements, which must be met to produce the highest yields. The metabolism of maize is constrained by the lack of accessible water in the soil, which also affects its biomass, number of leaves, leaves area and reduces its photosynthetic rate by lowering the number of leaf chlorophyll (Efeoğlu *et al.* 2009). The result is a loss in maize yield. Also, the risk of this strategy is that excessive water reduction at the critical growth stage can reduce the yield and/or quality of the crop. Another element that must be taken into account is the fact that water stress typically happens during hot weather spells, which, depending on the intensity and length, may also result in considerable reductions in shoot growth, leaf area, and yield (Mansouri-Far *et al.* 2010). It is commonly accepted that a water shortage significantly reduces the growth of maize, the growth of the surface area of leaves, and the effectiveness of the photosystem II. The plant height and leaf area can, however, be considerably made up for following re-watering. Conversely, several researchers discovered that proper moisture regulation boosted maize's WUE (water use efficiency) and improved its resistance to drought (Wang *et al.* 2004). At the silking stage of maize, according to Kebede *et al.* (2014), lowering soil moisture in the field to 75% during the maize silking stage did not significantly reduce grain output compared to full irrigation and resulted in significant water savings. The effects of a water shortage on maize at various growth stages have also been investigated by several researchers. In order to boost grain yield and WUE, Kang *et al.* (1998) found that a moderate water deficit at the seedling stage and a mild water shortage at the jointing stage is acceptable. Additionally, Oktem (2008) had reported that the loss in yield (22.6-26.4%) brought on by deficit irrigation was accompanied by a drop in kernel weight and quantity. Moreover, crop growth, canopy development, and morphological traits of the corn plant were reported to be affected negatively by water shortage. Also, he noted that a lack of water considerably lessens the buildup of dry materials. Due to a fall of 18% in kernel weight and 10% in kernel number under water stress circumstances, grain yield was decreased by 37%. According to Dağdelen *et al.* (2006), corn yield was considerably impacted by water scarcity, and full irrigation produced the highest yield. Furthermore, Nagy (2003) stated that irrigation guarantees increase in yield of maize, due to its ability to maintain optimum physiological functions of the plant and ensure optimum plant processes in the absence of rainfall. Additionally, Széles *et al.* (2012) reported that in addition to enhancing productivity, irrigation lowers annual yield variability and reduces agricultural production risks. Avramova (2015) also reported the impact of water on agronomic parameters (height, leaf area and numbers of leaves) of maize which can limit growth and yield due to its interference with some important physiological processes including photosynthesis, cell expansion and nutrient update.

111 Materials and Methods

111-1 Site Description

The study was conducted at the research farm of the Hungarian University of Agriculture and Life Sciences, from May to August of 2022. The study site is in Pest, Godollo, Hungary, at latitude 47.59373°N and longitude, 19.3605°E. The average annual precipitation in Hungary is 400–500 mm, and the country experiences temperatures between -10°C and 30°C. At planting, the temperature was 16.3°C, with precipitation of 0.22 mm. Between May and August 2022, an experimental growing period was in place. The maximum daily temperature during this experiment was in June with a temperature of about 29.8°C, while the minimum daily temperature was in August with a temperature value of 10.2°C. Also, the maximum daily precipitation was in June with a value of 24.9 mm, while the period of no rainfall were also recorded across the months. The area's predominant soil type is brown forest, which is distinguished by a fine-drained subsoil that is brownish in color. The pH of the soil at the research site was 6.5, making it nearly neutral.

Figure 1: Experimental Site

III-2 Characteristics of Test Crop (maize)

- Hybrid- Margitta (FAO 280)
- Type of kernel- Dent
- Use- Grain
- Suggested plant density- 65 to 70,000 stem/ha
- Kernel row number- 16 to 18 pcs
- Kernel/cob ration- 86.8%
- Length of cob- 21 to 22 cm

Figure 2: Margitta Maize

Table 3: Physico-chemical properties of the experimental site

Characteristics	Value
KA	45
pH (H20)	7.21
Humus (%)	2.65
CaCO3 (%)	1.86
AL-P2O5 (mg/kg)	643
AL-K2O (mg/kg)	293
CaCl-Mg (mg/Kg)	129
N min (0-60cm: Kg/ha)	67.4

III-3 Treatments, experimental design and procedures

This experiment has one treatment (Irrigation), which contains three levels (100, 50, and 0 liters) planned out in a randomized complete block design (RCBD), with two replications of every treatment. Margitta, a well-adapted type of maize that is popular among farmers in Hungary, served as a test crop. The experimental field was thoroughly cleaned, plowed, and prepared, and the seedbed was made with a combinator. The experimental unit (plot) consisted of a 30 m x 10 m space and containing four (4) rows of maize with equal length. Two maize seeds were sown in each hole, with inter and intra row spacings of 0.75 meter and 0.25 meter, correspondingly. The seeds were planted on 5th May 2022. Each plot's two middle rows served as harvestable rows, while its outermost rows were regarded as boundaries.

Flood irrigation was employed as the means of irrigating the plant. The irrigation were done on a weekly basis. The irrigation were in three parts, which are 100 litres, 50 litres and 0 litre were applied manually. Throughout the experimental period, all other maintenance tasks were carried out in a similar manner on all plots.

III-4 Data Collection and Analysis

The data collection were separated into two parts, which include growth and yield section;

The growth parameters: leaf number per plant, plant height, number of leaves, stem girth and leaf area were measured from fifteen randomly selected plants from the central rows in each plot, while the Chlorophyll contents (nmol/cm^2) were measured randomly from five selected plant per plot, with the use of the chlorophyll meter. Using a tape measure, the height of the plant (in centimeters) was calculated from its base to its highest leaves. Upon reaching the silking stage, the plant's number of leaves per plant was counted visually, stem girth (mm) were taking with the help of a vernier caliper, while leaf area (cm^2) were calculated by multiply the lead length and breadth (L X B) of individual plant.

On the other hand, **the yield parameters:** Number of lines per cob, weight of cob, length of lines per cob were calculated from ten randomly selected harvested cob. The number of lines per cob and length per cob were calculated by physical counting while the weight of cobs were estimated with the use of a laboratory weighing scale (g). Using the 2003 version of Excel program, the acquired data were subjected to analysis of variance (ANOVA). Difference among the treatments' means were compared using Bonferroni test at 0.05 probability level.

IV Results and Discussion

Figure 3: Effect of Irrigation on Number of Leaves (Maize)

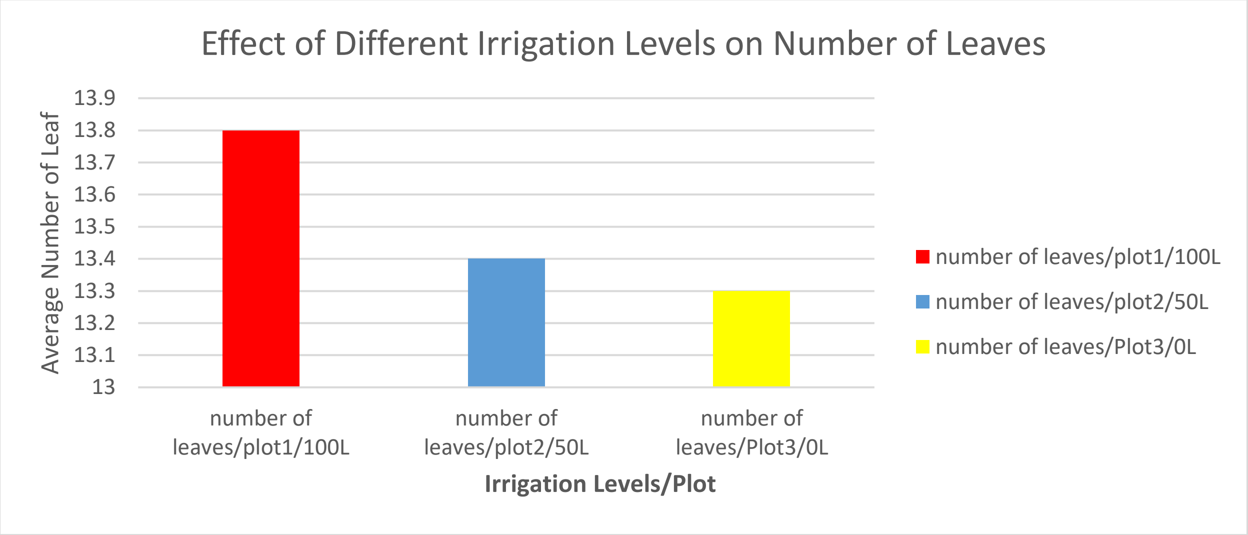


Table 4: Mean Separation of Factors Responsible For the Significant Difference in Number of Leaves Using Bonferroni Test

POST-HOC TEST	
Groups	**P-value (T test)**
Number of leaves (100litres/Plot1 V 50 Litres/Plot2)	0.22679
Number of leaves (50litres/Plot2 V 0 Litre/Plot3)	0.85875
Number of leaves (0 litre/Plot3 vs 100 Litres/Plot1)	0.13913

Data were analysed at 5% probability level and means were analysed using Bonferroni Test.

(Reference value: 0.01667)

IV-1 Effect of Irrigation on Number of Leaves (Maize)

Data of maize number of leaves in response to different irrigation levels (100 litres, 50 litres and 0 litre) are shown in figure 3, while the means were separated using the Bonferroni test at 5% alpha level (Table 4). The data depicts that, with increasing levels of irrigation water, the growth rate of maize leaves had a positive response that matches the level of irrigation. It was observed that Irrigation contributed significantly to the number of leaves during the period of growth of maize. The plot 1 (one) which was irrigated with 100 liters of water produced the highest yield number of leaves, which resulted in the average value of 13.8, this value was significantly highly than the non-irrigated plot 3 which resulted in the least number of leaves at 13.3. The findings of this study aligns with the claim of (Efeoğlu *et al.* 2009) who found out that irrigation had significant impact on maize metabolism which contributes to the number of leaves produced. Furthermore, it was found that irrigation had significant impact on all treatment at 5% probability level, while none of the treatment interactions were significant. The increment in number of leaves can be attributed to the function of water in transporting nutrients that are essential for growth of plants and also the function of water for maintaining turgour pressure which is necessary for plant growth.

Figure 4: Effect of Irrigation on Plant Height (cm)

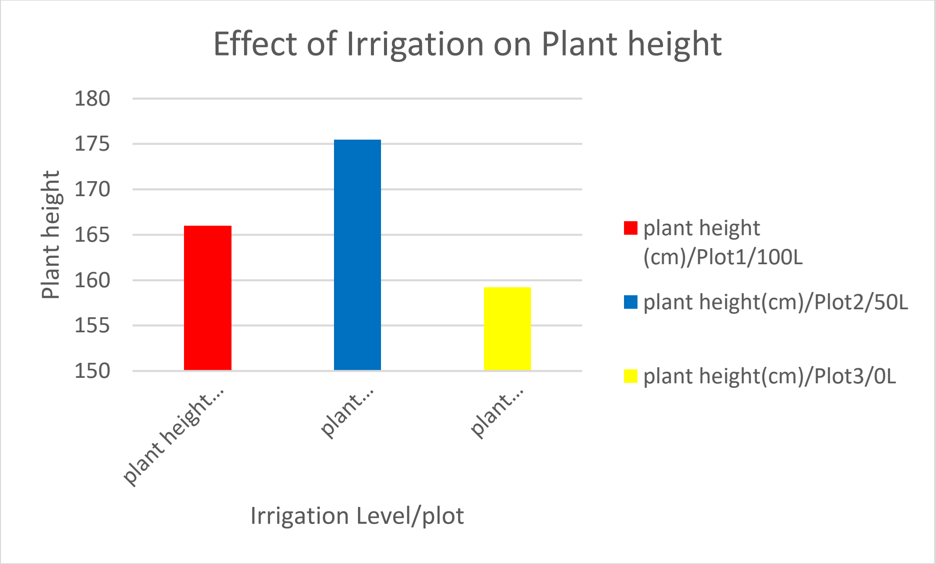


Table 5: Mean Separation of Factors Responsible For The Significant Difference In Plant Height Using Bonferroni Test.

POST-HOC TEST	
Groups	**P-value (T test)**
Number of leaves (100litres/Plot1 V 50 Litres/Plot2)	0.08598
Number of leaves (50litres/Plot2 V 0 Litre/Plot3)	0.00261
Number of leaves (0 litre/Plot3 vs 100 LitreS/Plot1)	0.22773

Data were analysed at 5% probability level and means were separated using Bonferroni Test.

(Reference value: 0.01667)

IV-2 Effect of Irrigation on Plant Height (cm)

The data stated in figure 4 shows that the average height of maize in response to different irrigation levels (100 Litres, 50 Litres, 0 litre) shows that water is a very important factor that determines the height of maize. The irrigated maize had a significantly greater height compared to the non-irrigated maize plants. The highest height was recorded at 175 cm for maize irrigated at 50 litres, while the least height was produced by the non-irrigated maize plants. This difference in height was statistically significant at 5% probability level, indicating that irrigation had a positive impact on maize growth. Furthermore, using the Bonferroni mean separation test, it was observed that there is a significant difference between plot 3 (0 Litre) and plot 2 (50 Litres). While the means of other pairs were not significant. These finding is in-line with the research of Avramova et al. (2015) that confirmed that irrigation had significant impact on maize height. The increase in root growth as a result of water availability can be attributed as the contributing factor to the observed increase in plant height.

Figure 5: Effect of Irrigation on Plant Girth (mm)

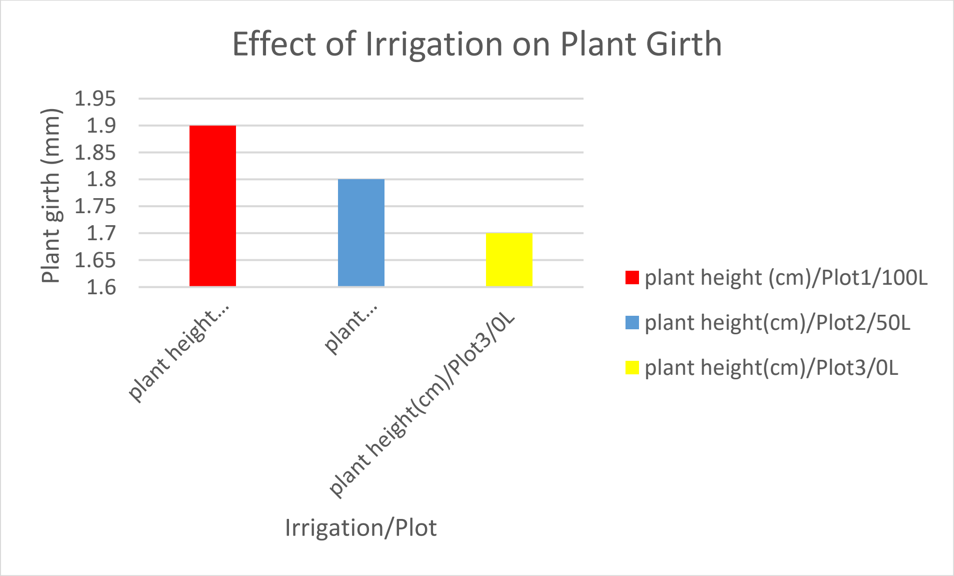
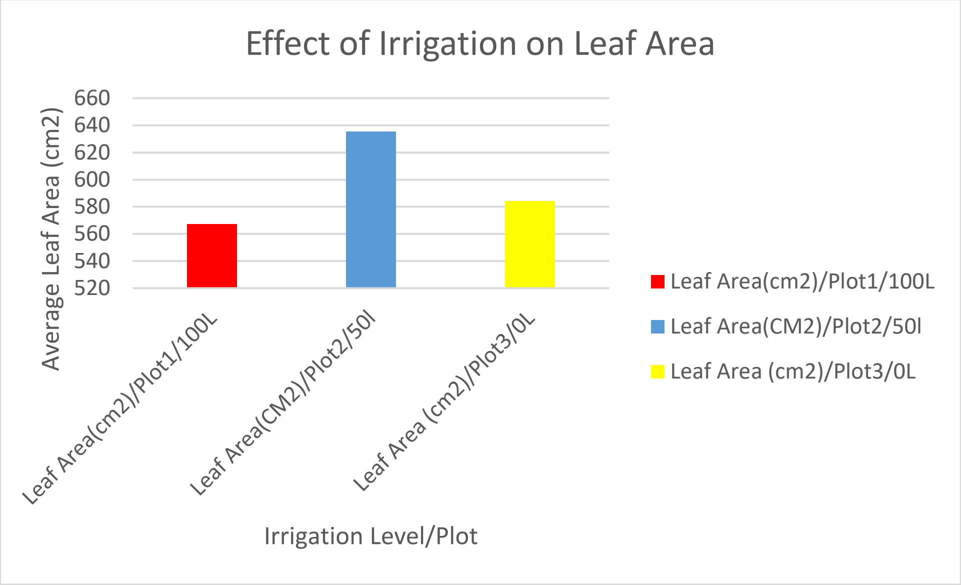


Figure 6: Effect of Irrigation on Leaf Area (cm^2)



IV-3 Effect of Irrigation of Plant Girth and Leaf Area

Although Irrigation led to increase in plant girth (figure 5), where the highest girth was 1.9 mm which was recorded in plot irrigated with 100 litres of water, while the lowest was 1.7 mm, in the plot without irrigation. This difference was not significant upon analysis at 5% probability level. Also, the leaf area had a similar report (figure 6) at 5% probability level, where the overall impact of irrigation on the maize leaf area were not significant. The highest leaf area was recorded at 635.4 cm^2 on the plot which was irrigated with 50 litres, while the least was on the plot with 100 litres at 567.4 cm^2.

Figure 7: Effect of Irrigation on Chlorophyll Content of Maize Leaves (nmol/cm^2).

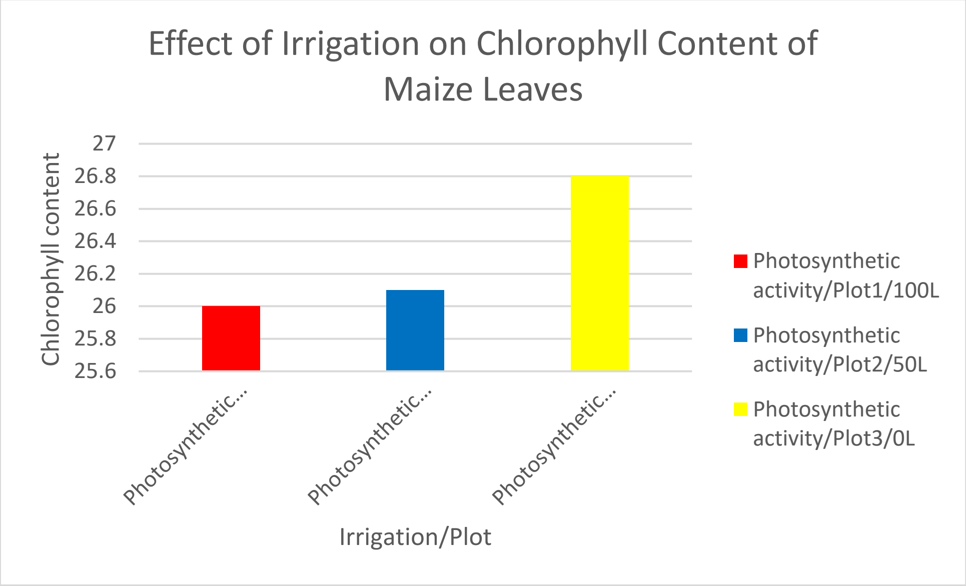


Table 6 Mean Separation of Factors Responsible for The Significant Difference in SPAD Value (Chlorophyll Content) Using Bonferroni Test.

POST-HOC TEST	
Groups	**P-value (T test)**
SPAD Value (100litres/Plot1 **V** 50 LITRES/Plot2)	0.939669
SPAD Value (50litres/Plot2 **V** 0 Litre/Plot3)	0.869874
SPAD Value (0 litre/Plot3 **V** 100 LitreS/Plot1)	0.835799

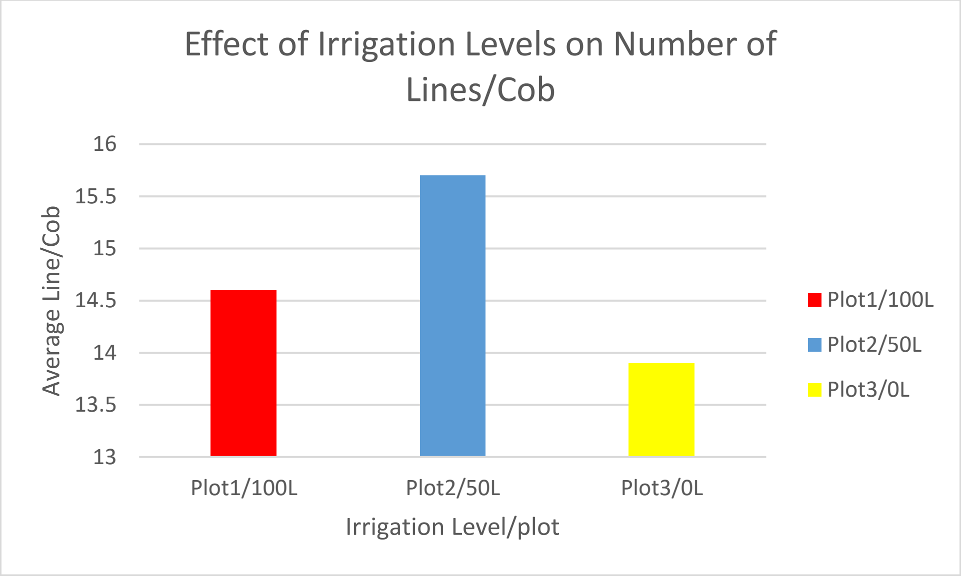
Data were analysed at 5% probability level and means were analysed using Bonferroni Test.

(Reference value: 0.01667)

IV-4 Effect of Water on Chlorophyll Content of Maize

As shown in this finding in figure 7; Water had a significant impact on the chlorophyll content of maize leaves on different plots at 5% probability level. Although, while pairing the treatment there were no significant mean difference in the interactions using Bonferroni test. The highest chlorophyll content was recorded at 26.8 nmol/cm^2 for plot without irrigation, while the least value of 26 nmol/cm^2 was on plot irrigated with 100 litres. The observed difference in each plot might be due to external irrigation source i.e. rainfall, make the plot with zero irrigation to have optimum water supply while others had excess. Also, the topography of the experimental site might also be the reason for the difference, as more nutrient tends to accumulate towards the lower slope of the soil.

Figure 8: Effect of Irrigation Levels on Number of Lines/Cob



IV-5 Effect of Irrigation Levels on Number of Maize Lines per Cob

The bar chart in figure 8 depicts the effect of irrigation on number of maize lines per cob. The statistical analysis (5% probability level) of the data above showed that there is no significant impact of different levels of irrigation (0, 50, 100 litres) examined in this experiment on the number of maize lines. Although the highest number of lines of 17.7 was recorded in the plot irrigated with 50 litres (plot 2), while the least was in the plot without irrigation which resulted in 13.9 (plot 1). Though, the impact was not significant across all the experimental plots (1,2 and 3). However, this might be due to the fact that the level of irrigation deployed in this experiment is not optimal to ensure similar increment as observed by the researcher. Also, the irrigation frequency could also be another factor that led to the observed difference.

Figure 9: Effect of Irrigation on Average Maize Line

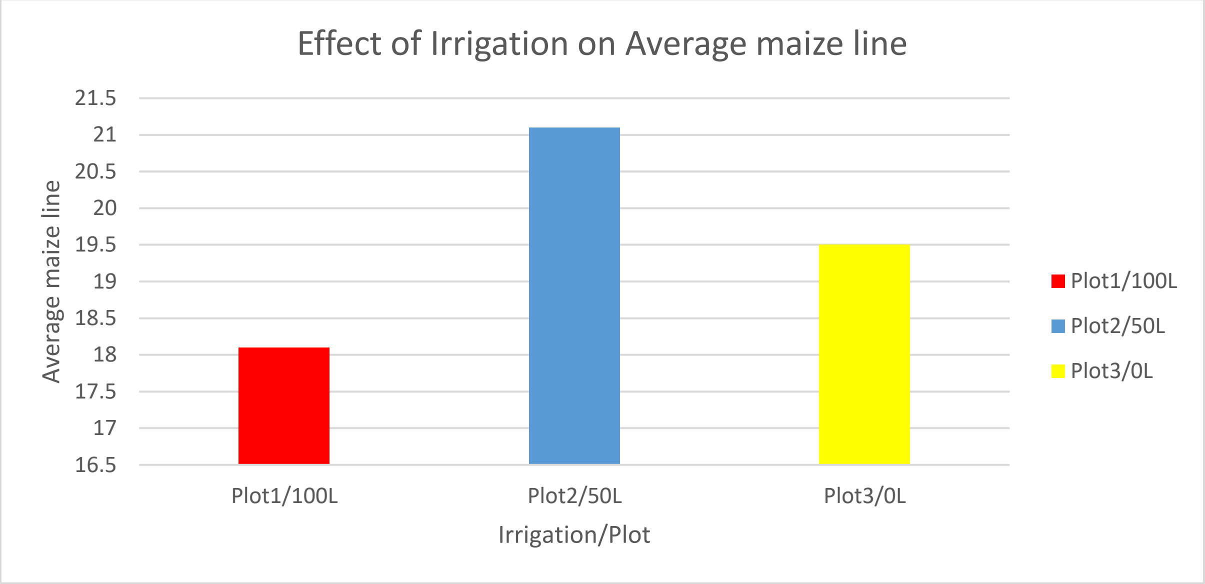


Table 7 Mean Separation of Factors Responsible For the Significant Difference in Maize Line Using Bonferroni Test

POST-HOC TEST	
Groups	**P-Value (T-test)**
Average maize length (Plot1 V Plot2)	0.214748
Average maize length (Plot2 V Plot3)	0.431235
Average maize length (Plot3 Vplot1)	0.553327

Data were analyzed at 5% probability level and means were separated using Bonferroni Test (Reference value: 0.01667)

IV-6 Effect of Irrigation on Average maize line

The Figure 7. Above confirmed that Irrigation has a significant impact of the length of maize lines. On the average, the plot irrigation with 50 litres of water produced the highest number of lines at 21.1, while the plot with 100 litres of water produced the lowest number at 18.1. This finding agrees with the report of Oktem (2008), who confirmed that irrigation increased quantity of maize kernels. This observation can be attributed to the fact that irrigation increase soil moisture which makes water available to plant roots at critical stages i.e. grain filling stage, leading to higher length of maize lines as observed in several studies. However, excess irrigation as seen in 100 litres might have impact of yield as observed in this study. As it has the capacity to deprive the plant of necessary oxygen needed for optimum development.

Figure 10: Effect of Irrigation on Average Cob Weight

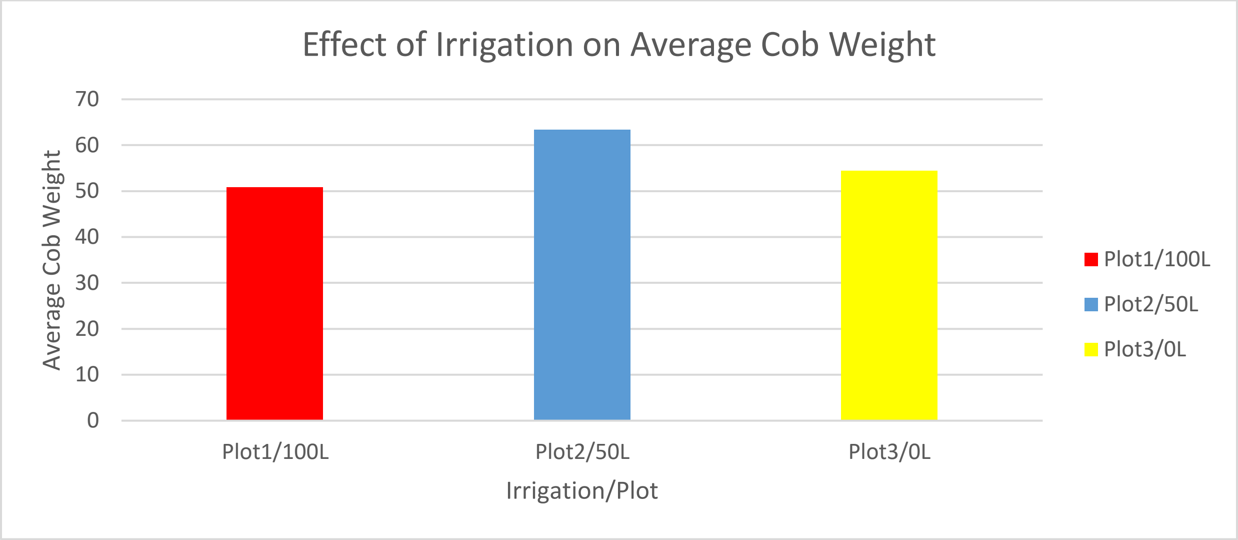


Table 8 Mean Separation of Factors Responsible For the Significant Difference in Cob Weight Using Bonferroni Test

POST-HOC TEST	
Groups	**(P-Value)**
Weight of Cobs (Plot1 V Plot2)	0.205022393
Weight of Cobs (Plot2 V Plot3)	0.24010825
Weight of Cobs (Plot3 V Plot1)	0.589713287

Data were analyzed at 5% probability level and means were separated using Bonferroni Test.

(Reference value: 0.01667)

IV-7 Effect of Irrigation on Average weight of cobs.

According to this experiment (figure 8), It was observed that Irrigation had significant impact on the weight of cobs at 5% probability level. The highest cob weight was recorded at 63.4 g while the least was recorded at 50.9 g on plot irrigated with 50 litres and 100 litres of water respectively. This observation is in accordance with the findings of Myers *et al.* (2017) who confirmed that irrigation had significant impact on maize yield including the weight of cob. This impact can be attributed to moisture availability during the grain filling stage, which led to heavier and high-quality grains and cobs.

IV-8 New Scientific Results

- Regarding most indicators, the 50 litres irrigation application proved to be beneficial in comparison to the rain fed (0 litre) and to the higher amount applications (100 litres).
- Strong irrigation impacts were detected in the case of the number of the leaves/plant as well as plant girth and on the number of seed rows/cob.
- The SPAD Value was found to be the highest in the case of non-irrigated applications.
- Irrigation positively influenced plant height, highlighting the crucial role of water in enhancing maize productivity.
- It was observed that with excess irrigation beyond 50 litres the average maize line and the weight of cobs will reach a plateau state where further irrigation will not lead to any positive increase i.e. (100 litres).

V Conclusion

This study evaluated the impact of different levels of irrigation on growth and yield of maize. From this experiment, it was established that irrigation had substantial impact on growth and yield of maize. Furthermore, the study suggests that irrigation is a critical factor in increasing the growth and yield of maize, particularly in areas with limited rainfall and in the face of climate change realities. These findings have important implications for global farmers and policymakers, as it now obvious that investments in irrigation infrastructure could significantly increase crop productivity and food security in regions where maize is a staple crop. From this experiment, it can be settled that appropriate irrigation for optimum growth and yield of maize is 50 litres for areas with similar climatic and soil conditions, this is because plots that were irrigated with the 50 litres of irrigation water produced the optimum growth and development of the maize which resulted in the high maize yield. Although plot irrigated with 100 litres also had an impact on the growth and yield of maize but the plots with 50 litres had a better yield. Therefore, irrigating maize field with 50 litres of water under similar soil and climate condition will result in optimum growth and yield. Finally, the study recommends that for effective production of maize, an irrigation of 50 litres is needed to have an optimum growth and yield response.

Summary

Thesis title: EFFECT OF DIFFERENT LEVELS OF IRRIGATION ON GROWTH AND YIELD OF MAIZE

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Course: M.Sc. Crop Production Engineering

Institute/Department: Crop Production

1. Primary thesis adviser: Dr. Ákos Tarnawa, professor, Institute of Crop Production Sciences
2. Independent consultant : Dr. Márton Jolankai, Institute of Crop Production Sciences

An important stressor affecting rainfed agriculture at the moment is climate change. Available evidences have demonstrated that climate change is a major contributor to the persistent irregular rainfall pattern that occur during the growing season. Maize is a vital crop in both Nigeria and Hungary, serving as a source of food and income for millions of people. In Nigeria, maize is a staple crop, while in Hungary it is grown for human consumption, animal feed, ethanol production, and as a raw material for various industries. However, the current climate change reality has led to the decline in the production of maize in both countries as a result of dependence on rainfall for maize production.

In this study, how varying irrigation levels affected the development and yield of maize was investigated in an open field setting. An important factor in enhancing food security for the global population and a topic of ongoing research is understanding how maize might react to climate change effects.

This research was conducted at the Hungarian University of Agriculture and Life Sciences research farm between May and August 2022. The experiment which was set in a Randomize complete block design (RCBD), having a factor (irrigation) with three irrigation levels (100 litres, 50 litres, 0 litre). A maize variety known as margitta was used as the test crop. These treatment was replicated two times.

The results showed that moderate irrigation (50 litres) application ascertained to be favorable in terms of growth and yield of maize in contrast to the rainfed and to the higher amount of irrigation application (100 litres). Furthermore, significant effects of irrigation were seen on the number of leaves per plant, plant girth, and number of seed rows per cob. The non-irrigated treatments were found to have the highest Chlorophyll content. Also, Irrigation positively influenced plant height,

highlighting the crucial role of water in enhancing maize productivity. It was observed that with excess irrigation beyond 50 litres the average maize line and the weight of cobs will reach a plateau state where further irrigation will not lead to any positive increase i.e. (100 litres).

It was concluded that increasing environmental stresses associated with climate change would adversely affect the global productivity, particularly maize production, but effective management of irrigation will help to boost food production in the face of climate change realities. Therefore, an irrigation level of 50 litres was concluded as optimum for maize production.

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Appendices

Appendix 1: ANOVA analysis of number of leaves

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
number of leaves (100litres)	15	207	13.8	0.45714
number of leaves (50litres)	15	201	13.4	1.11429
number of leaves (0litre)	15	200	13.3333	0.95238

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.911111111	2	0.955556	1.135849	0.330815	3.219942
Within Groups	35.33333333	42	0.84127			
Total	37.24444444	44				

Appendix 2: ANOVA analysis of plant height

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
plant height (cm) 100litres	15	2490	166	260
plant height(cm) 50litres	15	2633	175.5333	170.4095
plant height 0 litre	15	2388	159.2	196.0286

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2019.511	2	1009.756	4.8357	0.012882	3.219942
Within Groups	8770.133	42	208.8127			
Total	10789.64	44				

Appendix 3: ANOVA analysis of leaf area

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Leaf Area cm2 (100 litres)	15	8510.62	567.374667	11648.47197
Leaf Area cm2 (50 Litres)	15	9530.95	635.396667	3370.310881
Leaf Area cm2 (0 litre)	15	8762.13	584.142	8428.284374

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37675.884	2	18837.942	2.410272701	0.10211	3.219942
Within Groups	328258.94	42	7815.68907			
Total	365934.83	44				

Appendix 4: ANOVA analysis of chlorophyll content

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
SPAD Value (100litres)	5	129.8	25.96	14.153
SPAD Value (50 litres)	5	130.7	26.14	12.408
SPAD Value (0 litre)	5	133.9	26.78	59.167

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.8573333	2	0.928667	0.032498	0.968109	3.885294
Within Groups	342.912	12	28.576			
Total	344.76933	14				

Appendix 5: ANOVA analysis of Plant Girth

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
plant girth/100 litres	15	29	1.9333333	0.050952381
plant girth/50 litres	15	27	1.8	0.062857143
plant girth/0 litre	15	25.4	1.6933333	0.10352381

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.433777778	2	0.2168889	2.993865031	0.060884	3.219942
Within Groups	3.042666667	42	0.0724444			
Total	3.476444444	44				

Appendix 6: ANOVA analysis of maize lines per cob

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Lines/cob/100 Litres	10	146	14.6	1.82222222
Lines/cob/50 Litres	10	157	15.7	4.67777778
Lines/cob/0 Litre	10	139	13.9	2.98888889

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.46666667	2	8.233333	2.6030445	0.0925226	3.354131
Within Groups	85.4	27	3.162963			
Total	101.8666667	29				

Appendix 7: ANOVA analysis of average maize lines

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Longest maize Line/Plot1/100L	10	181	18.1	34.32222
Longest maize Line/Plot2/50L	10	211	21.1	20.1
Longest maize Line/Plot3/0L	10	195	19.5	19.38889

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	45.06666667	2	22.53333	0.915851	0.412251	3.354131
Within Groups	664.3	27	24.6037			
Total	709.3666667	29				

Appendix 8: ANOVA analysis of weight of cobs

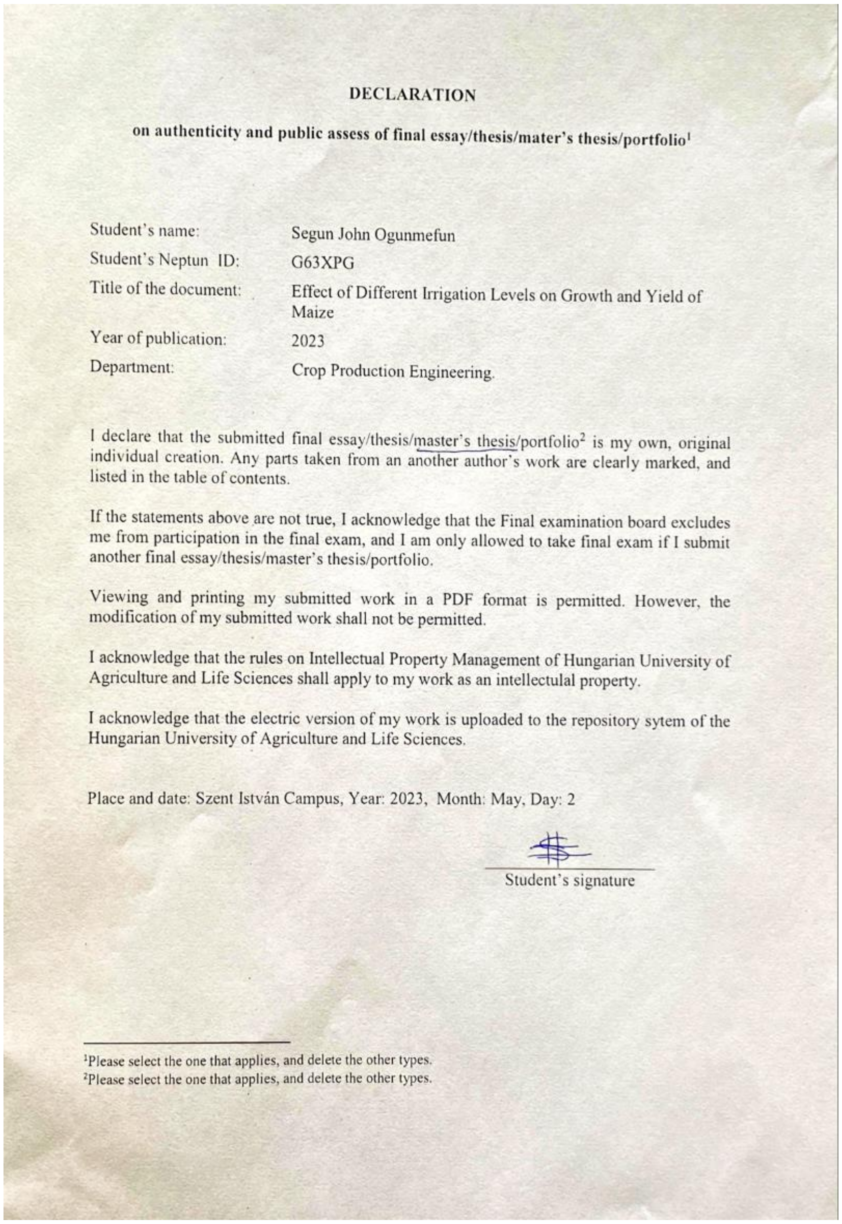
Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Weight of Cob/Plot1/100L	10	483.09	48.309	1006.29
weight of cob (g)/Plot2/50L	10	633.6	63.36	303.765
weight of cob (g)/Plot3/0L	10	544.3	54.43	236.536

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1145.813807	2	572.907	1.1113	0.34372	3.35413
Within Groups	13919.30629	27	515.53			
Total	15065.1201	29				



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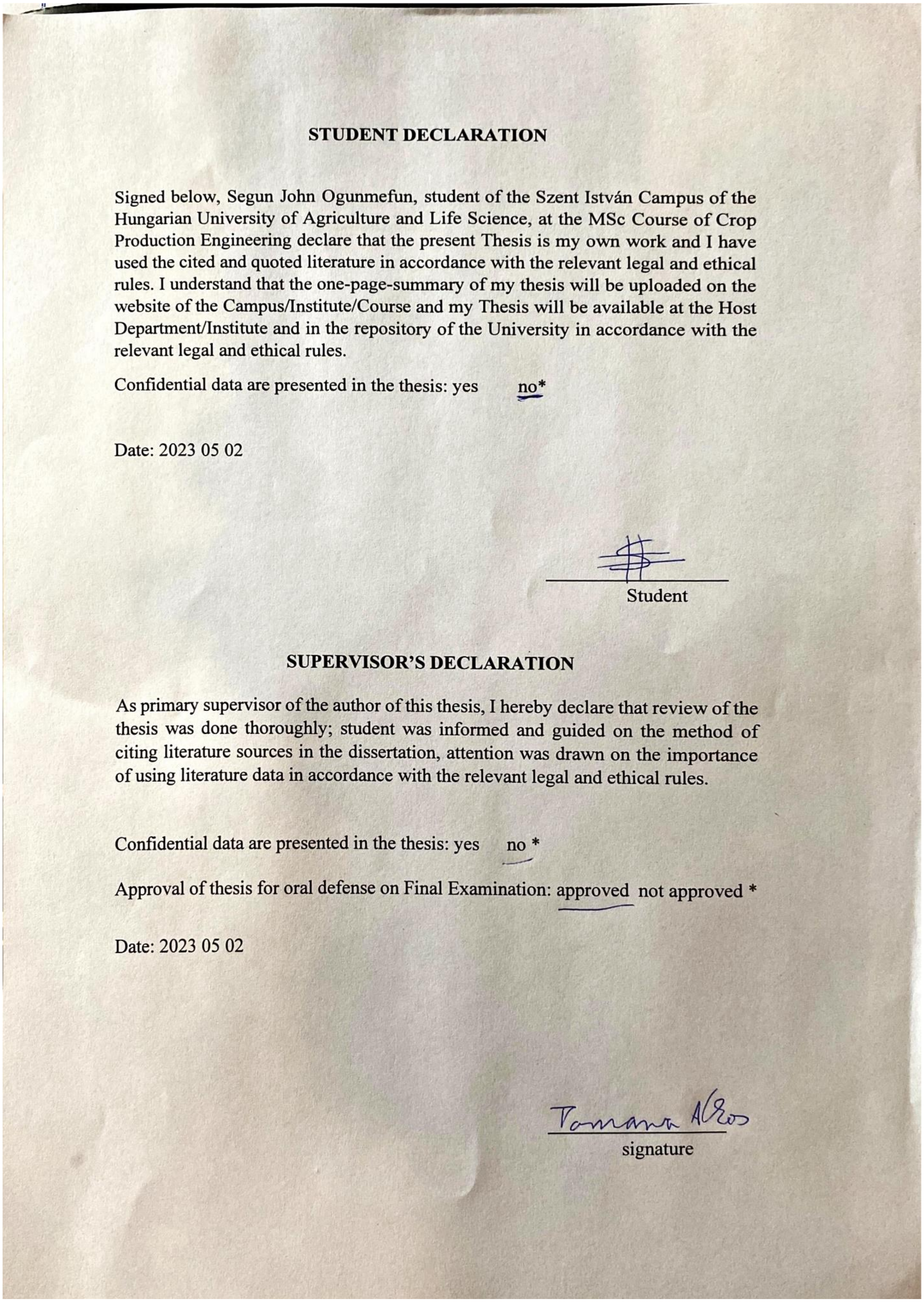

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Signed below, Segun John Ogunmefun, student of the Szent István Campus of the Hungarian University of Agriculture and Life Science, at the MSc Course of Crop Production Engineering declare that the present Thesis is my own work and I have used the 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.

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