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THE EFFECTS OF WATER SUPPLY ON THE VIABILITY, GROWTH, YIELD, PHYSIOLOGY, AND QUALITY OF MAIZE (Zea mays L.)

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1. INTRODUCTION

The human population is growing at an increasing rate over the years and has now hit a population of about 7.4 billion of people in the height of this twenty-first century. Agriculture has become a major player in the lives of human population and will also have a huge challenge in the foreseeable future, since the human population is predicted to rise to 9.7 billion by the year 2050. Therefore, as agriculture is developing tremendously, at the same time given a great challenge to scientist world over to find the best available solutions for one of the biggest questions for our today's world; thus, - How can we survive on the current vegetation amidst the ever-fast climate changes we have in our dear planet Earth? The biggest threat to the human population in the near future will not be war or conflict, but the possible starvation as a result poor access to food and clean water and agriculture will play a major role in the future of humanities. This study will specifically focus on Hungary, which has been recognized worldwide as one of the significant agricultures producing country with an outstanding strategic sector for the Hungarian national economy (Id, No, Republic and Republic 2015, pp.1-2).

Maize is one of the most researched and characterized plants with a significant amount of information available for many aspects of its biology (Regulator, 2008). Because of this, the importance of the cultivar different studies to optimize its studies cannot be over emphasized since it increases the production in the field and in a way all experimentation in the field can be applied to real farming situation which will have a future relevance and its application.

Maize is a main cereal plant worldwide, using as an important staple food for human and feed for livestock. It has become a major industrial resource and production of biofuel. Maize plant grain is largely used for corn starch, corn syrup, corn flake, and lactic acid preparation which are used for biodegradabe different industrial materials production such as foundry, textiles, fermentation etc. The consumption of maize as feed has increased greatly as the development of the livestock and poultry industries improves. (Hallauer and Miranda, 1988). Maize constitutes a stable food in many regions of the world. It is a basic stable for large population groups particularly in developing countries (FAO and ILO, 1997). Doebley (1994), reported that maize can be boiled or roasted on the cob, the grains can be cooked fresh or dry and the dry grain can be made into popcorn and eaten with roasted groundnuts.

Maize is one of the most abundant food crops in Nigeria. About 80% is consumed by man and animals while 20% is utilized in variety of industries processes for production of starch, oil high fructose, corn sweetener, ethanol, cereal and alkaline. Maize consists of 70 - 75% starch, 7 - 9% protein and 4% oil on a dry weight basis. Despite the economic importance of maize to the teeming populace in Nigeria, it has not been produced to meet food and industrial needs of the country. This could be attributed to low productivity from maize farms or that farmer have not adopted improved technologies for maize production.

World demand for maize is expected to raise from 526 million tons to 784 million tons from 1993 to 2020, with many of these increases in demand coming from developing nations. (Rosegrant et al.,1999). World area under maize crop was 147.6 million hectares with a grain production of 701.3 million metric tons and overall yield of 4752 kg per hectare during 2006-07. Maize plant is mostly cultivated as a grain for human food and as a fodder for animal feeding.

Maize is mostly cultivated under rain-fed conditions in many parts of the world and due to lack of rains, water shortage becomes a big problem for effective production of the maize crop. (Araus et al., 2002). Maize utilises moisture effectively and requires about 500 to 800 mm of water in its production life cycle of between 80 to 110 days according to Critchley and Klaus, 1991. Water for crop production is becoming a scares resource and has been anticipated that water for irrigational use may be drastically reduced up to about 50% (Anonymous, 2001).

Drought deficit or water stress is an unavoidable and recurring element of world agriculture phenomenon. According to Kramer (1980), about one-third of the world’s possibly cultivable lands suffers because of water scarcity and the largest part of crops production is mostly affected by drought. Water is an essential part of plant production and plays a vital role in the induction of growth, consequent maintenance of developmental stages throughout the plant’s life and eventually increases the economy of a country. Maize crop may experience decline in grain yield when introduce to water stress during key stages or periods of its growth such as tasselling period to grain filing stage and may result in reduction of grain yield. A long period of water stress of 48.8mm accounted for grain yield of 4.8 t/ha and whiles a short period of drought during the critical stages of maize growth reduced grain yield to less than 2 t/ha and affecting ear per plant and kernel per ear. (Bergamaschi et al., 2004).

Nonetheless, maize crops are very susceptible to water deficit and heat. Each year, an average of about 15% to 20% of the prospective global maize production is lost because of drought situation (Lobell et al. 2011). These yield losses hinge on when drought stress set in plant growth stages, as well as the long duration and the intensity of the stress period. Early season water stress reduces crops growth and Early season drought reduces plant growth and impedes plant development (Heiniger and Dunphy, 2001).

According to (IPCC, 2001), Climate change is any changes in climate overtime, whether because of natural variability or due to human activities. While climate change is a worldwide occurrence, its harmful impact is more harshly felt by rural poor people in developing nations who rely greatly on the natural resources for their survival. Poor people in rural settings rely mostly on agriculture and animal rearing for their survival which are among the main climate sensitive economic areas. The effect of climate change will have a severe on most crop production especially maize. A lot of research in relation to climate changes and their anticipated effect on crop production and other sectors of the economy have been reported recently at international levels. A report of IPCC working group II have it that, worldwide average temperature raises from 4.3 to 6.30 ^{o}C is expected until 2100, as well as an increase in extreme meteorological elements such as storms, heat waves, drought, floods, spatial and temporal differences being obvious both at global and regional levels. (Parry m.l., et al.,2007). (FAO, 2008) reported that, developing nations will be most affected as a result of absence of the required resource, knowledge and human resource and research development. The increase in the world population resulting in urbanisation, degradation of the environment, and raise in consumption of plant and animal food sources has made some most of the coping strategies inefficient (Sidehmed,2008).

In Africa and other parts of the world, the most dangerous environmental threat to the fight against poverty, malnutrition, disease, and human hunger is climate change, mainly on agriculture production. The harmful impact on crop production and yields will be made worse by the most frequent extreme weather occurrences. For instance, IPCC (2001) reported that, the increasing atmospheric carbon dioxides concentration in the atmosphere leads to higher temperature changes. Agriculture activities are most luckily to be negatively influence by the rate of events of volume, quality, quantity, and stability of food production as a result of climate change. Weather changes will have aftereffect on the accessibility of water resources, incidences of pest and disease on farmlands and soil quality and quantity, leading to considerable dangers in the condition for agriculture and livestock production and these are likely to increase reliance on food importation and the number of people at high risk of hunger. (Adegoroye, 1997).

With the above instances, there are high incidences and harmful effects on agriculture and its practices among many farmers in the world over. This has seen a continuous trend in agriculture failure thus, reducing yields of crops over the years and this calls for the education on the part of farmers on the issues of climate changes and farming practices.

Sustainable crop production in a multifunctional crop production model needs a quality optimum crop yield to meeting the market requirements for a high yield safety targeted under any given ecological conditions.

The efficiency of maize crop production, yield and yield safety are granted by a combination of factors such as agro technical elements (crop rotation, water supply, nutrient supply, soil cultivation etc.) and agro-ecological factors (soil and weather conditions). From these factors, the former can be influence by man; whiles the later especially weather make maize crop production quite vulnerable. In maize crop production situation, one of the major elements is water, which plays a major role in many ways in plant metabolism in several forms such as respiration, assimilation, evapotranspiration and other metabolic and physiological processes in the plant tissues and cells. The importance of adequate water supply in crop production cannot be over emphasized in that, it influences the effect of the different natural and production technology factors and thereby, increases the efficiency of the production process. Effective water management and its effects on maize crop are therefore of great significance for farmers, whose aim is to prevent or find best possible solutions of elimination of these water management situations which are detrimental to maize crop production.

Global climate change which is a current issue of concern worldwide is proven by now. In the hundred years, the temperature rose by 0.7 ^{o}C. The increasing warming of the environment is mainly as a result of human activities, at least since the middle of the twentieth century (Hare, 2009). The Macroclimate change which started many years ago has also shifted the climate of Hungary from the typical features of the continental climate. The future possibilities of crop production will probably be widened or limited by the level of adaptation to the changes in the climate. The weather phenomena of the past few years verify the forecasts. It is not only the dry or wet periods that are more frequent, but the probability of weather extremes and strength of their effects are increasing even within a year or a vegetation period. (Jolankai and Birkas, 2009).

World over, maize is an important crop because of its high grain and forage yield. It has extensive adaptation characters and is intensely cultivated in many parts of the world. The total production of maize is not sufficient to meet the continuous increase of consumption. Although the surfaces cultivated with maize are increasing, the total production of the maize is not enough in many parts of the world. Because of this, the attempts to increase maize production are of great importance. To increase the maize production, there is the need for the adequate supply of irrigation water, N, P, K fertilizers, high yielding cultivars, agronomical practices like optimum plant density, timing of different treatments and interventions etc. directly affecting the growth and productivity of maize.

Maize plants are very responsive to drought stress (Rhoads and Bennett, 1990; Pandey et al., 2000; Cakir, 2004; Kuscu and Demir, 2013). Payero et al. (2009) states that, water stress can affect growth, development, and physiological processes of maize plants, which reduce biomass yield. Farré and Faci (2009) noted that the maize needs for the highest water amount is during the flowering period. Because of this, one of the most important factors that can limit crop production is availability of water. If water stress can be avoided during silking and early ear development, high yield could be expected.

Irrigation water supplies are decreasing in many areas of the world in recent years. Because of the climate change, predictions of increase in temperature and decrease in rainfall mean, water will become increasingly scarce. Many farmers in parts of the world are currently facing some irrigation water problems because of shortage irrigation water supplies. This water shortage has motivated some researchers and farmers to find ways to produce maize with less irrigation water and changing from fully irrigated to deficit irrigated cropping system. Water is usually the most important natural factor limiting expansion and development of agriculture.

Farmers and researchers are motivated to find ways to produce crops with less irrigation water, such as using more efficient irrigation systems and changing from fully irrigated to deficit irrigated cropping systems (Kuscu *et al*., 2010). Some farmers think that when the amount of irrigation water is increased, the yield increases too, and because of this, they make excessive irrigation within the expectation of higher yield. This excessive irrigation can be seen especially in field areas with cheap irrigation water. However, excessive irrigation can cause some social problems such as the increase in frequency of water distribution conflicts. Furthermore, excessive irrigation increases the cost of production and cause environmental and agronomical problems such as salinity, erosion, and drainage.

Water deficit has been recognised as one most single yield reducing factor for crops. Water deficit may occur frequently even in regions characterized by high annual rainfall. Water deficits affect growth and decrease the conversion of radiation into biomass in the maize (Bohnert and Bressan, 2001; Otegui et al., 1995). Maize is very sensitive to drought two weeks before and two to three weeks after silking (Otegui et al., 1995; Hall et al., 1992). Drought stress is an important environmental factor in the reduction of plants growth and development. Hayat and Ali (2004), stated that, moisture stress is a limiting factor for crop growth in arid and semi-arid regions due to low and uncertainty precipitation. Water deficiency is a critical problem limiting maize growth through its impact on the physiological, morphological, and biochemical processes. Water stress in maize crop production affects cell enlargement and thus reduces stem length by inhibiting inter-nodal elongation and checks the tillering capacity of the maize plant (Ashraf M and Oleary JW, 1996; Chaves MM and Oliveira MM, 2004). Maize cultivars differ in their growth characteristics, yield and yield components and therefore it is recommended that growers and breeders must select the most promising combiners in their breeding programmes.

The phenotype of an individual is controlled by its genotype, the environment, and the interaction between these factors. The performance of one genotype in a particular environment is different in another environment and so the goals and objectives of this research was to;

Accessed the performance of genotypes according to the environment

To select individual genotypes that performs stably across sites.

Select genotypes that is well suited to each environment to maximize genetic gains.

2 LITERATURE REVIEW

2.1 Maize, drought, and photosynthesis

Drought and high temperature are two major environmental factors that severely limit plant productivity in the United States and worldwide, often causing extensive economic loss to agriculture. As global climate change progresses, agricultural production worldwide faces serious threats from frequent extreme weather conditions. Integrated approaches that improve the efficiency of agricultural water use and development of plant varieties that can alleviate the negative impacts of environmental stresses to maintain yield stability are essential to sustain and increase agriculture production.

The effect of drought on crop production like maize and its economic losses, particularly during flowering and grain-setting stage has been reported (Abdelmula and Ebrahim Sabile, 2007; Setter et al., 2001). In a study on the effect of drought stress at different growth stages of maize, Abdelmula and Ebrahim Sabile (2007) found that drought stress at reproductive stage had the most decreasing effect on yield so that the grain yield was 4310 kg/ha under optimum irrigation while it was 3060 kg/ha under drought stress at reproductive stage.

Drought stress and most other environmental stresses has harmful effects on maize crop yield. Water readiness is a main cause for crop failure interns of yield decline affecting many of the cultivated farmlands in many regions worldwide. As agronomic uses of water become more scares, the development of drought-tolerant breeds becomes highly more important. (Kitchen et al., 1999).

There is a reduction in photosynthetic actives in maize plants when crops confront water stress in the field. This is because light interference of the leaf is reduced as leaf expansion is reduced and decline in C fixation of leaves area leading to the closure of stomates in the photosynthetic mechanism. (Leung and Giraudat, 1998; Mugo et al., 2000).

Maize grain yield is influenced by many mechanisms for survival but may be affected under a certain level of drought stress that differ across cropping seasons. In water stress situations, with heterosis as a major source of stress tolerances, Hybrids normally do yield better than varieties. (Blum, 1997)

2.2 Drought and maize development

The harmful effects of climate change are threatening this life-giving crop call maize and millions of people all over the world and African farmers are seeing its impact on them. The harsh droughts in recent years have burned millions of hectares of maize crops across the continent, pushing farming families into poverty and hunger.

Maize being sensitive to drought, in many parts of the world is grown under irrigated conditions. Drought stress usually goes along with high temperature. In this conjunction drought has even more accentuated detrimental effects on crop production (Barnabas *et al.,* 2008).

High soil temperatures have been suggested to be more detrimental to plant growth than high air temperatures Xu and Huang, 2000; high soil temperatures are likely to occur in a row crop like maize before canopy closure. As a result of increased temperatures water and nutrient uptake to the root have been shown to be reduced in various species (Huang et al., 1991). Under drought conditions, maize ovule abortion appears to be related to the flux of carbohydrates to the young ear around the flowering and concurrent photosynthesis is required to maintain this above threshold levels (Zinselmeier et al., 1995). Drought has additionally been shown to reduce invertase activities in the ovaries, which would also likely result in a reduce influx of hexose sugar. Altered hormone balance, and ovary abortion (Zinselmeier et al., 2000).

The impact of drought stress on crop production like maize and its economic losses, especially during flowering and grain-setting period has been reported (Abdelmula & Ebrahim Sabile, 2007; Setter et al., 2001). Andrade et al., (2002) stated that the final grain number of maize had a high correlation with the amount of pre-flowering stored assimilates. Jones & Setter (2000) reported that drought stress changed the synthesis rate of the hormones involved in bearing the grains which in turn, weakened the relationship between assimilate and grain which resulted in ovule sterilization. In a study on the effect of drought stress at different growth stages of maize, Abdelmula & Ebrahim-sabile (2007) found that drought stress at reproductive stage had the most decreasing effect on yield so that the grain yield was 4310 kg/ha under optimum irrigation while it was 3060 kg/ha under drought stress at reproductive stage.

2.3 The impact of drought at different stages of maize development

Maize is very prone to drought stress because of the crop's high demand for water for its cell elongation and its failure to delay at the vegetative stage. Hence, yield loss is inevitable irrespective of the timing of the dry weather condition. Maize is such a crop that will produce high yield when environmental conditions are good at all stages of its growth and development. The yield losses are determined by the severity and the length of dry weather condition during its growth period. **(**Heinigre, R W.2000.**)**

The amount of soil moisture usage of maize plants differs depending on the stage of growth. Maize plants usually use about 0.1 inch per day in a layby to a maximum of 0.35 inch per day when it's at the pollination stage and declines to 0.05 inch per day at physiological maturity. In drought situations, the stress effects on the plant hinge on the growth stage of the plant, the level of deficiency of the moisture, nutrient content in the soil and environmental changes at the season of production. Significant yield losses can occur as a result of minor drought stress at the physiological stage of maize development. A few days of observable wilting of maize just before tasselling can decrease maize yields to about 10 to 25 %. Also, a week of visible wilting of maize between before tasselling and the milking stage will reduce maize grain yields by 50% of high. At reproductive stage, drought reduces yields leading to losses of maize at physiological maturity. Reports from researchers has it that, about seven inches of water is needed for average development and growth of corn from tasselling through to the soft dough stage. The requirement for moisture by maize at major periods of maize growth indicates its susceptibility to drought stress. **(**Mc Williams, et al, 2005**)**

2.4 Yield loss of maize through evapotranspiration

Maize grain yield is decline when the demand of evapotranspiration goes beyond the water supply from the field at any time during maize production cycle. The loss of moisture by plants from the surface of the soil through evaporation and through respiration by the plants is call evapotranspiration. The early growth stage of maize plant experiences soil evaporation which is a major loss of soil water for plants. When maize leaves expand, transpiration slowly becomes the route through which soil water moves from the soil to the root system through the main plant to the atmosphere **(**Lauer, et al. 2003**)**

Maize Plants biological activities such as transportation and utilization of nutrient from the soil are compromised without sufficient water supply. Water stress makes plants weak leading to their susceptibility to insect attack and diseases. Maize leaf rolling is a sign of water stress. Severely stressed corn plants are seen rolling their leaves early morning of the day. During the life cycle of maize, the demand of evapotranspiration of maize differs. Maize grain yield is very sensitive to drought stress at various stage or periods of its development such as during flowering and pollination, and at grain filling and at the vegetative growth period. **(**Lauer, et al 2003, Agrigold, 2005**).**

2.5 Yield reduction through loss of leaf surface area during early vegetative stage

Maize plant growth from germination to vegetative stage eight or four weeks after emergence defines the real size that the plant determines the size that the plant attains. Water shortage or weather changes at this stage will lead to a reduction in plant and leave size. Influence on grain yield will be established on the decline in leaf area availability for photosynthetic activities. Major leaf size reductions could potentially reduce yield to about twenty percent while as, minor leaf size will have very little influence on grain yield of maize. Long periods of dry seasons will result to leaves burning which will have huge effect on yield of plants. Maize Farmers should have it at the back of their minds that, drought stress reduces leaf size resulting to yield losses. **(**Heinigre, R W.2000**).**

The ear size maize plant is concluded at the 16^{th} leaf stage that is about 66 days after germination and the kernel number sets in. Water stress at this period will decrease ear size of corn and eventually reduce potential yield. About 10 to 30% Potential yield losses could be encountered. **(**Heinigre, R W.2000**).**

2.6 Drought and reproductive stage of maize

Drought stress at critical maize developmental stages such as flowering and pollination impedes silking, decreases silking length, and prevents embryo development after pollination. Drought stress during these critical periods above reduces maize grain yield to 3 to 8% for every day of the stress. Heat and moisture stresses impedes with harmonization of pollen shed and silk emergence. Emergence of pollen grains of corn is hindered by drought stress and may delay silk emergence until pollen shed is finished. Silk of maize is desiccated because of exposure of maize to low humidity, high temperature, and absence of soil moisture thus pollen becomes non-receptive. **(**Lauer, et al 2003**)**. Maize is more sensitive to drought stress at the silking and or at the beginning of the reproduction period.

100 % yield losses can be expected when maize is subjected to water stress and couple with high temperatures. Pollen grains of maize can be killed by high day-time temperatures before they get to the silking stage. High humidity often results in heavy dew which can help pollen reach the corn silk. Nonetheless, acute yield declines can occur because of yield reductions can occur due to inadequate pollination leading to loss of kernel number. **(**Lauer, et al 2003**)**

2.7 Drought and grain filling stage of maize

Maize kernel weight has been influenced by drought stress at after silking up to maturation period and thereby can decrease maize grain yield at this stage by 20 to 30%. Yet again, the major element is how severe and long the stress occurs. Considerable grain yield losses can be observed when drought stress is follows silking. However, after this period, minimal damage is caused but can be fasten maturation of corn kernel. Whereas every stage of maize development is important as far as drought is concern, some stages can be more destructive. The most important major stages are the silking stage, vegetative stage 8 to stage 16, and the grain filling period thus, from silking to maturity. Early dry seasons that occur and last long will have a severe effect on the reductions in grain yields of maize. **(**Heinigre, R W.2000**).**

Grain filling stage is an important period in maize growth and water deficit at this period facilitates leaf dying threatens the grain filling of maize, bringing about plant lodging and decreases kernel weight. About 2.5 to 5.8 % of yield losses is expected when maize experience water stress at the grain filling stage and kernels are more predisposed to abortion in the first two weeks after pollination. Fertilization near the tip of the corn ear normally delays resulting in poor kernel formation. At the dough stage of corn development, more yield loss is expected as there is a reduction in the dry weight of maize kernel. **(**Lauer, et al 2003**).**

When moisture in the soil is exhausted during grain filling stage, grain abortion may set in resulting in the shrivelled and light heap-weight grain. The highest grain yields are reached when moisture in the soil is available through the physiological maturity (Coffman, et al, 1998).

2.8 High temperature and crop production.

One important factor that causes losses in crop production is temperature. High night temperature is an element that is being experienced in crop production (IPCC, 2007). The survival and sustainability of agriculture production is being impede by high night temperatures, both currently and in the very near future. Data from current meteorological shows that, there is faster raises in night temperatures than recorded in day-time temperatures. (Alward et al., 1999).

Research and experiment data show that, there is a correlation between high night temperature and decrease in crop production. The importance of assessing the impact of night temperatures from day-time temperatures cannot be over emphasized in that, a small increase in nigh temperature leads to a drastic decline in crop production. (Peng et al., 2004). Research studies of Hall, 1992; Mohammed and Tarpley, 2009a reported a decline in crop yield as a result of high night temperatures. Separately from high night temperatures, long and short-term periods of heat treatment are foreseen to happen more regularly because of global warming which will influence many aspects of agriculture production, thus reducing crop quality and yields. There are many reports from many studies about the influence of long- and short-time temperature stresses on Agriculture crop production. (Peng et al., 2004). Decreases in crop yields due to high night temperatures has been reported in many crops such as Maize, rice, cowpea, soybean, and sunflower. (Gibson and Mullen, 1996; Izquierdo et al., 2002; Loka and Oosterhuis,2010; Seddigh and Jolliff, 1984;).

Photosynthetic functions and grain nutrition qualities like starch and sugar content is drastically affected by high night temperatures (Loka and Oosterhuis, 2010; Turnbull et al., 2002). There is an increase in respiration rate as reported by (Mohammed & Tarpley, 2009b), and there by restraining floral bud growth which causes the male sterile and low pollen grains feasibility and accelerating the maturity of the crop (Mohammed & Tarpley, 2009a; Seddigh and Jolliff, 1984). High night temperature can also cause a reduction in crop grain yield by decreasing the antioxidant ability of plants. In a regular normal physiological situation, the toxic influence on the reactive oxygen species is reduced by enzymatic and non-enzymatic antioxidants. In a water stress situation, oxidant levels can overpower the antioxidant bring to the death of plant cell. The increased production of ROS [oxide radical (O2-), H2O2, and the hydroxyl radical (-OH)], or the plant's decreased ability to neutralize ROS, because of heat stress negatively affects many physiological processes in plants, thus decreasing yield.

2.9 Effects of high night temperature on plant morphology

Maize plant geomorphology concerns with the pant growth development, structure, and form. For instance, plant morphological parameters include plant height and the numbers of tillers, leaves, panicles, and grains.

The negative impact of high night temperatures on the maize plant morphology differs for different varieties including no effect. Seddigh & Jolliff (1984) reported that, high night temperatures promoted early vegetative growth and hastened physiological maturity but did not affect morphological characteristics such as plant height, number of auxiliary branches and number of nodes in soybean. The high night temperature has no negative effect on rice cultivar japonica on its height and tiler number. It can, however, increase leaf number and leave area. Yoshida et al., 1981 and Cheng et al., 2009 nonetheless, stated in their work that, there was a decline in plant height and tiller number and total biomass for rice cultivar indica because of high night temperature. Decrease in leaf area, branches and plant dry matter was reported by Blackshaw and Entz,1995 in (Erodium cicutarium L). The decrease in plant dry matter is directly attributed to the reduction in manufacturing of photosynthates.

2.10 Effects of high night temperature on plant physiology

Plant physiology concern itself with the plant's functioning and it is intimately related to plant morphology. Essential processes like photosynthesis, respiration, plant water and nutrition status, plant hormone functions and translocation of photosynthates are incorporated in plant physiology. Photosynthesis is a complex process and leaf photosynthetic rates depend upon leaf chlorophyll and nitrogen content, photosystems, stomatal characteristics, and enzyme activities. The environmental pressures have a direct effect on leaf photosynthetic rates and an indirect effect through their effects on leaf chlorophyll and nitrogen content, stomatal characteristics, and enzyme activities. High night temperature has both negative and positive influence on plants photosynthetic rate in the next day's photosynthetic activities (Mohammed and Tarpley, 2009a,). Heat stress has been reported by Guo et al., 2006 as being the cause of untimely losses of maize plant's chlorophyll. Destruction of the transport system of photosynthetic electron from the site of production of photosystem II and obstruction of photosynthetic carbon dioxide fixation because of high heat stresses can affect and thereby reduces rate of photosynthesis (Havaux and Tardy, 1996; Sayed et al.,1989; Yamane et al.,1997) thus, leading to a decline in plant yield. Separately from decreases in photosynthetic rates, the increased respiration rates can also lead to crop yield decreases.

In understanding fully, the processes of plants growth and development, an essential physiological element like plant respiration must be understood in terms of it being exposed to heat stress. Global climate warming is a serious consideration in agriculture and raising respiration from it can affect huge part of the total photosynthetic activities. (Paembonan et al., 1992). Through photosynthesis, according to (Peterson and Zelitch, 1982) respiratory metabolism within a plant leads to a loss of about 30 percent of carbon and about 70 percent of carbon gained. Plant respiration is naturally apportioned into the operational mechanisms of growth, maintenance, and ion uptake to accelerate our understanding of the effect of the environment on respiratory processes (Amthor, 1986; Lambers, 1985).

Heat stress has been linked to physiological injury of plants which is associated with increases in oxidative destruction to the membrane in plant species (Larkindale and Knight, 2002). The preservation of plants respiration is increase to support repair mechanisms of the membranes due to oxidative damage (Amthor & McCree, 1990). Hence, an increase in respiration arises with an increase in temperature (Huang et al., 1998).

Again, cell membrane is known to be an important functional system in the centre of crop production and acclimatization of plants to high temperature and this positively associated with yield performance stability under high temperature stress situations as reported by Mohammed and Tarpley, 2009b in rice and wheat production.

2.11 Impact of high night temperature on yield and yield-related parameters

The most sensitive phase of maize growth in its development is the reproductive stage and maize plants are more vulnerable to heat stress at this phase compared to the vegetative period (Hall, 1992). Differential temperature sensitivity rate for various plants at the reproductive and vegetative growth stages has been reported by various authors in rice (Baker et al., 1992), wheat (Mitchell et al., 1993) and many other crops. Again, high night temperature is reported to induce male plants sterility and causes extreme floral abscission in cowpea (Warrag and Hall.,1984) whiles, daytime high temperatures reported no adverse effect on maize plants. Maize crop yield can be decrease by high night temperature by decreasing the crop’s growth duration, overwhelming flower bud development, and reducing pollen grains production and viability (Ahmed and Hall, 1993; Mohammed and Tarpley, 2009a;). A raised in night temperature 27 to 32 degrees reduces plant growth period by two days as shown by appearance of the first panicle in rice growth and development. Plant yield is reduced as a result of decreased crop duration due to high night temperature which decreases the time for carbohydrate accumulation (Cantarero et al., 1999). Badu-Apraku et al. (1983) reported remarkable yield loss under high temperatures during the period of grain filling to sucrose availability (Afuakwa et al., 1984) and activity levels of enzymes involved in starch and sugar metabolism. Again, high night temperature is responsible for the suppression of floral buds and flowering which is attributed to a shortage of photosynthetic assimilates supplied to the floral buds or the failure of floral buds to mobilize carbohydrates under heat stress (Dinar & Rudich, 1985). Many crop varieties have experienced decreased in pollen grain germination due to high temperature stresses and has been reported by some authors (Hall, 1992; Mohammed and Tarpley, 2009a). The decline in pollen germination due to heat stress leads to poor anther dehiscence and pollen reception (Prasad et al., 2006), and this reduced pollen swelling and decreased the plant’s anther pore size (Matsui & Kagata, 2003).

In agriculture crop production, especial cereal crops, spikelet fertility, described the ratio between filled grains and total grains, decreased with decrease in pollen germination. Increase in night temperature from 27 degree to 32 degree decreased spikelet fertility by 70 percent in rice. Apart from pollen germination, hormonal balance in the sink (Micheal & Beringer, 1980) and/or availability and transportability of photosynthates to the sink from the source (Afuakwa et al., 1984) and/or inability of floral buds to mobilize carbohydrates (Dinar & Rudich, 1985) and/or altered activities of starch and sugar biosynthesis enzymes (Keeling et al., 1994) can govern the spikelet fertility at high temperatures. The ability of crops to survive heat stress varies with plant species, genotype, developmental stage of the crop, and intensity of the heat stress.

2.12 Maize and low temperature

An important abiotic element in maize production is low temperature which influences the growth, development, and distribution of the plant. Maize crop is very sensitive to low temperature because it originates from the subtropical regions. The optimum growth temperature for maize lies between 30 and 35 degrees (Miedema, 1982). Maize plants growth and development is affected by low temperatures in terms of its germination, seedling growth, and early leaves development (Miedema, 1982). When maize is subjected to low temperature during its early growth and development, it results in poor photosynthetic performance (Leipner, et al, 1999) which is associated with retarded plant development (Miedema, 1982).Maize plants chloroplast is the primary zone where low temperature take place and this causes harm to developing or immature maize leaves leading to reserve of photosynthesis and, therefore, to premature senescence (Foyer, et al, 2002). Again, maize leaves grown under very cold temperature conditions are considered to have lower photosynthetic ability and lower quantum efficiencies of carbon fixation and electron transfer at photosynthetic PS II (4PSII) (Nie et al, 1992), and thereby changing the antioxidative defences (Leipner, et al,1997). There is reduction in the carbon cycle activity (Kingston-Smith, et al,1997) in comparison to leaves grown at more favourable temperature condition. Another problem associated with maize under cold is that chilling may prevent water absorption by plant roots and water transport to the shoot, leading to drought stress (Aroca, et al, 2001).

2.13 Maize and water logging

Maize assumes its cultivation under much diverse agro climatic zones extending from subtropical to cooler temperate regions. Therefore, inevitably the crop remains open to varied types of biotic as well as abiotic stresses. Among the various abiotic stresses, excess soil moisture stress caused by temporary waterlogging due to heavy rains or high ground water table or heavy soil texture is one of the most important constrains for maize production and productivity in most regions. In Southeast Asia alone, about 15% of total maize growing area is affected by floods and water logging. The maize crop suffers badly whenever it encounters temporary excess soil moisture conditions during the monsoon season or grown in poorly drained converted paddy fields after a rainy season rice crop (Shimizu, 1992)

Maize is generally considered to be a flood tolerant species due to its ability to produce early adventitious roots and morphological adapters during excess soil moisture conditions (Drew et al. 1979) and (Fausey and Mcdonald , 1985). Further low-lying area also faces severe water logging problems during winter season sowings. The tolerance of maize genotypes towards this stress varies considerably and is highly influenced by the degree of stress and the genotype of the plant (Torbert et al.1993). The degree to by which maize pants are injured by flooding is caused by many factors like, time of flood, frequency and duration, and soil air temperature at the time of flooding. (Belford et al., 1985).

Flooding impairs plants respiration process which is a sensitive physiological process and therefore reduces the exchange of air (oxygen) between soil and the atmosphere which in the end, leads to a decrease in total root volume and less transport of water and nutrients is carried to the shoot from the roots, and formation of sulphides and butyric acid by microorganisms that are toxic compounds to plants (Wesseling, 1974).

The pore spaces of soil contain water and gas and soil gases (oxygen and carbon dioxide) are important for pants respiration. Atmospheric oxygen is transfer into the plant root hair through the pore spaces of the soil, through the surrounding waters. Oxygen diffuses easily into pore spaces of soils filled by air than water, so the main limitation to oxygen movement is the thin water film surrounding root hairs in flooding situations. Roots plants of maize are injured if the soil remains waterlogged for a long period thereby causing poor aeration which leads cell death and even death of maize plants roots. Flooding impedes root growth in the upper 18 inches of soil, but root elongation continues in deeper soil horizons. Soil compaction and flooding will restrict root growth more severely than either factor separately (Klepper, 1990).

All plants biological processes are influenced by soil temperature (Wesseling, 1974). Wet soils have a large heat capacity and considerable amounts of heat are required to raise their temperature. Thus, usually wet soils are cold and corn growth is slower. Drainage lowers the moisture content of the upper soil layers so air can penetrate more easily to roots zone, and transport carbon dioxide produced by roots, microbes, and chemical reactions to the atmosphere. Lowering soil moisture content also leads to higher soil temperatures and faster growth.

Flooding may have a long-term negative effect on maize crop performance. Superfluous moisture in the root zone of crops during the early vegetative growth period slows down root development (Wenkert et al., 1981) and as a result, plants may be subjected to a greater injury later during a dry summer because root systems are not sufficiently developed to contact available subsoil water. Soil mineralization of nutrients elements from soil organic matter by microbes needs a lot of oxygen. Oxygen defects in flood soils reduce microbe activity, decreasing the rate at which ammonium and nitrate are supplied to plants resulting in nitrogen deficiency in waterlogged soils (Wesseling, 1974). Again, flooding can reduce the activity of mycorrhizae essential for symbiotic phosphorus uptake (Ellis, 1998). Flooding can also result in losses of nitrogen through denitrification and leaching. Where estimated nitrogen loss is significant in fields not yet tasselling and yield potential is reasonable, corn may respond to additional applied fertilizer.

3 MATERIALS AND METHODS

3.1 RUZSANYI EXPERIMENT

3.1.1 Experimental site

This research examinations were carried out in the cropping seasons of 2017, 2018 and 2019 in a multifactorial long-term experimental set up by the late professor Laszlo Ruzsanyi in 1983 and currently being directed by Professor Peter Pepo since 2004 at the experimental site of University of Debrecen, Institute of Crop Science, Faculty of Agricultural and Food Science and Environmental Management at Latokep located along the No. 33 main Road in the loess region of Hajdusag which is about 15 km from the Debrecen city town.

3.1.2 Soil characteristics of the experiment site

The experimental site contains soils of calcareous chernozem soil origin formed from loess with deep humic horizon content which has medium- heavy soil (plasticity index according to Arany: 43) belonging to the loam soil type according to texture class.

The fertile layer of this experimental site was 80-90 cm with a uniform layer of humus content of 40-50 cm. The average humus content was about 2.76%. The carbonated lime of the soil is at a level of 75 cm depth with a grain soil coating present. In this layer, there is a $CaCO_3$ content of between 10 and 13 %. The PH of the cultivated soil layer ranged between 6.3 to 6.5. The nitrogen supply of the experimental site could be described as medium, and the total nitrogen content of the top 50 cm layer was 0.12-0.15%.

The P_2O_5 and K_2O content of the experimental site was determined by the ammonium-lactate method. The phosphorus content in the soil was variable and could be qualified as medium to average of a sample of (133 mg/ kg^{-1}). The potassium supply was good with a value of about 240 mg/ kg^{-1}.

The soil hydrological for the experimental site could be classified into the group IV according to Varallyai et al, 1980 soil water management classification system. The soil has a medium water permeability and a good water-holding capacity. The available water is about 50% of the field capacity. The minimum field capacity was 275mm in the 0-100 cm layer and 265mm in the 100-200 cm layer. The minimum water capacity was 33.65-46% and water content at wilting point was 8.5 – 15.7% expressed as volume percentage in the 0-200 cm layer of soil. The ground water level was 3-5 m, and not increasing above 2m even in the rainy year.

Table 1: Water management parameters for experimental site

Soil Layer cm	Volume Weight g/cm3	Volume of pore P %	Capillary-gravitational Pore space %	Gravitational pore space + air inclusion Pg+a%	Capillary pore space %	Capillary water capacity V %	Minimum field capacity FCmin%	Wilting point WP%
5-25	1.34	49.6	17.9	0.9	30.8	31.7	30.8	15.55
27-33	1.53	42.2	3.9	1.2	37.1	38.3	37.1	15.70
47-53	1.31	50.5	12.0	3.1	35.4	38.5	35.4	14.75
72-78	1.45	45.4	6.4	3.3	35.7	39.0	35.7	11.13
97-103	1.57	40.8	3.7	1.5	35.6	37.1	35.6	9.38
122-128	1.6	39.8	2.6	1.1	36.1	37.2	36.1	9.03
147-153	1.65	37.7	1.3	0	36.4	36.4	36.4	8.50

Debrecen,1983, Results of Martin B – Gyori Z

3.1.3 Experimental Set – Up

The experiment set up is a long term four-factorial set up with a plot size of 9.2x5m, 46m^2. The studied factors are Crop Rotation, Irrigation, Plant Density and Fertilization. This experiment was established on a plot where the preceding crop and fertilization were set in four replications in a split-plot design on a fully irrigated and non-irrigated plots.

Statistical analysis of data for this study research was done using the software Microsoft Excel 2013 and SPSS for windows

Factor1: Crop Rotation

Treatments: Monoculture (maize) and Biculture (maize - wheat)

Factor 2: Irrigation

Treatments: Non-irrigated and Irrigated

Factor 3: Plant Density

Treatments: 60,000 plants ha^{-1}

72,500 plants ha^{-1}

85,0000 plants ha^{-1}

Factor 4: Fertilization

In the research station, five fertilization levels are used, but in this research as indicated in below, three fertilization levels were employed. Fertilizer treatments applied in the experiment.

Table 2: Fertilizer treatments applied in the experiment (Debrecen-Latokep 2017)

Treatment	**Active ingredient (kg ha^{-1})**		
	N	**P_2O_5**	**K_2O**
1	0	0	0
2	60	45	45
4	180	135	135

In the irrigated treatment, the irrigation water dosages and dates were as follow: The irrigation mothed that was used in the study was sprinkler irrigation water is distributed by overhead high-pressure sprinklers or guns from a central location in the field or from sprinklers on moving platforms.

2017 cropping year: 8th July 50 mm

22ndJuly 50 mm

2018 Cropping Year: 24th June 50 mm

7th July 50 mm

30th July 25 mm

6th August 25 mm

2019 Cropping year: 9th June 50 mm

15th July 50 mm

3.1.4 Agrotechnics used in the experiment.

In this research, the agrotechnical technology used met modern maize production requirements. By the crop rotation systems used, the soil preparation operations were as follows in the Table 3 below.

Table 3: Soil operations for crop rotation systems in ruzsani experiment (Debrecen-Latokep 2017)

MONOCULTURE		**BICULTURE**	
Date	**Operation**	**Date**	**Operation**
12th September, 2018	Stalk crushing	15th July,2018	Disc and Guttler packer roller
13th September, 2018	Twisting and baling	1st August, 2018	Väderstad Carrier
25th September, 2018	Guttler roller	31st August	Väderstad Carrier
25th September, 2018	vaderstad Carrier	5th October, 2018	Plowing (35cm)
14th October, 2018	Plowing (35cm)	4th March	Combinator
4th March, 2019	Combinator	2nd April, 2019	Combinator
3rd April, 2019	Combinator		

The experiment was sown in the two crop rotation systems on April 11, 2019, with a Gaspardo planter. The corn hybrid used in the long-term experiment was the Pioneer 9241. In the experiment, fertilizer application used was performed at the following times: for the monoculture field, in September 25, 2018, 100% of phosphorus and potassium fertilizers and 50% of nitrogen fertilizers were applied. The autumn nutrient doses were applied in the form of a complex fertilizer 13:19:19. In the Spring, fertilization date was on April 03, 2019.Where 50% of the amount of nitrogen fertilizer was applied. Nitrogen fertilizer form: 34%

In the biculture field, fall fertilization date was on August 01, 2018. Where 100% of phosphorus and potassium fertilizers and 50% of nitrogen fertilizers were applied. The nutrient doses in autumn were applied in the form of a complex fertilizer 13:19:19. Whiles the fertilization in the Spring was 2nd April 2019 where 50% of the amount of nitrogen fertilizer was applied. Nitrogen fertilizer form: 34% NH4NO3. The plant protection technology used in the experiment for both monoculture and biculture were as follows; soil disinfection - Force 1.5G 14 kg / ha (including sowing) and weed control - Adengo 0.4 l / ha (02 May 2019) and interrow Cultivation (May 27, 2019).

Irrigation is a limiting factor in newly established areas due to the shortage of water resource in many parts of the world's farming areas, which causes serious damages to crop. Therefore, there is a dire need to determine the optimum water requirement in order to reach the highest crop production with water rationalization. Presences of enough amount of water at critical stages of plant growth do not only optimizes the metabolic process in plant cell, but also increases the effectiveness of the mineral nutrients applied to the crops.

Two irrigation levels were applied through the motorize sprinkle irrigation system, thus full irrigation, and non-irrigation. Latokep dam water was the source irrigation. Water amount of irrigation levels was determined based on the evapotranspiration rate for each stage during the growing season. Irrigation requirement for maize was calculated using the meteorological data of the experimental site as follows:

A. crop evapotranspiration was calculated according to Doorenbos et al. (1977).
   $ET_c = ET_o \times K_c$
   Where;
   ET_c = Crop evapotranspiration (mm/day),
   ET_o = Reference evapotranspiration (mm/day),
   K_c = Crop coefficient,
B. Applied irrigation water for maize crop was calculated using Keller and Bliesner (1990); $IR = ET_c \times LR \times 4.2 / E_a$

Where;
IR = Irrigation requirement (m^3/ha)
LR = Leachingrequirement (%), (15%).
E_a = Water application (80%)

3.1.5 Assessment of weather condition in the survey years.

Brief description of the weather of the experimental years and its effect on the development of maize plants. The most important meteorological parameters of precipitation and temperature are shown in (figures 1, 2, 3) below.

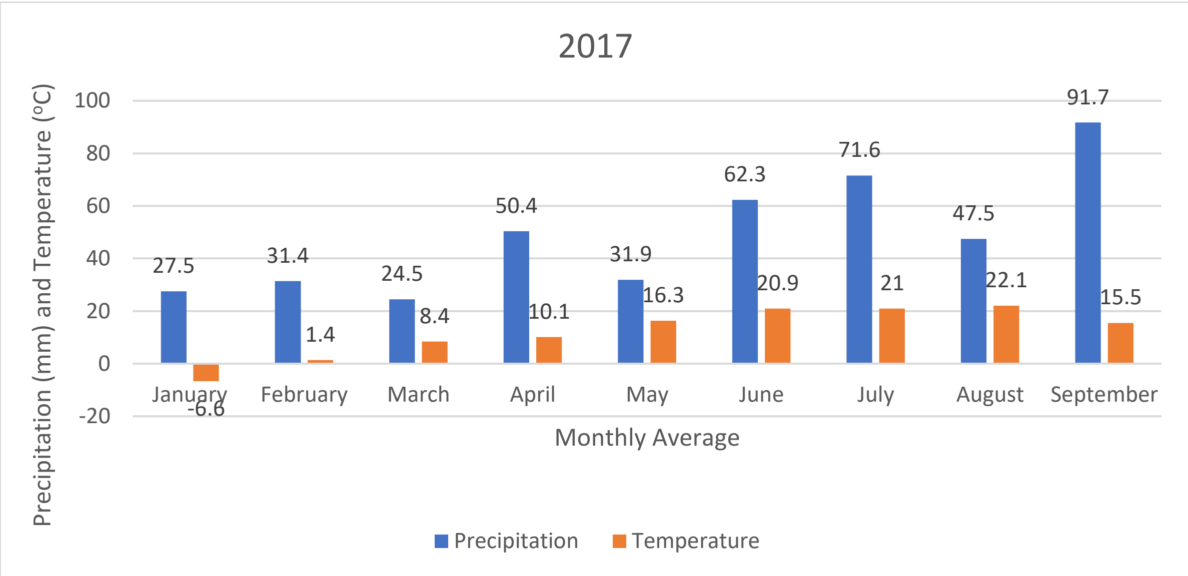

Figure 1: Precipitation and Temperature data (Debrecen – Latokep 2017)

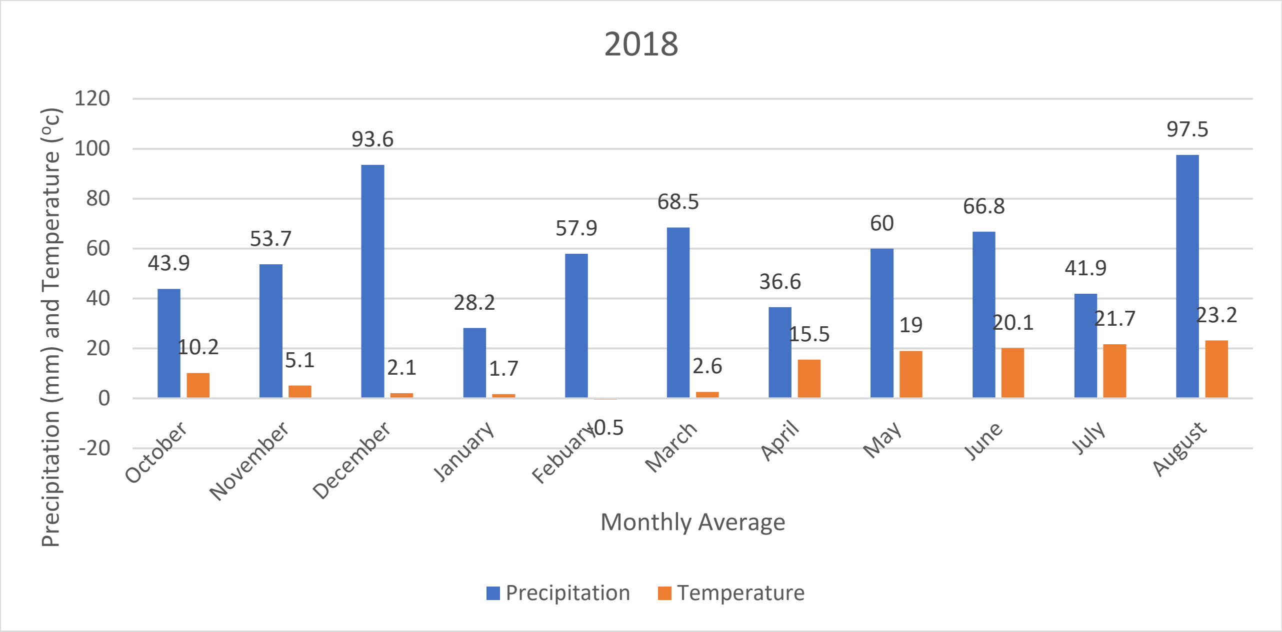

Figure 2: Precipitation and Temperature data. (Debrecen-Latokep 2018)

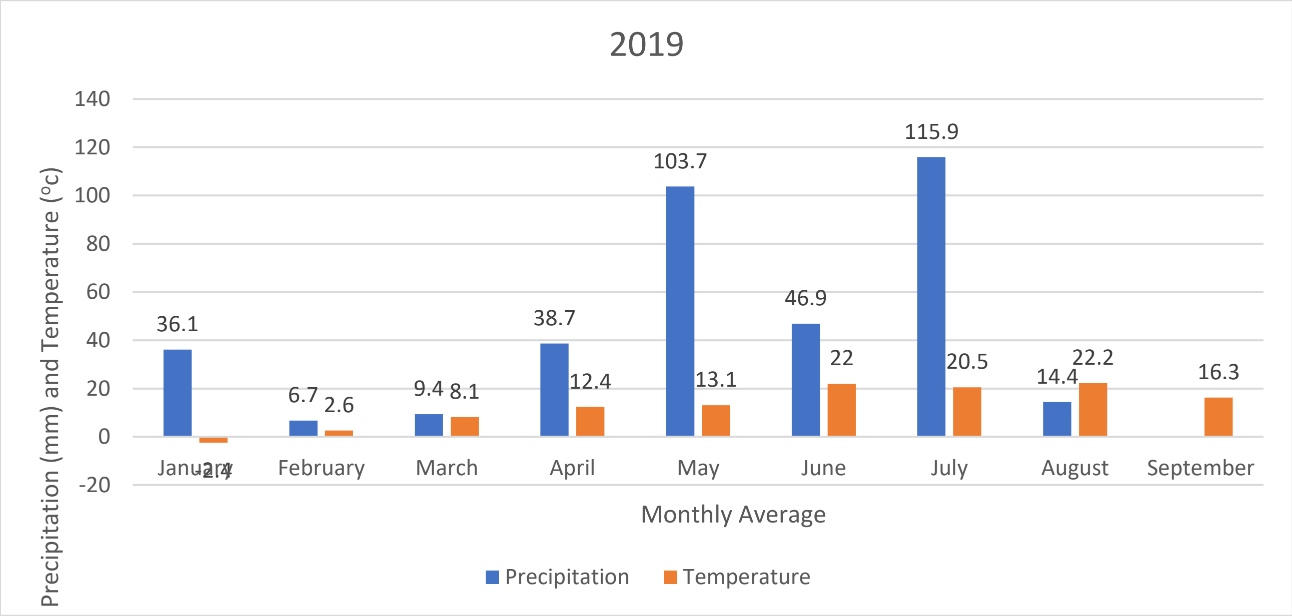

Figure 3: Precipitation and Temperature data. (Debrecen-Latokep 2019)

For maize development, it is important to consider the weather effects during the growing season, and the intervals preceding it, due to the water supply of the plant. Precipitation and temperature in the autumn-winter-early spring months can significantly affect the amount of water stored in the soil, which is the disposable water available to maize populations during the growing season. The water supply of the soil also influences the soil preparation, sowing and plant protection works and the uptake of nutrients and their utilization.

The weather conditions for 2017 cropping year were averagely similar comparing with the 30-year weather data of the planting area. Precipitation in April was 50.4 mm which was significant compared to the 30-year average for the month of April was good for maize seedling for a strong germination vigor. The precipitation for the previous months thus January and February were enough (27.5 mm and 31.4 mm) for microbial activities in the soil and could sustain the soil for aeration. The temperatures in April were normal seeing that the average of the 30-year temperature in April was (10.4 ^{o}C). There was a significant change in precipitation in the months of May and June (31.9 mm and 62.3 mm) as against the 30-year average of (58.8mm and 79.5mm) respectively and the high temperature recorded in those months of 16.3 ^{o}C and 20.9 ^{o}C which was far higher than the 30-year average for those months for the 2017 cropping season. The increase in precipitation level in the July compared to the average of 71.6 mm could however augment for the low precipitation for the previous months which the maize plants will use for the development of cobs at this stage.

Autumn 2018 was marked by a significantly warmer and drier than average season. After a dry and warm September, only 10.1 mm of precipitation fell in October (37.9 mm on average for many years), while the monthly average temperature (12.3 ^{o}C) was about 2 ^{o}C above the 30-year average (10.4 ^{o}C). This weather was typical of much of November, but at the end of the month - after a long time - rainfall arrived. Thus, the November precipitation (52.0 mm) was the same as the multi-year average (41.6 mm), while the average monthly temperature (6.2 ^{o}C) was significantly higher than the multi-year average (4.6 ^{o}C). Due to the dry autumn weather, the quality of the soil preparation work was not optimal. The precipitation in the winter months was around average, that is, 50.7 mm in December (43.7 mm in the multi-year average), 36.1 mm in January (29.7 mm in the multi-year average), followed by minimal precipitation in February (6.7 mm, the multi-year average is 31.0 mm). The average temperature in December (-0.4 ^{o}C, long-term average -0.1 ^{o}C) was followed by stronger cooling in January (-2.4 ^{o}C, multi-year average -1.4 ^{o}C). February was not only extremely dry but also significantly lighter than average (+0.1 ^{o}C) (+2.6 ^{o}C). Due to the autumn and winter weather (less rainfall, milder temperatures), the water supply of the chernozem soil was only moderately recharged. This reduced water supply continued to decrease during the extremely windy, dry and warm spring months. Although the early dehydration of the soil allowed for an early start of soil tillage, the soil's disposable water supply, both before and after sowing, decreased despite the sealing. March and mainly April were extremely dry and significantly warmer than average. Early maize plants were saved by rainfall in late April. Extreme weather conditions are characterized by rainfall of 9.4 mm in March (30.2 mm on average), 38.7 mm in April (52.8 mm on average), while average monthly temperatures (8.1 ^oC and 12.4 ^oC) well above the 30-year average (5.1 ^oC and 11.1 ^oC). There was a huge turnaround in the weather in May. Abundant precipitation (103.7 mm, 64.0 mm per year average) was favourable for soil water absorption and plant uptake, but was accompanied by low temperatures, which was unfavourable for the development of heat-demanding maize (13, 1 ^oC, the multi-year average is 16.6 ^oC). In June, conditions were optimal for the vegetative development of maize. Although the precipitation in June (39.4 mm) was below the multi-year average (66.5 mm), the combination of the useful water supply in the soil and the temperature significantly above the average (19.4 ^oC) (22.0 ^oC) for corn stocks. The July weather was also favourable for the generative processes of maize, with the initial periods of male and female flowering and fertilization and grain filling being ideal. In July, abundant rainfall (115.9 mm, long-term average 66.1 mm) and moderate warm (20.5 ^oC, multi-year mean 21.3 ^oC) combined positively on early generative stages of development. In August, the weather turned extremely adversely. Precipitation in August was low (14.4 mm, 49.0 mm for many years), but the average monthly temperature (22.2 ^oC) was significantly higher by almost 2 ^oC (20.7 ^oC). This dry, heat of heat has accelerated biological ripening, leaf drying and grain drainage. As a result, maize stocks showed biological maturity by mid-September.

In the winter season prior the 2019 planting period, there was small rainfall of about 127 mm which was lower than the average (87 mm). This means that deep soil layers at the field were not adequately saturated. The month of May was loudly characterised by heavy clouds, rainy, and of cool weather atmosphere. Precipitation fell with an even distribution of more than average (76 mm). The month of June was drier than the average, with about half of the normal rainfall of 32 mm. The average monthly temperature of 22.8 °C was considered very high. The middle period of the month was exceptionally warm. The dry phase, which continued at the start of July was however less warm. The July average temperature of 21.1 °C has never been so low for the past 10 years. Because of the substantial rains in the second part of the month and at the end of the month, the average monthly precipitation was significantly above the annual average, with a value of 99 mm showing a positive irregularity of 33 mm. The month of August was branded by dry, warm and with very little rains. The end of the month was marked by a significant positive anomaly which accelerated the maturation process of the maize plants. The weather of the growing year 2019 was generally contradictory regarding the vegetative and generative development of maize.

3.1.6 Description of Measurement Methods and Data Evaluation

Measurements of LAI, SPAD and NDVI were taken on the following dates (25th May, 12th June, 3rd July, and 7th August) in cropping seasons of the study period.

Leaf aera index (LAI) : Data on Leaf area index was recorded four times during the growing period and at each sampling date, leave area measurement was taking from four rows using a Sun Scan Canopy Analysis System portable device. Leaf area size per each square meter is considered as leaf area index.

Relative chlorophyll content (SPAD-value) was measure on four times and ten crops on each plot were sampled using a SPAD-502 PLUS (Konica Minolta) portable device. The advantage is that chlorophyll amount can be measured by it under field conditions without any crop destruction.

Normalized Difference Vegetative Index (NDVI) was measured using a green seeker handheld crop sensor. Five samples were measured in each plot to assess the health or vigor of crop to make better nutrient management decision.

Plant height was measured just before harvest using a long meter rule and five sample were selected randomly and measured.

Maize grain quality parameters (protein, starch, and moisture) were measured after harvest using granolyser which instantly display results.

Results of data was processed and statistically evaluated using software Microsoft Excel 2013 and SPSS for windows. The probability level was set for $p = 0.05$ which commonly used in agriculture research.

3.2 GENOTYPE EXPERIMENT

3.2.1 Experimental site

This research examinations were carried out in the cropping seasons of 2018 and 2019 in a multifactorial long-term experimental set up by the late professor Laszlo Ruzsanyi in 1983 and currently being directed by Professor Peter Pepo since 2004 at the experimental site of the University of Debrecen Centre for Agricultural and Applied Ecological Science at Latokep located along the No. 33 main Road in the loess region of Hajdusag which is about 15 km from the Debrecen city town.

This study was carried out to examine the effect of irrigation and non-irrigation on different maize genotypes (DKC4943, P9903, P9911, KWS4484, S.Y ZEPHIR) subjected to the same treatments.

3.2.3 Agrotechnical intervention

The agrotechnical interventions used in the experiment met the requirements of modern maize growing. The preproduction of the experiment was winter wheat. It was wheat – maize biculture rotation. During soil preparations, the following operations were carried out:

July 22, 2018	-	Stubble disc+ packer roller
September 21, 2018	-	Easing.
October13, 2018	-	Arable old earth cultivator
April 08, 2019	-	Combinator

Nutrient supply:

In the autumn of September 14, 2018, 30 kg of nitrogen, 72 kg P_2O_5 and 72 kg K_2O were delivered in autumn. During the spring period, 135 kg/ha of nitrogen was applied on 08 April2011.

The experiment was conducted on April 17, 2019, using a germ count of 72.000/ha.

PLANT PROTECTION

The following plant protection operations were carried out in the experiment:

May 2, 2019.	-	Adengo 0.44 l/ha post-emergent weed control
May 23, 2019	-	Banvel 480 0.3 l/ha post-emergent weed control

The experiment was harvested in 2019 using 10-ber 1and10-year-old-Sampo parcel charm with adapter.

Non-irrigated, average plant protection:

Pest control

June 24, 2019 -Steward 30 DF 0.17 kg ha^{-1} + Fendona 10 EC 0.15 l / ha^{-1}

insecticide treatment

July 11, 2019 - Decis Mega 0.2 l / ha^{-1}

Chemical treatment

July19, 2019 - Decis Mega 0.2 l / ha^{-1}

Irrigation intensive and plant protection;

Pest control

June 24, 2019 - Steward 30 DF 0.17 kg ha^{-1} + Fendona 10 EC 0,15 l / ha^{-1}

Insecticide treatment

July 11, 2019 -Decis Mega 0.2 l / ha^{-1} + Prosaro 1.0 / ha^{-1} + Retengo Plus 1.5 l/ ha^{-1}

insecticide and fungicides treatment

July 19, 2019 - Decis Mega 0.2 l / ha^{-1}

Irrigation dates and rates - July 5, 2019. 25 mm

July 15, 2019. 25 mm.

3.2.4 Methods of sampling, measurements, and data evaluation

Yield of maize is influenced by many ecological, biological and agrotechnical factors which interact with each other. Agrotechnical factors such as genotypes and their properties cannot be over emphasized. Even more hybrids which are produced both locally and internationally, the availability of hybrids has become even wider in their selection process.

The field experiment was carried out and the experiment design was a split-plot design, with two irrigation regimes; full irrigation and non-irrigation with four (4) replications in each regime with a plot size of 9.2x5 m, 46 m^2. The full irrigation treatment in addiction to precipitation received a total of 100 mm of water in 2017 cropping year, 150 mm of water in 2018 Cropping Year, and 100 mm of water in 2019 Cropping year.

Plant morphological parameters were measured in cases of studied years.

Plant height (cm) was measured just before harvest using a long meter rule and five plants were randomly measured from each plot and the average taking. The distance between the soil and the highest point of the male flower was considered.

Cob weight (g) was measured at after harvest using electronic weighing scale and three cobs were considered from each plot.

Seed weight was measured by taking the seeds from the cobs and weighed using the electronic scale.

Plant physiological parameters were monitored in cases of the selected plots at different levels of growth of the plant's development stage in all replications. Thus, at 4-6 leave, stem elongation, male and female flowering, grain filling and ripening phases.

Relative chlorophyll content (SPAD) was measured by a SPAD 502 plus (Konica Minolta) portable device. Its advantage is that chlorophyll amount can be measured by it under field conditions with plant destruction.

Leaf area index (LAI) was determined using a Sun Scan Canopy Analysis System portable device. Leaf area size per each square meter is considered as the leaf area index.

Normalized Difference Vegetation Index (NDVI) values were recorded using a Trimble Greenseeker Handheld device. Ten (10) plants were randomly selected from the middle row of each plot for the values.

Seed quality parameters such as moisture content, protein content and starch content were determined after harvest using NIR analyser Granolyser (Pfeuffer, Germany).

Results and data evaluation or analysis form this experiment was process and analysed using software Microsoft Excel 2013 and SPASS for windows to compare the means. Whiles repeated measurement was done during the germination phases. All analysed data presented are means of of the three years experiments.

4. RESULTS AND DISCUSSION

4.1 RUZSANYI EXPERIMENT

4.1.1 Effect of irrigation and NPK-levels on photosynthetic parameters and grain quality in Monoculture crop rotation system 2017

Results and analysis of data on the effects of irrigation and NPK- levels on photosynthetic parameters and grain quality from the 2017 cropping year from the monoculture field as shown in Table 3 below indicates that, irrigation and NPK- levels did not have impact on the SPAD, NDVI and LAI performance in the irrigated and non-irrigated plots in the monoculture field. Plant height was however significantly affected by irrigation and NPK levels as it recorded a high mean value (243.67 cm and 251.77) at a significant level of ($P < 0.05$ and $P < 0.01$) respectively. The increase in plants height in irrigated treatment could be as a result of increase in absorption of NPK because of availability of available soil water which facilitates nutrients dissolving and movement, there by contributing linear increasement of maize plant above ground biomass. This study is in tendon with (Teixeira et al., 2004; Wang et al., 2017) who reported on the effects of water and nutritional stress on reduction of LAI and plant height in irrigated maize.

From the results, protein content of maize grains and moisture content after harvest was significantly affected by irrigation and NPK doses respectively in the monoculture field. 0.22% and 0.27% of water supply and NPK doses accounted for the significant impact on the protein content of grains and 0.51% and 0.63% of irrigation and NPK doses accounted for the maize moisture content in this research as recorded in Table 3 below The influence of nitrogen on the maize crude protein reported by (Haque et al 2001) indicated that, insufficient supply of nitrogen could cause a hindered the growth in maize owning to be a constituent of protein and nucleic acid. Also, (Ayuba et al.,2002a) reported that, nitrogen application could increase the nutritive value of maize grain due to the increases in grain crude protein concentration. Maize grain protein was affected by the level of irrigation in this study as show in the Table 3. The protein content was significantly lower in the fully irrigated treatment of (8.41 %). This shows that the protein matter of maize decreases if the quantity of irrigated water is above or below a certain rate, and water deficit is beneficial for maize protein content on a monoculture field. The higher protein content registered under non-irrigated condition can be attributed to the increase glutamate and glutamine synthase activities which involves the breakdown of nitrogen by increasing the accumulation and increasing maize grain protein (Cai et al., 2007).

Table 4: Effect of irrigation and NPK-levels on photosynthetic parameters and grain quality of maize in monoculture (Debrecen-Latokep, 2017)

Monoculture	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**Height (cm)**	**Protein (%)**	**Starch (%)**	**Moisture (%)**
Non-Irrigation	50.99	0.76	2.81	232.51*	8.63*	73.78	17.02*
Full Irrigation	50.87	0.77	2.98	243.67	8.41	74.10	17.60
CV%	3.32	1.93	0.34	9.35	0.22	0.52	0.51
Treatment							
$NPK_{O:O:O}$	50.17	0.74	2.67	227.20**	7.92**	73.90*	17.95**
$NPK_{60:45:45}$	51.80	0.76	2.96	235.30	8.08	74.47	16.95
$NPK_{180:135:135}$	50.82	0.77	3.06	251.77	9.57	73.45	17.03
CV%	4.07	2.36	0.83	11.45	0.27	0.64	0.63

Note: * is significant at 0.05 level, ** is significant at 0.01 level

Starch content in this study is not affected by irrigation as seen in the Table 4. Although the irrigation treatment recorded a high mean value, this value was not statistically significant. The starch content increased with increase in water supply showing that the grain filling stage was the same between the irrigated and non-irrigated plots. One reason that could be assigned to this phenomenon is starch biosynthetic enzyme activities and accumulation of starch in the maize grain and this may result in qualitative or quantitative differences in the level of carbohydrates metabolism in the endosperm leading in the changes that reduces starch synthesis in maize grain. The study of Zhao et al., 2009 indicated that, minor drought stress increases and water deficit deceased starch matter content. Water stress at a time grain development can lead to a decline in starch maize due to changes in enzyme activities responsible for starch biosynthesis. (Thitisaksakul et al., 2012). A research conducted in China by Lu et., al 2015 reported that, starch content of fresh waxy maize did not record any significant effect because of water deficit. Similarly, starch matter content of maize grain samples grown with less irrigation was 3.0% smaller than high irrigation (Liu et al., 2013).

Moisture content in grain at the harvest was affected by irrigation. The irrigated treatment had a higher significant mean value of 17.60% against 17.02% for non-irrigated treatment (Table

4). Newton and Eagles (1991) reported variations in grain moisture content at harvest was established mainly by drying rates after physiological development as a result of drought stress and not by silking time. Hard mass of endosperm is greater than that of soft endosperm making diffusion of water from the maize grain inside to the outside more complicated, thus declining the rate of grain dry down. Grain moisture content was less in the non-irrigated treatment may be because of fast grain moisture loss, resulting from very small and soft grains (Table 4).

4.1.2 Effects of Irrigation and NPK-levels on photosynthetic parameters and grain quality in biculture crop rotation system in 2017

Results from the biculture field from this research on the analysis of irrigation and NPK levels on photosynthetic parameters and grain quality shows that, irrigation and NPK level did not have a significant effect on SPAD reading (Table 5). NDVI was affected by water treatment in the biculture, the non-irrigated plants recorded a high mean value at ($P < 0.05$). NPK levels however did not have a significant difference between those on SPAD. The effects of water stress was evident on the photosynthetic characteristic of maize in the biculture plots as NDVI was significantly affected as indicated in Table 5. The noticing impact of drought stress on photosynthesis is clear sign at the stem elongation period of maize developmental growth and the low level of photosynthesis rate could have a great effect on food construction and influences on dry matter accumulation. (Kisman., 2003; Osborne et al., 20022) have reported the effect of water stress on photosynthesis and dry weight loss on maize. Leaf area index was significantly affected by NPK levels at $P < 0.05$ but was not influenced by irrigation treatment although the irrigated plants saw a high LAI reading. Pandey et al., 2000 stated that drought stress reduces the leaf area. High NPK dose in this study accounted for the high record of LAI values and this indicates the higher leaf will perform better than in terms of capturing more solar radiation to produce more carbohydrate. The impact of nitrogen on maize leaf expansion is immeasurable for maize production as to capturing light to produce photosynthesis. The significantly higher mean leaf area was ranged at 2.60 for irrigated and 2.96 for fertilization effect respectively (Table 5).

Maize plant height was significantly affected by both water stress and NPK levels in the biculture at ($P < 0.05$ in Table 4). Maize plant cells and tissues expansions are sensitive processes that requires enough water and therefore, water stress can significantly reduce the turgor pressure thereby reducing plant height growth. (Hsiao, 1973), reported similar effect of water stress on cell division and further state that water stress delays leaf emergence and reduces leaves expansion in maize. $NPK_{180:135:135}$ applied to plants produced taller plants at a mean of (255.5 cm) than the control (246.7 cm). The significant increase in plant height with application of $NPK_{180:135:135}$ might be due to increase level of nitrogen levels as nitrogen increases maize plant cell division, cell elongation and nuclear formation. This study is like that of (Keskin et al., 2005; Siddiqui et al., 2006 and Kamara et al., 2014), who reported that, higher nitrogen doses application produces a maximum emergence in maize and increased plant elongation and yield.

Table 5: Effects of Irrigation and NPK-levels on photosynthetic parameters and grain quality in biculture maize (Debrecen-Latokep, 2017)

Biculture	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**Height (cm)**	**Protein (%)**	**Starch (%)**	**Moisture (%)**
Non-irrigation	54.88	0.77*	2.33	242.8*	8.88*	74.08	17.29*
Full irrigation	53.30	0.74	2.60	253.5	9.27	74.00	18.22
Treatment							
$NPK_{O:O:O}$	55.20	0.77	2.96*	246.7*	8.32**	74.65**	17.07*
$NPK_{60:45:45}$	53.67	0.75	2.24	247.5	9.12	73.98	17.70
$NPK_{180:135:135}$	53.40	0.75	2.20	255.5	9.78	73.48	18.50

Note: * is significant at 0.05 level, ** is significant at 0.01 level

In this biculture field experiment, maize grain nutrient quality of protein content and moisture content of maize grains were statistically significantly affected by water stress and NPK levels. Starch content was not affected by water stress, but it was however significantly affected by NPK levels as recorded in Table 5 above. From the analysed data, irrigated treatment plants had higher protein content and non-irrigated plants had low mean value accounting to 9.27 % of protein content while $NPK_{0:0:0}$ levels accounted for about 8.32 % of Protein content in the maize grains. The effect of different irrigation treatment was statistically important as similar results were reported by Vartanli and Emeklier (2007) who had between 6.21 and 8.65%. Again, Ertek and Kara (2013) who worked on a similar subject in sweet corn reported that deficit irrigation levels affected maize crude protein which vary between 10.63-11.25%. Other researchers such as Esmailian et al. (2013), Farhad et al. (2013) and Aydinsakir et al. (2013) who worked different irrigation levels and on different maize cultivars also reported that maize grain protein contents were significantly influence by different water stress levels. The difference observed could be because variation in experimental ecological and soil difference. Different NPK levels significantly affected protein content in maize grain in this study. Increasing nitrogen supply to maize plants generally resulted in increased grain and protein yield concentration. Studies from (Pierre et al.,1977; Cromwell et al.,1983; Tsai et al.,1983 and Anderson et al 1984) all reported about nitrogen levels effects on grain protein content of maize. Tsai et al. (1983) reported that, protein content of maize grain increases with increase in nitrogen supply due to preferential deposition of zein over the other endosperm proteins.

Starch content of maize grains were significantly influenced by different NPK levels at P<0.01 in this study in the biculture field. The starch content in the control treatment had the higher mean value of 74.69 % as against the 73.98 % and 73.48 % for the moderate and high doses respectively. The low starch content recorded under high nitrogen rate might be because of downregulation of genes related to starch synthesis. Again, enough assimilate supply favouring starch accumulation was demonstrated by nitrogen fertilizer additions or ear truncation (Seebauer et al., 2010).

Maize grain moisture content in this study was significantly influenced by both water stress and NKP levels at (P<0.05) Table 5. Grain moisture content at harvest varies in maize cultivars and so, are determined largely by the drying rate after physiological maturity and not by the time of silking. Nitrogen plays a role by increasing the percentage of hard endosperm as shown by grain hardness and percentage of grit following grinding. Newton and Eagles (1991) reported that, the intensity of hard endosperm is higher than that of soft endosperm making diffusion of moisture from the grain of low nitrogen utilized grain from the inside to the outside harder, thus decreasing grain dry down.

4.1.3 Effects of NPK on monoculture maize yield components in 2017

Table 6: Effects of NPK on monoculture maize yield components in 2017 (Debrecen-Latokep, 2017)

Monoculture	Non-Irrigated							
Treatment	**Cob Weight (g)**	**Grain Weight (g)**	**Cob Weight (g)**	**Cob Diameter (mm)**	**Cob Length (cm)**	**No. of row/cob**	**No. of grain/row**	**No. of grain/cob**
Control ($NPK_{0:0:0}$)	153.47a	132.6a	20.23a	42.3b	17.7ab	15.0a	34.0a	465.1a
$NPK_{60:45:45}$	128.33a	110.5a	36.67a	39.3a	15.9a	16.2a	29.4a	524.2ab
$NPK_{180:135:135}$	210.71b	183.8b	26.17a	43.7b	18.9b	14.8a	41.0b	605.6b
Treatments	Fully Irrigated							
Control ($NPK_{0:0:0}$)	188.58a	164.5a	23.5a	44.1a	18.5a	15.2a	38.2a	570.8a
$NPK_{60:45:45}$	197.03a	170.8a	33.5a	43.3a	19.0a	15.7a	37.1a	569.6a
$NPK_{180:135:135}$	189.67a	166.7a	23.7a	41.9a	18.8a	15.5a	38.6a	595.3a

Note: Means with the same letter within columns are not significantly different at $P<0.05$

Table 6 above present an analysis of NPK levels effect on yield components in the monoculture field for non-irrigated and fully irrigated treatments. From the analysis, cob weight, grain weight, cob diameter, no of grain per row and no of grain per cob were all significantly influenced by NPK-levels in the non-irrigated monoculture plot at $P<0.05$. Cob weight and no of rows per cob were not significantly affected by NPK-levels even though their means at $NPK_{180:135:135}$ rate were higher compared to the other two treatments as shown in Table 6 above. The role of NPK in maize production and its impact on yield components cannot be overestimated.

From the Table 6, the highest number of grains per cob was recorded under treatment $NPK_{180:135:135}$ which was statistically similar to the treatment $NPK_{60:45:45}$. The treatment without NPK recorded the smallest number of grains per cob in this study. NPK fertilizers affects crop production in different ways. It promotes formation of chlorophyll and increases plant cell counts and leaf area volume thereby affecting the biological yield by way of biomass increases in maize plant. Tsai et al., 1990 reported that, maize yield components below the most precise effect of nitrogen are grain number per ear. Researcher like Muhammad et al. (2009) and Zeidan et al., (2006) reported that grain number per cob was higher at the highest nitrogen rates and explain that the increase in grain number per cob from high nitrogen levels could be because of the lower race for nutrients thus allowing the maize plants to amass more above biomass with the ability to convert more photosynthates into sinks ensuing into more maize grains per cob.

Cob length of maize was affected by NPK levels in this experiment. The highest cob length was registered under the treatment of $NPK_{180:135:135,}$ while the minimum cob length was recorded in NPK $_{60:45:45}$ treatment. The increase in cob length in the highest dose of NPK could be that favourable environmental accelerated ideal use of solar light, enhancing higher assimilation of production and conversion to starch resulting in cob length elongation as indicated by (Derbay et al., 2004).

Grain weight was significantly affected by nitrogen levels in the non-irrigated plot in this experiment at $P<0.05$. The highest mean was achieved under the high nitrogen dose and the minimum grain weight was recorded in NPK $_{60:45:45}$ treatment which was significantly different from the control (Table 6). Nitrogen deficit causes leaf size reduction thereby reducing the amount of light absorption and utilization for plants for photosynthesis processes which causes a reduction in biological yield which nitrogen has a positive effect on. Mishra et al. (1995) stated that, with increasing in nitrogen consumption, the number of grains per head increases there by increasing the grain weight per cob.

The agronomic traits of grain number per row was significantly increased by high nitrogen rate compared to the control treatment which was similar and did not have any significant difference with the second treatment as registered in table 5. This study agreed with that of Fancelli and Doura-do Neto (2002). No. of row per cob in this study was not affected by NPK levels and could be understandable because maize crop could probably use the nitrogen in developing the grain number per row instead of increasing the number of rows per cob.

Cob weight presented in Table 5 shows that NPK levels did not have a significant effect on the cob weight in this study. The maximum value was recorded for the second treatment of NPK $_{60:45:45,}$ while the control experiment had the minimum cob weight of (20.23 g) which shows that increased in NPK could result in increase in cob weight. The results of Sharma and Adamu (1984) indicated that number of cobs, weight of cobs and grain weight per cob were highest at the highest nitrogen levels in a lower plant population. Alessi and power (1974) also indicated decreased in cob weight with decline in NPK levels in different maize hybrids.

Ear weight in the monoculture non-irrigated was significantly influenced at ($P<0.05$) by NPK levels in this study as the maximum mean weight of maize ear was achieved under the highest NPK dose as recorded in Table 6 above. There was no significant difference observed between the control and the $NPK_{60:45:45}$ levels.

In the monoculture fully irrigated plots in the study, maize yield parameters were not significantly affected at $P<0.05$ by NPK-levels Table 6. In these plots, it was observed that, even though there was not statistically different between the treatments, the maximum mean values were recorded under the $NPK_{60:45:45}$ dose for all the measured yield parameters except the cob diameter, number of rows per cob and grain number per cob which had the control and $NPK_{180:135:135}$ having the maximum mean values respectively as recorded in Table 5. The observation is that, under irrigated condition in the monoculture practice, $NPK_{60:45:45}$ will be more efficient than other treatments under similar conditions for maize yield parameters.

4.1.4 Effects of NPK on maize yield components on biculture plots in 2017

Table 7: Effects of NPK on maize yield components on a Biculture plot (Debrecen-Latokep, 2017)

Biculture	**Non-Irrigated**							
Treatment	**Cob Weight (g)**	**Grain weight (g)**	**Empty Cob Weight (g)**	**Cob Diameter (mm)**	**Cob Length (cm)**	**No. of row /cob**	**No. of grain/row**	**No. of grains/ cob**
Control ($NPK_{0:0:0}$)	248.2a	214.8a	30.3a	45.9a	19.7a	15.6ab	38.3a	548.1a
$NPK_{60:45:45}$	198.2a	170.7a	26.2a	44.1a	19.0a	14.7a	40.8ab	651.2a
$NPK_{180:135:135}$	216.8a	187.9a	27.3a	40.1a	18.4a	16.4b	43.6b	660.0a
Treatment	**Fully Irrigated**							
Control ($NPK_{0:0:0}$)	237.3a	207.1a	28.4a	44.2a	19.5a	14.9a	39.4a	623.6a
$NPK_{60:45:45}$	246.8a	214.9a	54.4a	44.6a	20.13a	15.1a	41.9a	657.2a
$NPK_{180:135:135}$	240.7a	211.3a	28.6a	46.7a	20.81a	19.2a	42.3a	671.3a

Note: Means with the same letter within columns are not significantly different at P<0.05

Table 7 presents an analysis of mean of NPK-levels on yield components in biculture non-irrigated and fully irrigated plots. From this study, NPK levels did not have influence in all the measured yield components except the number of rows per cob and number of grains per row. It was observed that, the control had the maximum mean values for the cob weight, grain weight, empty cob weight, cob diameter, and cob length. The number of grains per cob had the highest mean corresponding to the highest dose of NPK, although this value is not statistically different from the other treatment. In case of the number of rows per cob, high rate of NPK significantly affected this parameter, which was similar to the control, whiles the control and the $NPK_{60:45:45}$ dose was not statistically different at $P<0.05$. Grain number per row registered the maximum grain number per row under the highest dose of NPK and the minimum mean value was registered under the control treatment. Odeleye and Odeleya (2001) and Reddy et al, (2003) observed that high nitrogen treatments had the highest number of rows per cob and control had the lowest number of rows per cob at $P<0.05$ (Table 7). Results of Amin and Morteza (2015) showed that differences in nitrogen doses treatments had a significant influence on the grain number per row as highest number of grains per row (43.6) corresponds with the highest nitrogen rate as against (38.3) for the control (Table 7).

4.1.5 Effect of irrigation on yield components of maize on monoculture plots in 2017

Table 8 presents an analysis of impact of water supply on the yield components of maize in the monoculture field. The effects of water in maize crop have been researched by many authors and its critical role in maize crop production cannot be over emphasized. Maize cob weight, grain weight, cob diameter and number of grains per row were significantly affected by irrigation treatment at $P<0.05$. Also, empty cob weight, cob length, number of rows per cob and number of grains per cob all recorded a higher mean value in the fully irrigated treatment against the non-irrigated treatment which recorded the minimum mean value as indicated in Table 8 at $P<0.05$. The outcome of this research coincides with other studies which indicated on the effects of irrigation on maize yield components. The study of Istanbulluoglu et al. (2002) reported that, the values of cob length between irrigated and non-irrigated varying 20.5 and 16.4. Ertek and Kara (2013) also reported on this subject with is in consistent with the current findings. Again, the number of grains per row was statistically affected by irrigation treatment (Table 8). Results shows that the highest number of grains per row was found in the irrigated treatment of (38.2), whereas the lowest was recorded under the non-irrigated plot (34.0). Our findings are similar with that of Sampathkumar et al. (2013).

Table 8: Effect of irrigation on yield components of maize on monoculture plots using independent samples T Test (Debrecen-Latokep, 2017)

Treatment		N	Mean	t	Sig. (2-tailed)
Cob weight (g)	Non-irrigated	4	153.5	-2.454	**0.050**
	Fully irrigated	4	188.6		
Grain weight (g)	Non-irrigated	4	132.6	-2.494	**0.047**
	Fully irrigated	4	164.5		
Empty-cob weight (g)	Non-irrigated	4	20.2	-1.606	0.160
	Fully irrigated	4	23.5		
Cob diameter (mm)	Non-irrigated	4	42.3	-3.031	**0.023**
	Fully irrigated	4	44.1		
Cob length (cm)	Non-irrigated	4	17.7	-1.596	0.161
	Fully irrigated	4	18.5		
No. of row/cob	Non-irrigated	4	15.0	-.277	0.791
	Fully irrigated	4	15.2		
No. of grain/row	Non-irrigated	4	34.0	-2.712	**0.035**
	Fully irrigated	4	38.2		
No. of grain /cob	Non-irrigated	4	524.2	-1.469	0.192
	Fully irrigated	4	570.8		

Note: BOLD is significant at 0.05

Grain weight per ear was considerably reduced by irrigation in this study (Table 8). The maximum grain weight mean was observed under irrigated plot, whiles the lowest ear grain weight was recorded in the non-irrigated plot (164.5 and 132.6) respectively. Ertek and Kara (2013) also reported that, deficit irrigation decreased the number of grains per ear, which coincides with our findings.

The results in table 8 above indicates a significant difference in maize yield components in response to different water treatments in the parameters measured. Water deficit in maize is a very sensitive situation for maize plants as it affects yield components as reported by Reddy et al, (2003). The decrease in the yield components in the non-irrigated plot may be attributed to the limitation of dry matter partitioning to the reproductive sinks or grain formation factors as reported Turk and Hall, (1980). Water stress occurring at the thesis or tasseling stage in maize development causes a severe reduction in yield and yield components. (Seghatoleslami et al., 2008). Reports of other researchers shows that, reduction in yield components as a result of non-irrigated treatment will drastically result in yield reduction. (Gwathmey and Hall, 1992; Ziska and Hall, 1983).

4.1.6 Effect of irrigation on yield components of maize on biculture plots in 2017

Results in the biculture plots present the effects of water treatment yield components in Table 9 below. From the table, irrigation had a severe impact on the yield parameters measured at P<0.05.

Table 9: Effect of irrigation on yield components of maize on biculture plots (Debrecen-Latokep, 2017)

Treatment		N	Mean	T	Sig. (2-tailed)
Ear weight (g)	Non-irrigated	4	128.3	-2.617	**0.040**
	Fully Irrigated	4	197.0		
Grain weight (g)	Non-irrigated	4	110.5	-2.534	**0.044**
	Fully Irrigated	4	170.8		
Empty-cobweight (g)	Non-irrigated	4	36.7	.137	0.896
	Fully Irrigated	4	33.5		
Cob diameter (mm)	Non-irrigated	4	39.3	-2.283	0.063
	Fully Irrigated	4	43.3		
Cob length (cm)	Non-irrigated	4	15.9	-2.696	**0.036**
	Fully Irrigated	4	18.9		
No of row/cob	Non-irrigated	4	16.2	1.083	0.320
	Fully Irrigated	4	15.7		
No of grain/row	Non-irrigated	4	29.4	-2.627	**0.039**
	Fully Irrigated	4	37.1		
No of grain/cob	Non-irrigated	4	465.1	-2.392	**0.054**
	Fully Irrigated	4	569.6		

Note: **BOLD** is significant at 0.05

Tube weight, grain weight, cob length, number of grains per row and number of grains per cob were significantly affected by irrigation. The maximum mean value was recorded under the irrigated treatment in the above-mentioned yield components, whereas the minimum mean value was observed in the non-irrigated treatments in those same parameters. Cob diameter and number of grains per row however registered maximum mean value under the non-irrigated treatment which was statistically not significant from the means of the irrigated treatment in the biculture plot. Also, the cob diameter had the highest mean value (43.3 mm) under the irrigated treatment again (39.3 mm) for the non-irrigated treatment which was statistically not significant.

The analysis of independence T-test shows that the effect of water treatment on maize cob length were significant (Table 9). Comparison of mean values of the cob length for water treatment showed that the irrigated plants had the highest (18.98 cm) cob length and non-irrigated plants had the lowest cob length of (15.91 cm) and the difference was significant at $P<0.05$ (Table 9).

Grain number per row in this study was influenced by water treatment. The mean comparison of grain number of rows per cob showed that, the irrigated treatment plants had the maximum number of grain number per row (37.1), whereas the non-irrigated treatments had a minimum number of grains per row of (29.4) which was significant at $P<0.05$ (Table 9).

Number of grains per cob was significantly affected by irrigation treatment in this study at $P<0.05$ (Table 9). The highest grains number per cob was registered under the irrigated treatment (569.6), against the lowest grain number per cob which was recorded under the non-irrigated treatment (465.2) which was significant. Ahmad et al. (2002) reported that irrigated crops produced the highest grain number per cob and attributed it to due to better nutrition of plants in grain filling stage as a result of enough moisture to make nutrients accessible by plants roots.

Maize grain number was influenced by water treatment, and this is attributed to the partitioning of plant dry matter to reproductive structures at critical stages of the grain or kernel development as reported by Andrade et al, (1999). The reduction in grain number in non-irrigated treatment as a result of drought stress has been reported by Page at al. (2010) who suggested that drought stress contributed to kernel number per plant as a result of plants setting fewer kernels per plant and less biomass to the developing ear in response of physiological responses to other factors like weed competition. Number of rows per cob was not significantly affected in this study by irrigation and the reason for this could be that number of rows per ear is most likely to influenced by heredity factors rather than by crop management. Rivera-Hernandez et al (2010) findings are in tendon with this current study.

4.1.7 Effect of NPK treatment on yield in monoculture and biculture plots in 2017

Table 10 presents an analysis of NPK levels on the maize grain yield in both monoculture (non-irrigated and fully irrigated) and biculture (non-irrigated and fully irrigated) plots for the 2017 cropping season.

Table 10: Effect of NPK treatment on yield in monoculture and biculture plots (Debrecen-Latokep, 2017)

Treatment	Monoculture (Yield kg ha^{-1})		Biculture (Yield kg ha^{-1})	
	Non-Irrigated	Fully Irrigated	Non-Irrigated	Fully Irrigated
Control ($NPK_{0:0:0}$)	2614.7a	2611.9a	5146.2a	5604.9a
$NPK_{60:45:45}$	3810.8a	4364.0b	6455.8b	6675.8a
$NPK_{180:135:135}$	5696.9b	6249.9c	6934.7b	6770.8a

Note: Same letters within each column do not differ significantly at P<0.05

Maize grain yield in the monoculture non-irrigated plot had a great significant difference between the NPK levels in this research. The maximum grain yield was recorded under the NPK $_{180:135:135}$ (5696.9 kg ha^{-1}) and the minimum mean value was observed in the control which did not have a significant difference with the NPK $_{60:45:45}$ although the later had a higher mean than the former as indicated in Table 10.

In the fully irrigated treatment in the monoculture plot, there were significant differences between all the three levels of NPK doses at P<0.05 as shown in table 10. The highest mean grain yield was observed in the highest NPK dose and followed by the second highest rate and then by the control which has zero rate of NPK.

In the biculture non-irrigated plot, NPK levels had a significant effect on maize grain yield with the maximum grain yield (6249.9 kg ha^{-1}) registered under the highest $NPK_{180:135:135}$ rate , whiles the lowest grain yield was observed in the control experiment which had a zero rate of NPK. There was also significant difference between the NPK $_{60:45:45}$ and the control at P<0.05 (Table 10).

In the fully irrigated treatment in the biculture plot, NPK levels did not have a significant effect on the maize grain yield in the study at P<0.05 as recorded in Table 8 above. Although the NPK $_{180:135:135}$ had the highest grain yield, followed by the NPK $_{60:45:45}$ and by NPK $_{0:0:0}$ (control), there was no significant difference between the grain yield in the different NPK rates.

Maize production responds positively to nitrogen and supplementary water supply for both factors limit the yield of maize (Araus et al. 2002). Maize yield decreases when the maize crop is subjected to drought stress with a high rate of nitrogen (Grant et al. 2002; Moser et al., 2006) and this current study coincides with this finding as it can be observed in the monoculture plot, when nitrogen dose was increased with a decreased in water in the non-irrigated treatment, grain yield decreased (5696.9 kg ha^{-1}) compared to the irrigated treatment (6249.9) Table 10. The observation reveals that, photosynthetic active radiation and water potential positively correlate with grain yield. Nitrogen deficiency reduces light interception by decreasing leaf area and thereby resulting in low crop yield (Uhart and Andrade, 1995; Glamoclija et al. 2011). The study of Ding et al., 2005 reported that, there is a positive relationship between photosynthetic rate and yield formation processes of various maize hybrids. Enough dose of nitrogen application at the right time is shown to be the significant factor in improving crop productivity and yield Magdoff,1991b and prudent use of nitrogen and management optimizes grain yield and reduces nitrogen leaching. To achieve physiological and agronomic characteristic of maize, one to properly balance nitrogen and water in a proper management level for optimum productivity and crop grain yield.

Nitrogen affects maize crop production through different mechanisms, since it facilitates formations of chlorophyll and increase plant cell counts and volume per leaf area. The nitrogen treatment affected grain yield due to an increase in the biomass of maize crops during the early parts of growing stages. Drought stress imposed at maize vegetative stage during its development decreases the leaf thereby affecting grain yield parameters (grain number per cob, 1000-grain weight, number of rows per cob etc) thus, reducing grain yield (Hammad et al. 2011; Anjum et al 2011; Akcura, 2001). The decrease in grain yield in the non-irrigated treatments could be as a result no availability of water to dissolve available nutrients for use by maize plants at the reproductive stage. Cakir (2004) reported that, water deficiency during reproductive stage reduced plant growth, resulting in reduction in grain yield.

4.1.8 Effects of irrigation on grain yield of maize in monoculture plots in 2017

Table 11 is an analysis of effects of water supply to maize grain yield in the monoculture field for the 2017 cropping season.

Table 11: Effects of irrigation on grain yield of maize in monoculture plots (Debrecen-Latokep, 2017)

Treatment monoculture		N	Mean yield	T	Sig. (2-tailed)
$NPK_{O:O:O}$	Non-irrigated	3	2614.6	0.008	0.994
	fully irrigated	3	2611.9		
$NPK_{60:45:45}$	Non-irrigated	3	3810.8	0-.837	0.449
	fully irrigated	3	4364.0		
$NPK_{180:135:135}$	Non-irrigated	3	5696.9	-1.534	0.200
	fully irrigated	3	6249.9		

Note: BOLD: is significant at P<0.05

From the table 11, irrigation did not have a statistically significant effect on maize grain yield from all the NPK levels. Except in the control experiment where the non-irrigated treatment registered the highest grain yield more than the fully irrigated, the other two NPK levels had the fully irrigated treatments with the maximum grain yield in this experiment as recorded in table 11. The reason for the non-impact of the drought stress in the non-irrigated treatment is the good precipitation for the cropping year under review in June/July (Fig.1), which is seen as the dryer's months where temperatures are mostly higher. Nonetheless, the higher mean grain yield in the fully irrigated treatment against the non-irrigated treatment shows the importance of water to maize crop production and yield. Many scholars have reported on the effects of irrigation on grain yield. The non-significant reduction in grain yield indicates that crops did not suffer water deficit during their critical growth stage. Findings of Kang et al. (2000), reported that water deficit during early growth stage had a no significant effect on grain yield. Fapohunda and Hossain, 1990; Pandey et al., 2000 reported water stress effect on grain weight and grain number per ear during the reproductive stage of maize development.

In Table 11, irrigation did not have a statistically significant effect on maize grain yield in the biculture plots between the three different levels of NPK doses. The fully irrigated treatments in the control and the $NPK_{60:45:45}$ rates had the maximum grain yield whereas the non-irrigated treatments had the minimum grain values. In the NPK 180:$_{135:135}$ dose however, the non-irrigated treatment had had the maximum grain yield (6934.7 kg ha^{-1}) against the fully irrigated treatment which had a minimum grain yield of (6770.8 kg ha^{-1}). These did not however show any statistically significant difference at P <0.05 (Table 11).

Table 12: Effects of irrigation on grain yield of maize in biculture plots (Debrecen-Latokep, 2017)

Treatment biculture		N	Mean Yield	T	Sig. (2-tailed)
$NPK_{O:O:O}$	Non-irrigated	3	5146.2	-1.071	0.345
	fully irrigated	3	5604.9		
$NPK_{60:45:45}$	Non-irrigated	3	6455.8	0-.396	0.712
	fully irrigated	3	6675.8		
$NPK_{180:135:135}$	Non-irrigated	3	6934.7	0.166	0.882
	fully irrigated	3	6770.8		

Note: **BOLD**: is significant at P<0.05

4.1.9 Effects of irrigation on grain yield of maize in biculture plots in 2017

Grain yield reduction in the non-irrigated treatments could be assigned to embryo abortion which usually occurs in maize plants when abiotic stresses such drought or temperature are at extremes during reproductive stage of maize crop development. This effect has been observed in most cereal plants like rice, wheat, barley etc. suggesting that this phenomenon is a widespread situation in the plant life and has been reported by many authors (Andersen et al., 2002; Feng et al., 2011; Setter et al., 2011). Maize grain yield reduction caused by drought stress is a threat to food security worldwide (Ji et al., 2012). Westgate and Boyer, (1986) reported that endosperm/embryo development has shown to sensitive to water deficits thus resulting to failure of seed production in maize which is an important component of kernel reduction in number. Water stress affects transport of carbohydrates to ovules in floral development in plants. Campos et al, (2006) has also reported grain yield losses in the United State as a of drought stress. Maize is highly sensitive to drought, specifically two weeks before and after silking. Drought frequency and intensity is a major problem compounding maize production areas in many parts of the world affecting grain yields. (Bänziger et al., 2000; Tollenaar and Lee, 2011; Campos et al., 2004).

4.1.10 Effects of NPK levels on maize grain quality in 2017

Table 13 below present an analysis of NPK-levels on grain nutrition quality in both monoculture and biculture plots in the 2017 cropping season.

In the monoculture non-irrigated plot, maize grain moisture content at harvest was affected by NPK levels at P<0.05 (Table 13). The maximum grain moisture content was found in the control with zero NPK dose (18.3%) whereas the $NPK_{180:135:135}$ had the minimum grain moisture content (17.1%) which was statistically different. There was however no significant difference between the control and the $NPK_{60:45:45}$ and, no difference was noticed between the $NPK_{60:45:45}$ and $NPK_{180:135:135}$.

Grain moisture content in the monoculture fully irrigated plot was significantly affected by NPK levels. Just like in the non-irrigated plot, the control experiment which has a zero dose of NPK had the maximum grain moisture content (17.6%) whiles the $NPK_{60:45:45}$ had the minimum grain moisture content (16.6%) which was statistically not significant. The $NPK_{180:135:135}$ dose however has a significant difference effect between it and the control as shown in table 12 at P<0.05.

Grain moisture content varies between the NPK levels in both non-irrigated and fully irrigated plots in this study. Newton and Eagles (1991) reported that, difference in grain moisture were primarily determined the drying level after physiological maturity. The significant difference between the NPK levels in both non-irrigated and fully irrigated treatments could be ascribed to the high ratio of hard endosperm by grain hardiness and percentage grit because of efficient use of available nitrogen. Maize grain value is partly related to grain endosperm properties which accounts for about 85% of total grain dry weight at maturity and contains about 70% 0f grain protein. Agronomic practices such as nitrogen fertilizer inputs and environment may influence grain quality characteristics (Sabata and Mason, 1992).

Grain protein content was significantly affected by different NPK levels in both non-irrigated and fully irrigated plots in the monoculture field. The highest protein content was observed under the highest NPK dose in both non-irrigated and fully irrigated treatments (9.23% and 9.90%) respectively, whereas the control which has a zero dose of NPK had the lowest grain protein % (8.0% and 7.8%) for the non-irrigated and fully irrigated treatments respectively (Table 13). Protein is an important component of maize grain quality. With an increase in nitrogen level, protein content in maize increased in both non-irrigated and fully irrigated plots (Table 13). Almodares et al. (2008) stated that, maize crude protein content increased significantly with an increase in nitrogen fertilizer level. The increase in protein content may be as a result of the improvement of the amino acid formation due to fertilization and it might also be that the relative proportion of the various components of amino acid in raw protein of maize has been influence (Radulov et al. 2010; Almodares et al. 2008). Other researchers like Johnston, (2000) ; Mahmud et al. (2003); Almodare et al.(2008) findings are in line with this current study when they reported that higher nitrogen significantly affected grain protein content. Nitrogen fertilizer plays a major role in the synthesis of amino acid, nucleic acids etc which is necessary for maize crop growth and development and its reduction affects grain yield and quality (Zhao et al., 2005).

Table 14: Effects of NPK levels and irrigation on maize grain quality on monoculture and biculture plots. (Debrecen-Latokep, 2017)

Treatment	**Monoculture non-irrigated**			**Monoculture fully irrigated**		
	Moisture %	**Protein %**	**Starch %**	**Moisture %**	**Protein %**	**Starch %**
$NPK_{O:O:O}$	18.3b	8.0a	74.1a	17.6b	7.8a	73.7ab
$NPK_{60:45:45}$	17.3ab	8.0a	74.4a	16.6b	8.2a	74.6b
$NPK_{180:135:135}$	17.1a	9.23b	73.8a	16.9ab	9.90b	73.1a
	Biculture non-irrigated			**Biculture fully - irrigated**		
$NPK_{O:O:O}$	17.5a	7.6a	75.2b	16.7a	8.6a	74.40b
$NPK_{60:45:45}$	18.4a	8.8b	74.9ab	17.2a	9.18a	73.45a
$NPK_{180:135:135}$	19.1a	9.5b	74.4a	17.9a	10.0b	73.03a

Note: Same letters within each column do not differ significantly at P<0.05

Grain starch content was not affected by different NPK levels in the non-irrigated treatment in the monoculture plots, but significant difference between the different NPK levels was noticed in the fully irrigated treatment in the monoculture plot (Table 14) at P<0.05. Plant nutrients, especially potassium is very essential in increasing the sugar and starch content in grains of maize. Sugar content in maize is closely correlated with carbohydrate formation and use. Nyakpa et al. (1988) reported that, potassium could raise the starch content in maize grains. Sufficient availability of potassium could help the plant height, leaf width and chlorophyll content which enhances starch production in maize. Insufficient utilization of potassium in plants results to low sugar and starch content in grain. The findings of Miao et al, 2006; Sharma and Arora, 1988 do not agree with the current study when they reported that, with an increase in nitrogen doses, starch content decrease in cereal grain. Masoero et al.

(2011) experiment observed that different application of nitrogen doses was the cause of change in starch content in maize grain. Our experiment agrees with that of author Li et al, (2013) and Srikumar (1990) when they that, NH_4^+ nitrogen is responsible for the increased accumulation of starch in maize grain and found a positive correlation between nitrogen and starch, respectively.

In the biculture field as shown in table 14 above, different NPK doses did not have a significant effect on maize moisture content in the non-irrigated and fully irrigated remedies in this experiment at ($P<0.05$). Protein content was significantly affected with an in increased in NPK dose in both non-irrigated and fully irrigated treatments. The highest grain protein content percentage was observed in $NPK_{180:135:135}$ (9.5%), whereas the lowest mean protein (7.6%) was recorded under the control which has zero dose of NPK in the non-irrigated treatment (Table 14), which was significant at $P<0.05$. No significant difference was however noticed between the $NPK_{180:135:135}$ and $NPK_{60:45:45}$. In the fully irrigated treatment, there was significant difference between the $NPK_{180:135:135}$, and both the $NPK_{60:45:45}$ and the $NPK_{0:0:0}$. With the maximum protein content percentage recorded in the highest dose of nitrogen treatment, whiles the minimum grain protein content recorded under the control which has a zero dose of NPK (Table 14). From the above finding, the increasing effect of NPK doses on protein cannot be over emphasized in that high NPK rates significantly increase protein content in maize grains. This stimulating effect was due to the close relationship between nitrogen and protein and these results are in agreement with other research findings like Javed et al. (1985) and Hejjati and Maleki (1992), who reported significant effect of NPK on protein content in maize.

Starch content in the biculture non-irrigated and full irrigated treatments in this research was significantly affected by different NPK doses. The zero dose of NPK in both the non-irrigated and fully irrigated registered the highest starch content percentage (72.2% and 74.4%) whereas the highest NPK dose recorded the lost starch content percentage (74.4% and 73.0%) for both non-irrigated and fully irrigated treatment respectively. In the case of the non-irrigated treatment, there was no significant difference between the control and the $NPK_{60:45:45}$ and also, no difference was noticed between the $NPK_{60:45:45}$ and $NPK_{180:135:135}$ at $P<0.05$ (Table 14). For the fully irrigated treatment, no significant difference was found between $NPK_{60:45:45}$ and $NPK_{180:135:135}$ at $P<0.05$. Our result from this study coincides with that of Miao et al, 2006; Sharma and Arora, 1988, when they reported that, with an increase in nitrogen fertilizer dose, generally starch content in cereal grains decreased.

4.1.11 Effects of crop rotation (A) and water treatment (B) on photosynthetic parameters and grain quality of maize in 2017

Table 15 is an analysis of the correlation effects of crop culture and water treatment on photosynthetic parameters and grain quality in the 2017 cropping season. Results from the table indicate that, SPAD, LAI and plant height were significantly affected by crop rotation in this study. SPAD values in the biculture plots had the maximum SPAD reading values whereas the monoculture plots recorded the minimum SPAD values which were statistically different at $P < 0.01$ level (Table 15). NDVI values were not significantly affected by crop rotation although the biculture plot crops had a higher mean value as against the monoculture plot crops. Leaf area index was statistically influenced by cropping system in this study at $P<0.05$ level (Table 15). Biculture plot crops has the maximum crop leaf area index whiles the monoculture plot crops have the minimum crop leaf area index. Plant height was also significantly affected by cropping system. Biculture plot crops have the highest mean height as against the monoculture plot crops as shown in (Table 15) below at $P<0.01$ level.

Maize plant reacts to different kind of stresses in relation to their photosynthetic characteristics. Mayfield and Taylor (1984) underlined a connection between a decreased in light harvest of maize plants and low carotenoid content. Bonis et al, (2006) has reported positive effects of cropping system on photosynthetic components, which may lead to increase in maize yielding potential. The increase in the photosynthetic parameters in the biculture plot crops could be as a result of efficient and effective use of plant nutrients in the biculture soil since different crops are being planted on that plot year after year.

Plant grain nutrition in this study was not statistically significantly affected by cropping system as it is shown in (Table 15). The mean value reading from the granulizer shows maximum values for the biculture plot grains for protein, starch, and moisture content, but these maximum values did not significantly differ from the monoculture plot grains. Water treatment affected NDVI and grain moisture content at $P<0.05$ levels (Table 15). The combined effect of crop culture and water treatment on maize had a significant effect on plant height at $P<0.01$ and grain protein at $P<0.05$ level.

Table 16: Effects of crop rotation (A) and water treatment (B) on photosynthetic parameters and grain quality of maize (Debrecen-Latokep, 2017)

Crop Rotation (A)	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**Height (cm)**	**Protein (%)**	**Moisture (%)**	**Starch (%)**
Monoculture	50.93**	0.76	2.45*	238.09**	8.52	17.31	73.94
Biculture	54.09	0.76	2.89	247.42	9.07	17.76	74.04
Water Treatment (B)							
Non-Irrigation	52.93	0.77*	2.57	241.77	8.76	17.16*	73.93
Full Irrigation	52.09	0.75	2.79	243.74	8.84	17.91	74.05
CV%	1.76	1.85	0.36	6.54	0.27	0.69	0.40
Combined Effect (A X B)	ns	ns	ns	**	*	ns	ns

Note: * correlation is significant at 0.05 level, ** correlation is significant at 0.01 level

4.1.12 Effect of NPK on plant height and stem diameter in a monoculture plots in 2017

Table 16 presents an analysis of effect NPK doses on maize plant height and stem diameter on monoculture plots. From the table, maize plant height was significantly affected by NPK doses in this study. The maximum plant height in both the irrigated and non-irrigated monoculture plots was recorded under the highest $NPK_{180:135:135}$ dose (256.20 cm and 252.70 cm). There was however no statistically significant difference between the control NPK dose and $NPK_{60:45:45}$ in the both the irrigated and non-irrigated treatments (Table 16) at $P<0.05$. The significance in maize plant height with increasing nitrogen dose might be due to increase in cell division, Cell elongation and nuclear formation. Many scholars have reported similar findings (Keskin et al., 2005; Siddiqui et al., 2006; Kamara et al., 2014) application of higher dose of nitrogen produced maximum emergence in maize seedlings and promote plant stem elongation and yield. Difference in nitrogen levels resulted in increase in pants height can be attributed to the fact that nitrogen promotes plant growth, increase the number and length of internodes which results in progressive increase in plant height. The result of this study agrees with that of Koul, 1997, and Gasim, 2001.

Table 17: Effect of NPK on plant height and stem diameter in monoculture maize plots (Debrecen-Latokep, 2017)

Treatment	**Monoculture Irrigated**		**Monoculture Non-Irrigation**	
	Plant height (cm)	**Stem diameter (cm)**	**Plant height (cm)**	**Stem diameter (cm)**
$NPK_{O:O:O}$	223.45a	1.94a	226.95a	2.03a
$NPK_{60:45:45}$	238.20a	1.96ab	238.10a	2.07a
$NPK_{180:135:135}$	256.20b	2.18b	252.70b	2.35b

Note: Numbers with the same letters in the same column have no significant difference

Stem diameter in this study was affected or influence by nitrogen levels. In the irrigated treatment, the maximum plant stem diameter was registered under the highest dose of $NPK_{180:135:135}$ (2.18 cm) which was statistically different from the control but was not different from the $NPK_{60:45:45}$ (1.96) dose (Table 17) at $P<0.05$. In the monoculture non-irrigated treatment, the maximum stem diameter was seen under the highest nitrogen dose which is significantly different from the both the control and $NPK_{60:45:45}$ as shown in Table 17. Generally, nitrogen promotes maize plant growth. The largest stem diameter was noticed under the highest nitrogen rate. Elmar (2001) reported an increase in stem diameter because of NPK application, and the fact that, the nitrogen source was composed of many nutrients.

4.1.13 Analysis on 2018 cropping season.

Table 18: Effect of NPK dose on photosynthetic parameter in monoculture full irrigated plots (Debrecen-Latokep, 2018)

Monoculture Treatment	**First Measurement**			**Second Measurement**			**Third Measurement**		
	SPAD	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**
$NPK_{O:O:O}$	52.2a	0.60a	0.41a	54.3a	0.77a	2.04a	56.33a	0.76a	3.24a
$NPK_{60:45:45}$	49.4a	0.63a	0.56ab	53.7a	0.78ab	2.34ab	58.20a	0.76a	3.96ab
$NPK_{180:135:135}$	52.6a	0.70a	0.75b	61.1b	0.80b	2.51b	64.71b	0.78a	4.52b

Note: Numbers with the same letters in the same column have no significant difference

From the monoculture full-irrigated treatment plot, NPK levels had effects on the photosynthetic parameters of maize plant in this study. From Table 18, SPAD values ware not significantly affected in the first measurement but were significantly influenced in the second and third measurement. In both the second and third measurements, there was significant difference between the $NPK_{180:135:135}$ dose and the $NPK_{60:45:45}$ and the control $NPK_{0:0:0:0}$. The highest nitrogen dose treated maize plants recorded the maximum SPAD values of (61.02 and

64.71) for the second and third measurements respectively which is significantly different compared with the control treatment (54.33 and 56.33) for the second and third measurements respectively (Table 18). NDVI measurement in the monoculture full irrigated did not show significant difference in the first and third measurements, but there was a significant difference in the second measurement where the highest nitrogen dose significantly influenced the NDVI readings. The maximum NDVI mean was seen under the $NPK_{180:135:135}$ (79.8) whiles the minimum dose NDVI mean was recorded under the control which has a zero dose of nitrogen. There was however no difference between the control and the $NPK_{60:45:45}$ doses (Table 18). Leaf area index was significantly affected in all the three measurements in this study in the monoculture fully irrigated treatment. The highest nitrogen dose of $NPK_{180:135:135}$ treated maize plants recorded the largest LAI values (0.75, 2.51 and 4.52) respectively for the first, second and third measurements as against the control with zero nitrogen dose $NPK_{0:0:0}$ (0.41, 2.04 and 3.24) respectively for the first, second and third measurements. No significant difference was observed between the control and the $NPK_{60:45:45}$ doses (Table 18) at $P<0.05$.

Table 19: Effect of NPK dose on photosynthetic parameter in a monoculture non-irrigated plot (Debrecen-Latokep, 2018)

Monoculture Treatment	First Measurement			Second Measurement			Third Measurement		
	SPAD	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**
$NPK_{O:O:O}$	54.82a	0.62a	0.57a	56.35a	0.79a	2.38a	47.52a	0.78a	3.28a
$NPK_{60:45:45}$	55.00a	0.67ab	0.64a	57.25a	0.80a	2.41a	50.82a	0.80b	3.33a
NPK180:$_{135:135}$	56.75a	0.73b	0.82b	64.08b	0.80a	2.72a	58.15a	0.81b	4.61b

Note: Numbers with the same letters in the same column have no significant difference.

In the non-irrigated monoculture treatments as presented in Table 19, SPAD values were not affected by nitrogen levels in the first and third measurements even though the highest SPAD values were recorded under the $NPK_{180:135:135}$ which has the highest nitrogen dose, but this was not statistically significantly different from the other treatments. In the second measurement however, there was a significant difference between the treatments. The $NPK_{180:135:135}$ recorded the highest SPAD mean value which was significantly different at $P<0.05$ as shown in Table 19.

NDVI measurements in this plot of non-irrigated monoculture shows significant difference in the first and third measurements whereas no difference was observed in the second measurement. In the first measurement, the maximum NDVI value was observed under the $NPK_{180:135:135}$ (0.73) whereas the minimum NDVI value was recorded under the control which has zero nitrogen dose (61.50). In the third measurement, no difference was observed between the $NPK_{180:135:135}$ and $NPK_{60:45:45}$, but there was significant difference between $NPK_{180:135:135}$, $NPK_{60:45:45}$ and the control ($NPK_{0:0:0}$).

Leaf area index in this monoculture non-irrigated treatment was influenced by nitrogen levels in the first and third measurements but was not affected in the second measurement. In the first measurement, there was a statistically significant difference between the $NPK_{180:135:135}$ and both the control and the $NPK_{60:45:45}$. The $NPK_{180:135:135}$ dose treatment plants recorded a high mean index (0.82) as against the control (0.57) which was significant (Table 19). In the third measurement, there was no difference between the control and the $NPK_{60:45:45}$, but there was significant difference between the $NPK_{180:135:135}$ and both the control and the $NPK_{60:45:45}$. The maximum leaf area index was seen in the treatment with the highest dose of nitrogen ($NPK_{180:135:135}$) as indicated in (Table 19).

Table 20 present an analysis of effects nitrogen levels on the photosynthetic characteristics of maize in a fully irrigated plot in a biculture field in the 2018 cropping year. There measurements were taking at different growth period of the maize crop growth. From the table, SPAD measurement was not statistically different from the first and third measurement among the different nitrogen level, but significant difference was observed in the second measurement where the highest dose of nitrogen treated plants recorded the maximum spad values as against the control with zero dose of nitrogen. No difference was however noticed between the $NPK_{60:45:45}$ and $NPK_{180:135:135}$ at $P<0.05$ (Table 20)

NDVI measurement in this study shows a significant difference between the $NPK_{60:45:45}$ and $NPK_{180:135:135}$ and the control ($NPK_{0:0:0}$) in the first measurement. No statistically significant difference was however observed in the second and third measurement among the different nitrogen rates in this study although the $NPK_{180:135:135}$ dose recorded the maximum NDVI values as against the other levels in both the second and third measurements as shown in (Table 20).

Leaf area index measurement was significantly influenced by nitrogen levels in all the three measurements. In the first measurement, there was a significant difference between the $NPK_{180:135:135}$ and the control but there was no significant difference between the $NPK_{180:135:135}$ and $NPK_{60:45:45}$ and, no difference was observed between the control and the

$NPK_{60:45:45}$ (Table 20). In the second measurement, the maximum LAI was seen under the highest nitrogen dose treated maize crop (2.89) whereas the minimum LAI value was recorded under the control (2.28) which was however not significantly different from the $NPK_{60:45:45}$ (2.30) at $P<0.05$ (Table 20).

Maize plant leaf area index is an evaluative mechanism used to determine the structure canopy and therefore nitrogen deficiency results in the reduction of LAI since leaves become thinner, which results in light leaking thus not able to absorb enough light rays from the sun. (Wilhelm et al., 2000; Bavec and Bavec, 2002). Adequate nitrogen intake by maize plants makes vegetative organs grow resulting in self shading within a plant growing population which has a negative effect on plants growth and production. NPK had a significant effect on photosynthetic parameters (Sinclair and Horie, 1989; Sade et al., 2018). LAI in this study increased with increase in nitrogen rates which coincides with previous research of (Liu et al., 2017). Chlorophyll SPAD values are used to determine the chlorophyll content in leaves and in this study, more NPK will help in maintaining the high chlorophyll SPAD values at the growing stage, however there was no significant difference at the early developmental stages (Table 20). Significant difference was however observed at the second measurement which will promote efficient use of light for vegetative organ development in the maize plant. Nitrogen improves gas exchange parameter greatly. According to Sadras and Milroy, 1996; Anjum et al., 2011; Hura et al., 2007, absence of nitrogen limits photosynthetic parameters resulting in stomatal reduction, thus limiting the gas exchange between functional leaves and the environment and non-stomatal limitation, that is carboxylation is impaired destroying photosynthetic apparatus.

Table 20: Effects of NPK levels on photosynthetic parameters in biculture fully irrigated plots (Debrecen-Latokep, 2018)

Biculture Treatment	**First Measurement**			**Second Measurement**			**Third Measurement**		
	SPAD	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**
$NPK_{O:O:O}$	53.42a	0.61a	0.67a	58.42a	0.80a	2.28a	65.09a	0.79a	3.59a
$NPK_{60:45:45}$	52.73a	0.69b	0.74ab	62.56ab	0.80a	2.30a	65.81a	0.79a	4.58ab
$NPK_{180:135:135}$	53.80a	0.75b	0.97b	64.48b	0.81a	2.89b	65.26a	0.80a	4.73b

Note: Numbers with the same letters in the same column have no significant difference

Table 21 presents measurement and analysis of nitrogen levels in non-irrigated biculture plots. As indicated in the table, SPAD values were not statistically significantly different in the first and third measurements, but significant difference was observed in the second measurement, where nitrogen dose significantly influenced SPAD values. The maximum SPAD value (65.1) was recorded under the highest dose of nitrogen ($NPK_{180:135:135}$) whereas the minimum spad reading (56.3) was observed under the control with zero nitrogen dose ($NPK_{0:0:0}$).

NDVI measurements in this plot as shown in table 18 shows a significant difference in the first measurement, but no significant difference was seen in the second and third measurements. In the first measurements, nitrogen levels affected the NDVI readings such that the highest dose of nitrogen recorded the maximum mean NDVI value (0.73) whiles the control recorded the lowest mean NDVI value (0.64). Leaf area index (LAI) in the first and second measurements were not significantly affected but in the third measurements, there was a significant difference between the nitrogen levels. The highest dose of nitrogen treated plant recorded the maximum LAI mean value (2.4) which was significantly different from the control. There was however no difference between the control and the $NPK_{60:45:45}$ at $P<0.05$ (Table 21).

Table 21: Effects of NPK levels on photosynthetic parameters in biculture non-irrigated plots (Debrecen-Latokep, 2018)

Biculture Treatment	**First Measurement**			**Second Measurement**			**Third Measurement**		
	SPAD	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**
$NPK_{O:O:O}$	53.7a	0.64a	0.82a	56.3a	0.81a	2.4a	54.0a	0.67a	1.8a
$NPK_{60:45:45}$	53.8a	0.69ab	0.81a	56.9ab	0.80a	2.4a	53.0a	0.69a	1.9ab
$NPK_{180:135:135}$	53.4a	0.73b	0.89a	65.1b	0.81a	2.6a	58.4a	0.70a	2.4b

Note: Numbers with the same letters in the same column have no significant difference

Nitrogen effects on photosynthetic parameters on maize is very important and cannot be overlooked. Lindguist et al., (1998) reported that maximum leaf area index was achieved with high nitrogen supply resulting in maximum grain yield. Varvel et al.,(1997) demonstrated that nitrogen fertilizer significantly increases SPAD reading values with coincide with this study. LAI value also increases with increase in nitrogen dose and this has been reported by Valadabadi and Aliabadi Farahani, 2010 . The current results show the vital role of nitrogen in maize plants life and its role in increasing photosynthetic characteristics resulting in grain yield. This result indicates that nitrogen is important for cell division and elongation as well as root growth and development.

Table 22 is an analysis of irrigation effect on maize yield components in the monoculture field using 2-tailed independent sample T-Test. From the results as shown in Table 22, no statistically significant difference was observed between the irrigated treatment and the non-irrigated treatment among the yield components in the monoculture field. The main reason for this phenomenon is that the precipitation for this cropping (2018) season was high and so drought did not play a significant role. (Figure 2).

Table 22: Effects of irrigation on yield components in monoculture maize using the independent samples t test (Debrecen-Latokep, 2018)

Treatment		N	Mean	T	Sig. (2-tailed)
Cob weight (g)	Non-Irrigated	4	210.71	0.61	0.57
	Fully Irrigated	4	189.67		
Eye weight (g)	Non-Irrigated	4	183.82	0.57	0.59
	Fully Irrigated	4	166.72		
Empty-cob weight (g)	Non-Irrigated	4	26.18	0.58	0.58
	Fully Irrigated	4	23.73		
Cob diameter (mm)	Non-Irrigated	4	43.67	1.05	**0.34**
	Fully Irrigated	4	41.92		
Cob length (cm)	Non-Irrigated	4	18.86	0.02	0.98
	Fully Irrigated	4	18.83		
No. of Row/Cob	Non-Irrigated	4	14.83	-0.88	**0.41**
	Fully Irrigated	4	15.50		
No. of grain/Row	Non-Irrigated	4	41.00	1.02	**0.35**
	Fully Irrigated	4	38.58		
No. of grain/Cob	Non-Irrigated	4	605.58	0.23	0.83
	Fully Irrigated	4	595.33		

Note: **BOLD** is significant at $P<0.05$

Contrary to the well-known fact that irrigation increase yield parameters, this study did not agree with this fact in this season and rather coincide with Elzubeir and Mohamed, (2011); Yazar et al., (2009) who reported that irrigation water supply did not significantly affect yield parameters. According to the studies of Moosavi (2012), maize ear diameter is closely related with the assimilates produced by photosynthesis which varies greatly with water stress. So, the results of this current studies mean that for the deficit irrigation treatment plants lower the quantity of assimilate was produced by photosynthesis, which probably might affect cob growth and its related parameters. The studies of Aydinsakir et al., 2013 and Karasu et al., 2015 reported a significant difference between yield components of irrigated crops and non-irrigated crop.

Table 23: Effect of NPK treatment on yield in monoculture and biculture maize (Crop Rotation) (Debrecen-Latokep, 2018)

Treatment	Monoculture (Yield kg ha^{-1})		Biculture (Yield kg ha^{-1})	
	Non-Irrigated	Fully Irrigated	Non-Irrigated	Fully Irrigated
Control ($NPK_{0:0:0}$)	5210.9a	5124.2a	10519.0a	10933.3a
$NPK_{60:45:45}$	9501.9b	9241.3b	11600.0ab	12669.3b
$NPK_{180:135:135}$	11980.1c	11732.7c	12077.3b	12695.5b

Note: Numbers with the same letter in same column, have no significant difference (P<0.05)

Table 23 above presents an analysis of nitrogen effect on maize grain yield in both monoculture and biculture fields in the 2018 cropping season. From the table, nitrogen levels have a significant effect on maize grain yield in both the irrigated and non-irrigated plots in the monoculture field as shown in Table 20. The maximum grain yield of maize (11980.1 kg ha^{-1} and 11732.7 kg ha^{-1}) in this research were recorded under the highest dose of nitrogen $NPK_{180:135:135}$ whereas the lowest grain yields were recorded under the control NPK0:0:0 (5210.9 kg ha^{-1} and 5124.2 kg ha^{-1}) for both non-irrigated and fully irrigated treatments respectively in the monoculture field at P<0.05. Again, there was a significant difference between the control and the $NPK_{60:45:45}$ and significant difference was noticed between the NPK180:135:135 and $NPK_{60:45:45}$ as shown in the (Table 23) in both non-irrigated and fully irrigated treatments in the monoculture field.

In the biculture non-irrigated plot, nitrogen levels played a significant role in increasing the grain yield under the highest nitrogen dose (12077.3 kg ha^{-1} and 12695.5 kg ha^{-1}) for $NPK_{180:135:135}$ whiles the minimum grain yield was seen under the control treatment with zero nitrogen dose (10519.0 kg ha^{-1} and 10933.3 kg ha^{-1}) for both non-irrigated and fully irrigated treatments respectively in the biculture filed. No significant difference was recorded between the control and $NPK_{60:45:45}$ dose and also, no difference was observed between the NPK60:45:45 and $NPK_{180:135:135}$ in the non-irrigated treatment at P<0.05. In the fully irrigated treatment, significant difference was not noticed between the $NPK_{60:45:45}$ and $NPK_{180:135:135}$ at P<0.05 (Table 23).

The important role of nitrogen in maize plant development and its impact on yield cannot be over emphasized. The present results indicate sufficiently the contribution of nitrogen in both irrigated and non-irrigated plot that, nitrogen is important for cell division and elongation as well as root growth, development and dry matter mass of maize crops as indicated by Marschner, (1995). The finding of this study also agrees with that of Valero et al., (2005), who reported more grain yield with increasing rate of nitrogen applied. Grain yield of maize is the result of yield components demonstrated that maximum grain yield was seen under high nitrogen doses (Table 23). Similar results were reported by Inman et al. (2005), which are in line with this study that, increasing nitrogen dose results to increase in grain yield.

Table 24: Effect of irrigation on yield in monoculture maize using independent samples t test group statistics (Debrecen-Latokep, 2018)

Treatment Monoculture		**N**	**Mean (Yield)**	**t**	**Sig. (2-tailed)**
$NPK_{O:O:O}$	Non-Irrigated	4	5210.9	0.25	0.81
	Fully Irrigated	4	5124.2		
$NPK_{60:45:45}$	Non-Irrigated	4	9501.3	0.71	**0.50**
	Fully Irrigated	4	9241.3		
NPK180:135:135	Non-Irrigated	4	11980.1	0.49	0.64
	Fully Irrigated	4	11732.7		

Note: **BOLD** is significant at 0.05

Results from the monoculture field as shown in Table 24, irrigated treatment did not show any significant difference between maize grain yield in irrigate and non-irrigated plants under the different levels of nitrogen doses. The non-irrigated treated crops in this study under all the different nitrogen dose recorded the highest mean grain yield as compared to the fully irrigated treatments, but these means did not show a statistically significant difference between the treatment in the monoculture field. These results could be ascribed to the good moisture retention from the field as a result from good precipitation in the cropping season.

Table 24: Effects of irrigation on yield in a biculture plot using the independent samples t test group statistics (Debrecen-Latokep, 2018)

Treatment_Biculture		N	Mean (Yield)	t	Sig. (2-tailed)
$NPK_{O:O:O}$	Non-Irrigated	4	10519.00	-0.71	**0.50**
	Fully Irrigated	4	10933.25		
$NPK_{60:45:45}$	Non-Irrigated	4	11600.00	-2.17	0.73
	Fully Irrigated	4	12669.25		
$NPK_{180:135:135}$	Non-Irrigated	4	12077.25	-1.20	0.28
	Fully Irrigated	4	12695.50		

Note: **BOLD** is significant at 0.05

Water treatment effect was analysed using an independent sample t-test for group statistic to find the significant effect on the grain yield in biculture field as shown in Table 24. The results show water treatment (irrigation) has no statistically significant effect on maize grain yield in this study although the irrigated treated plants had the maximum mean grain yield in all the different nitrogen levels, as against the non-irrigated plants which had minimum mean grain yield, the difference was not statistically significant as recorded in Table 24 above at $P<0.05$.

From this research, the highest grain yield for the different nitrogen levels was recorded under the fully irrigated treatments which clearly shows the vital role of soil moisture in plants growth and development as its presents dissolves soil available nutrient and make it accessible to plants roots for the biochemical activities. The lowest grain yield was observed under the non-irrigated treatments as shown in the Table 24 which represents the effects of deficit irrigation on maize grain yield by reduction in the grain yield per hector. The above results are in line with the results of Anac and Ma et al. (1992), Yildirim et al. (1996), Stan and Naescu (1997), Pandey et al. (2000), Mansouri et al. (2010), who all reported that grain yield was affected by irrigation water treatment.

Table 25: Effects of NPK on yield components in monoculture maize plots (Debrecen-Latokep, 2018)

Monoculture	**Non-Irrigated**						
Treatments	**Cob Length (cm)**	**Cob Diameter (mm)**	**No of Row/cob**	**No of seed/row**	**Seed Weight (g)**	**Cob Weight (g)**	**1000 grain weight (g)**
$NPK_{O:O:O}$	18.1a	48.5a	15.3a	39.0a	134.5a	174.1a	68.5a
$NPK_{60:45:45}$	18.9a	48.4a	15.8a	37.4a	139.3a	175.6a	66.7a
$NPK_{180:135:135}$	19.6a	49.6a	16.5a	40.0a	141.6a	196.9a	70.5a
Treatment	**Fully Irrigated**						
$NPK_{O:O:O}$	17.6a	48.1a	14.8a	37.5a	136.4a	176.9a	70.5a
$NPK_{60:45:45}$	18.4ab	49.3a	15.7a	38.3a	141.6a	180.1a	71.8a
$NPK_{180:135:135}$	19.6b	49.5a	15.7a	42.3a	150.5a	209.1a	72.5a

Note: Numbers with the same letter in same column, have no significant difference ($P<0.05$)

Yield components in the monoculture non-irrigated plot were not significantly influenced by different nitrogen doses in all the parameters measured. It is however worth noting that, the treatments with the highest dose recorded the maximum mean values of yield components as measured in Table 25. In the fully irrigated plot, significant difference was only observed in the cob length where the maximum cob length (19.6 cm) was recorded under the $NPK_{180:135:135}$ dose whereas the minimum cob length (17.6 cm) was noticed under the control $NPK_{0:0:0}$ which has zero nitrogen dose. The number of seeds per row, number of rows per cob and 1000 grain weight are vital determinants of grain yield of maize. The results shown in Table 25 shows the maximum grain yield was recorded under nitrogen supplied of $NPK_{180:135:135}$. Similarly, the highest 1000-grain weight was recorded under $NPK_{180:135:135}$ for both irrigated and non-irrigated (70.5 and 72.5) treatment respectively, although this was not significant at $P< 0.05$ (Table 25), whereas the minimum 1000-grain yield was observed under the control treatment in both the non-irrigated and full irrigated treatments. These results agree with Valero et al, (2005), who reported grain yield increased when nitrogen rate was increased.

Table 26 below presents effects of irrigation and N-levels on yield components and yield in monoculture field. Cob weight and maize grain were significantly affected by water treatment in this study. Irrigated treated crops weighed more than the non-irrigated crop and the difference was significant at $P<0.05$ (Table 26). The maximum grain yield in the monoculture field was observed under the full irrigated treatment (6450.63 kg ha^{-1}) whereas the minimum grain yield was seen under the non-irrigated (6174.88 kg ha^{-1}), which was significantly different at P<0.05 (Table 26). Cob length and row number per cob were not significantly affected although the full irrigated treatments recorded the maximum means against the non-irrigated treatments. Nitrogen and irrigation had a significant effect on cob weight and grain yield in this study. The correlation was significant at P<0.01 for cob weight and significant at P<0.05 for grain yield as shown in Table 26. The studies of Magalhaes, et al (2006) assessing the physiology of maize reported that water deficit results in thinner stems, smaller plants, and smaller leaf area, with an associated yield reduction in the ranged of 10 to 20 percent. Water stress did not significantly impact on number of rows per plant and cob length (Table 26). Conversely, it had a significant effect on the grain yield with is in agreement with the research findings reported by Denmead and Shaw (1960) who reported that, the occurrence of drought resulted in the decrease in maize production by 25%. Again, the findings of Na et al., (2018) showed that grain yield of maize was significantly reduced (18.6%-26.2%) to progressive drought during the vegetative stage.

Table 26: Effects of irrigation and N-levels on yield components and yield in monoculture maize. (Debrecen-Latokep, 2018)

Monoculture	**Cob weight (g)**	**Cob length (cm)**	**No of Row/Cob**	**Yield** (kg ha^{-1})
Non-Irrigated	17.02*	17.63	15.32	6174.88*
Full Irrigation	17.60	19.09	15.48	6450.63
CV%	0.51	2.04	0.93	30.48
		Treatment		
$NPK_{O:O:O}$	17.95**	18.37	15.11	5056.16*
$NPK_{60:45:45}$	16.95	17.76	15.78	6355.72
$NPK_{180:135:135}$	17.03	18.94	15.33	6835.79
CV%	0.63	2.50	1.14	0.335

Note: *Correlation is significant at 0.05 level, ** correlation is significant at 0.01 level

In Table 27 is an analysis of effects of water supply and nitrogen effect on yield and yield components in the biculture field. As shown in the table, cob weight and cob length were significantly affected by irrigation at P<0.01. The maximum cob weight and cob length were observed under the full irrigated treatments (23.57g and 20.16 cm) respectively. Number of rows per cob and grain yield in this measurement also saw a higher mean value recorded under the irrigated treatment, but these values were not statistically significant (Table 27). Maize grain yield components and yield increased in response to irrigation. Maize plants treated with irrigation considerably recorded the maximum mean value of yield and yield components. The lower mean yield (6178.88 kg/ha) from the non-irrigated treatment may primarily be due to reduction in carbon dioxide assimilation to the leaves. The study of Aydinsakir et al., (2013) registered the highest grain yield in full irrigation and lowest grain yield with no irrigation. Maize grain yield decline because water depends on many factors such as soil, climate condition during growing season, drought severity and duration, stage of growth and hybrid sensitivity to soil drought (Ertek and Kara , 2013). Nitrogen levels did not show a significant effect on yield components but rather significantly affect grain yield in this study. The maximum grain yield was recorded under the highest dose of nitrogen whereas the control with zero dose of nitrogen recorded the minimum grain yield (5146.16 kg ha^{-1}) which was statistically significantly different at $P<0.01$ (Table 27). This indicate that grain yield difference between treatments was as a result of increase in the number of kernels per ear by each stand of than cob weight and length. High nitrogen treated plants carried significantly higher number of kernels per ear resulting in high yields. Many studies have reported nitrogen effect on maize grain yield and yield components. Abera (2003) indicated that higher nitrogen rate increase kernel number and weight. Fageria et al. (1997) reported that yield of maize is a product of kernel number unit area and kernel weight and that, grain difference in yield is the result of fluctuations in grain number. This study is in line with Fageria (2007) and Workayehu (2000) who reported that grain yield of maize increases progressively with added nitrogen fertilizer up to a certain rate. Plant nutrients especially nitrogen is an important plant element for maize crop survival, and it's lost from the soil can cause environmental pollution. Nitrate (NO^{-3}) pollutes ground and surface waters (Karlen et al.,1994), ammonia (NH^3) when deposited in a soil increases soil acidification nitrogen eutrophication (Roelofs et al, 1991) and nitrous oxide contributes to global warming and breakdown of stratospheric ozone (Crutzen, 1981).

Table 27: Effects of irrigation and N-levels on yield components and yield in biculture maize (Debrecen-Latokep, 2018)

Biculture	**Cob weight (g)**	**Cob length (cm)**	**No of Row/Cob**	**Yield (**kg ha^{-1}**)**
Non-Irrigation	21.12*	19.02*	15.56	6178.88
Full Irrigation	23.57	20.16	16.41	6350.63
CV%	28.70	0.95	2.83	30.78
Treatment				
$NPK_{O:O:O}$	242.82	19.60	15.33	5146.16*
$NPK_{60:45:45}$	222.49	19.91	14.78	6455.75
$NPK_{180:135:135}$	228.73	19.26	17.83	6934.73
CV%	35.1	1.16	3.46	0.236

Note: *Correlation is significant at 0.05 level, ** correlation is significant at 0.01 level

This study presents in Table 28 below an analysis of the effects of crop rotation and irrigation on yield component parameters. The impact of crop rotation on the maize crop cannot be over emphasized as it has shown below. Yield and yield components were significantly influence. The maximum mean cob weight, cob length, grain yield was recorded under biculture which were significantly different compared to the monoculture at $P<0.01$ for cob weight and grain yield and $P<0.05$ for cob length (Table 28).

Water treatment significantly influenced yield and yield components in this research. The minimum means of crop yield components and grain yield was observed under the non-irrigated treatments whereas the maximum means were recorded under the full irrigation treatments and the difference between these treatments were significant at $P<0.05$ for cob weight and cob length and at $P<0.01$ for grain yield as shown in (Table 28). The combined effect of crop rotation and water treatment did not significantly affect yield components in this study, maize grain yield performance was however significantly affected at $P<0.05$ level. From the above analysis, cropping system has a great influence on maize yield and yield components and this study coincides with that of Riedell et al., (2009). Crop rotation resulted higher yields compared to monoculture because of activities of residues remaining of previous crops on the soil, most especially on lands where the system is already consolidated (Silva et al., 2005). The negative effect of monoculture is that it reduces leaf area thus resulting in low levels of radiation absorption and it impact on yield resulting in lowering yield performance as observed in Table 28 and this has been reported by Wozniak (2008).

Water treatment played a significant role in this study on the yield and yield component parameters as shown in (Table 28) and this finding is in line with other research findings such as (Claassen and Shaw, 1970; Setter et al., 2001) who reported that water deficit inhibits photosynthesis, reduces the assimilate supply and thus decrease the rate and duration of grain-filling and pre-pollination and post-pollination water reduce the kernel number and kernel size of corn and also cob length respectively. Crop growth in any areas in the world cannot be meaningfully successful without enough water supply to the crops, but unfortunately, because of climate changes and its influence on the environment, most crops are grown in many parts of the world without sufficient water supply at some parts of the crops during their developmental stages.

Table 28: Effects of crop rotation and irrigation on yield component parameters (Debrecen-Latokep, 2018)

Crop rotation(A)	**Cob weight (g)**	**Cob length (cm)**	**No of Row/Cob**	**Yield (kg ha^{-1})**
Monoculture	185.50**	18.36*	15.41	4957.77**
Biculture	231.35	19.59	15.98	6122.54
CV%	25.77	1.11	1.37	31.45
Water Treatment(B)				
Non-Irrigation	194.63*	18.33*	15.52	5245.56**
Full Irrigation	222.22	19.62	15.87	5831.89
CV%	25.77	1.11	1.37	31.45
Combined Effect (A X B)	Ns	ns	ns	*

Note: *Correlation is significant at 0.05 level, ** correlation is significant at 0.01 level

Table 29: Effects of NPK treatments on maize yield components in monoculture irrigated maize (Debrecen-Latokep, 2018)

Treatment	**Cob-length (cm)**	**Cob-diameter (mm)**	**No of row/Cob**	**No of seeds/Cob**	**Cob weight (g)**	**1000 Seed weight (g)**	**Yield (kg ha^{-1})**
$NPK_{O:O:O}$	17.4a	49.1a	14.8a	37.5a	167.7a	265.5a	2611.9a
$NPK_{60:45:45}$	18.4ab	49.3a	15.7a	38.3a	171.2a	269.7a	4364.0b
$NPK_{180:135:135}$	19.6a	49.5a	15.7a	42.3a	198.5a	271.6a	6249.9c

Note: Numbers with the same letter in same column, have no significant difference (P<0.05)

In this cropping season under review in Table 29, different nitrogen doses did not have a significant difference on yield components of maize, but a very significant difference was observed in the grain yield between then different doses of nitrogen. The maximum grain yield was recorded under $NPK_{180:135:135}$ (6249.9 kg ha^{-1}) and the lowest grain yield was seen under the control which had a zero dose of nitrogen. Significant difference was also seen between the $NPK_{60:45:45}$ and $NPK_{180:135:135}$ as shown in (Table 29). Nitrogen effect on maize grain has been reported by many authors. From this study, the irrigated water aided in well utilization of applied nitrogen by the maize plant thus resulted in high yields. El-Gizawy, (2009) reported that, kernel yield rose with an increase in nitrogen rate in all three cultivars he used in this study. Maize grain yield is a function of integrated effects of different conditions, genetics of cultivars and environmental conditions. Nitrogen application has a positive influence on grain yield and enhances grain yield because of increased number of grains per cob and other yield components. Samad (1992), Adediran and Banjoko (1995) and Maqsood et al. (2000) reported a similar effect of fertilizer levels on maize yield and its components.

Table 30: Effect of N-dose on yield (kg ha^{-1}) in monoculture and biculture maize (Debrecen-Latokep, 2018)

Treatment	**Monoculture Non-Irrigation**	**Monoculture Full Irrigation**	**Biculture Non-Irrigation**	**Biculture Full-Irrigation**
$NPK_{O:O:O}$	2614.7a	2611.9a	5146.2a	5604.9a
$NPK_{60:45:45}$	3810.8a	4364.0b	6455.8b	6675.8a
$NPK_{180:135:135}$	5696.9b	6249.9c	6934.7b	6770.8a

Note: Numbers with the same letter in same column, have no significant difference ($P<0.05$)

Table 30 above presents nitrogen effect on yield in both monoculture and biculture fields in this study. From the analysis, nitrogen high nitrogen dose positively affected grain yield in the various plots except in the plot of biculture full irrigated where no significant was noticed between the different levels of nitrogen dose. In the monoculture non-irrigated plot as shown in the table above, the maximum grain yield was observed under the highest nitrogen dose $NPK_{180:135:135}$ (5696.9 kg ha^{-1}) whiles the minimum grain yield was recorded under the control experiment $NPK_{0:0:0}$ (2614.7 kg ha^{-1}) which was not significantly different from $NPK_{60:45:45}$ at $P<0.05$ (Table 30). In the fully irrigated plots in the monoculture field, there were significant differences among the three levels of nitrogen doses. The maximum grain yield in the monoculture full irrigation is seen under the highest nitrogen rate of $NPK_{180:135:135}$, followed by the second highest dose of nitrogen of $NPK_{60:45:45}$ and then the control which has zero dose of nitrogen as shown in (Table 30) above. In the biculture non-irrigated plot, there was a significant grain yield difference between the control and both the $NPK_{180:135:135}$ and $NPK_{60:45:45}$ dose, there was however no significant difference between $NPK_{180:135:135}$ and $NPK_{60:45:45}$.

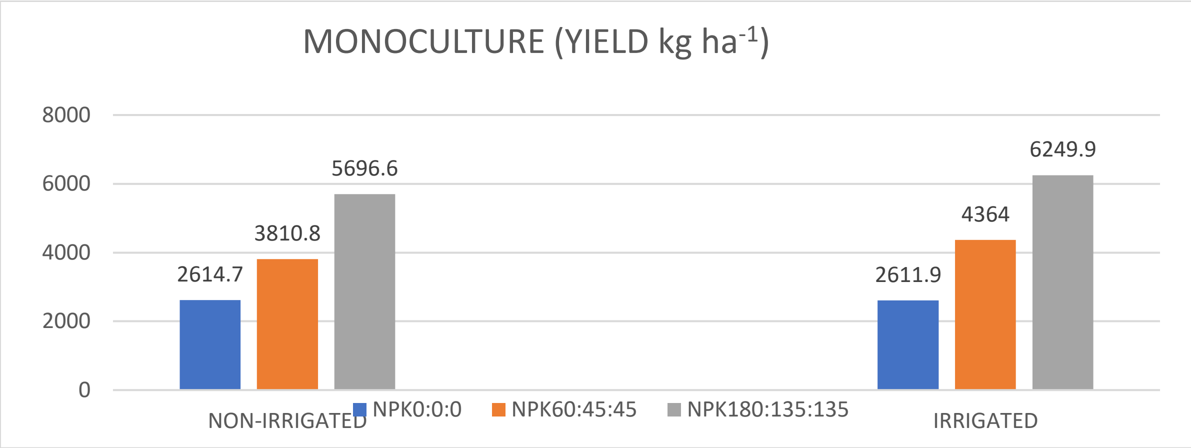

Figure 4: Effect of N-dose on yield in monoculture maize (non-irrigated and irrigated) (2018, Latokep)

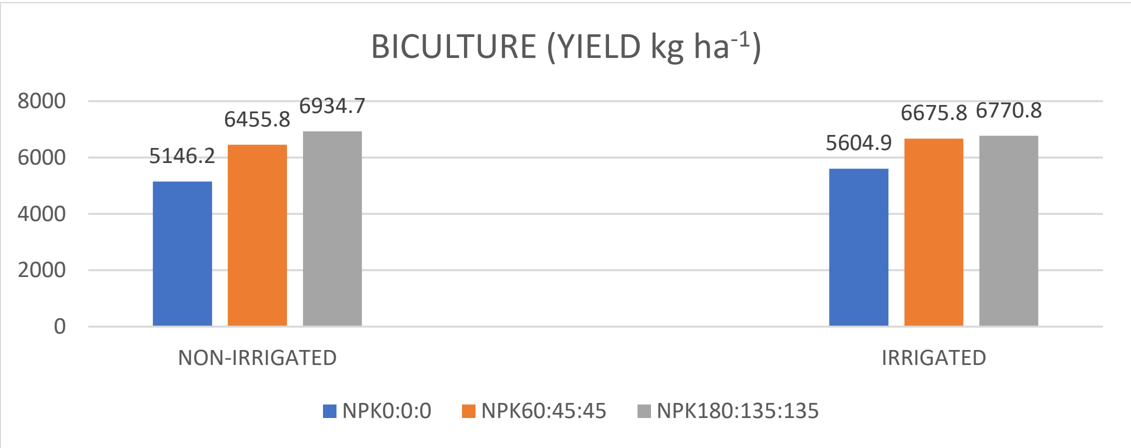

Figure 5: Effect of N-dose on yield in biculture maize (Non-irrigated and Full irrigated) (2018, Latokep)

In this research, established on the increase in yield due to increasing nitrogen rates seem to make maize crop nitrogen levels of 180 kg/ha, has been founded and subsequently increase grain yield performance at the rate of application. Kamprath et al (1980) reported that, corn grain yield increases significantly because of increase in nitrogen and increase the number of grains per ear and grain weight per ears compared. Ghasemipirbaloti and Akbari (2002) reported that grain weight and yield of maize were affected by different amount of nitrogen. Influence of nitrogen levels had a significant effect on grain yield of maize. Mean values of the data revealed that application of nitrogen at a rate 180 kg ha^{-1} in both monoculture non-irrigated and full irrigated and in the biculture, non-irrigated had the maximum grain yield which is statistically significant, respectively. These results are in line with Sharifi et al,

(2009) who reported that increase in nitrogen significantly increase in grain yield and the minimum grain yield was recorded in the control plots with zero dose of nitrogen.

4.1.14 Analysis of 2019 cropping season.

Table 31 presents data on the effect of different NPK doses on photosynthetic parameter on maize in the monoculture field for the 2019 cropping season. From the table, SPAD, NDVI and LAI were not significantly affected by different nitrogen doses in the first measurement in the fully irrigated plot. In the second measurement, SPAD was significantly affected by nitrogen dose at $P<0.05$. The maximum SPAD value was observed under $NPK_{180:135:135}$ dose ,whereas the minimum SPAD value was recorded under the control treatment $NPK_{O:O:O}$. NDVI and LAI were not statistically different in the second measurement. Measurements in the third round shows that NDVI and Lai were significantly affected by nitrogen levels as the maximum NDVI and LAI were recorded under the highest dose of nitrogen $NPK_{180:135:135}$ (60.45 and 3.35) respectively whiles the minimum NDVI and LAI were registered under the control with zero nitrogen dose $NPK_{O:O:O}$ (45.35 and 1.80) respectively in the fully irrigated plot (Table 31).

In the non-irrigated plot, LAI was influenced by nitrogen levels in the first measurement and in the third measurement. The other parameters measured were not statistically significant. The maximum leaf area in the non-irrigated plots were observed under the highest of nitrogen in both the first and third measurement $NPK_{180:135:135}$ (2.80 and 2.28) respectively, whereas the minimum dose of nitrogen which is the control treatment recorded $NPK_{O:O:O}$ (2.04 and 1.77) respectively. Generally, in this study, values of chlorophyll meter readings increased with crop development as nitrogen levels increased, SPAD meter readings increased though not significantly in most cases. Schepers et al., (1992) reported that SPAD meter readings increased as nitrogen fertilizer level increases at each measurement date and this somehow coincides with this study. Nitrogen limitation reduces canopy carbon assimilation by directly reducing photosynthesis and extent, reducing the rate of new leaf area development, and increasing leaf senescence. Hammer et al., 2001 reported previously that, leaf area of maize was affected by increased in nitrogen. Nitrogen stress reduces crop photosynthesis by reducing leaf area and leaf photosynthesis rate and there by accelerating leaf senescence (Banziger et al., 2000). Nitrogen up-take by maize plants positively related to crop growth rate and biomass accumulation (Gastal and Bemaire, 2002). In this study, there is a low relationship between the NDVI values and LAI which show that grain yield may not be a function of biomass of plant at early stages of their growth. High NDVI values shows more energy was trapped by leaves which is used is vegetative growth because of good photosynthetic activities thereby increasing grain yield.

Table 31: Effects of NPK on photosynthetic parameter on maize in monoculture crop rotation (Debrecen-Latokep, 2019)

Monoculture Treatment	**First Measurement**			**Second Measurement**			**Third Measurement**		
	Fully Irrigated								
	SPAD	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**
$NPK_{O:O:O}$	55.63a	0.81a	2.34a	59.02a	0.78a	3.30a	38.07a	0.45a	1.80a
$NPK_{60:45:45}$	56.71a	0.82a	2.66a	64.10b	0.79a	4.34a	36.37a	0.46a	1.90a
$NPK_{180:135:135}$	58.23a	0.83a	2.77a	68.38b	0.79a	3.57a	38.23a	0.60b	3.35b
Non-Irrigated									
$NPK_{O:O:O}$	56.67a	0.82a	2.04a	57.78a	0.78a	3.03a	36.36a	0.42a	1.77a
$NPK_{60:45:45}$	58.37a	0.82a	2.76b	62.07a	0.80a	2.95a	37.92a	0.44a	1.61a
$NPK_{180:135:135}$	59.52a	0.82a	2.80b	62.87a	0.80a	3.23a	40.39a	0.50.a	2.28b

Note: Same letters within each column do not differ significantly at P<0.05

Nitrogen rates in the monoculture field in the 2019 cropping season had marked effect on maize yield components as presented in Table 32 below in the non-irrigated plot. From the analysis, there was a significant difference between treatment dose of $NPK_{180:135:135}$ and both $NPK_{60:45:45}$ and $NPK_{O:O:O}$ in cob diameter, number of rows per cob, grain weight per cob and cob weight. The maximum mean value of the above-mentioned parameters was recorded under the highest dose of nitrogen $NPK_{180:135:135}$ whereas the minimum mean values were recorded under the control experiment with zero dose of nitrogen $NPK_{O:O:O.}$ There not significant difference between the $NPK_{O:O:O}$ dose and the $NPK_{60:45:45}$ at P<0.05 (Table 32).

Maize grain number per row and grain number per cob were influenced by nitrogen doses. There were statistically significant differences among both $NPK_{180:135:135}$**,** $NPK_{60:45:45}$ and $NPK_{O:O:O}$ dose. There was however no significant difference between $NPK_{180:135:135}$ and $NPK_{60:45:45}$ treatments. Cob length and empty cob weight in this measurement was not significantly different thought the means from $NPK_{180:135:135}$ treatment was higher than the other treatment as shown in table 32.

In the monoculture fully irrigated plot, cob diameter, cob length, empty cob weight and cob weight were significantly influenced by $NPK_{180:135:135}$ dose. The maximum mean values were registered under the $NPK_{180:135:135}$ whiles the minimum mean values were observed under the control $NPK_{O:O:O}$ which was not statistically different from $NPK_{60:45:45}$ dose.

The number of grains per row, grain weight per cob, and number of grains per cob had the same statistical readings such that there was no difference between treatments under $NPK_{180:135:135}$ and $NPK_{60:45:45}$ rates and no difference was seen between $NPK_{60:45:45}$ treatments $NPK_{O:O:O}$ dose. Significant difference was however observed between $NPK_{180:135:135}$ and $NPK_{0:0:0}$ treatments in this study at P<0.05 (Table 32).

Table 32: Effects of NPK-levels on maize yield components in monoculture crop rotation (Debrecen-Latokep, 2019)

Monoculture	**Non-Irrigated**							
Treatment	**Cob-Diameter (mm)**	**Cob-Length (cm)**	**No of row/Cob**	**No of grain/row**	**Empty Cob weight (g)**	**Grain weight/cob**	**Cob weight (g)**	**No.of grain/cob**
$NPK_{O:O:O}$	47.30a	20.92a	15.11a	39.98a	38.11a	217.92a	256.93a	587.78a
$NPK_{60:45:45}$	48.68a	21.82a	16.00a	45.58b	42.01a	248.08a	292.94a	668.78b
$NPK_{180:135:135}$	52.46b	22.01a	19.23b	45.78b	44.82a	265.88b	320.56b	705.00b
Fully Irrigated								
$NPK_{O:O:O}$	48.60a	21.27a	14.33a	41.00a	35.23a	216.60a	254.53a	589.00a
$NPK_{60:45:45}$	49.12a	21.37a	16.00a	43.00ab	38.10a	229.53ab	280.17a	643.67ab
$NPK_{180:135:135}$	53.96b	23.92b	18.67a	46.00b	59.37b	244.23b	349.73b	664.00b

Note: Same letters within each column do not differ significantly at P<0.05

The impact of nitrogen on maize yield components has been documents by many researchers which is in line with this current finding. Uhart and Andrade (1995) reported that the number of grains per head increased with increased in nitrogen consumption due to improvement of crop growth rate. This could explain as nitrogen consumption causes increased in light use efficiency at maize flowering stage and thereby increasing the plat growth rate since there is a relationship between plant sap growth during flowering and nitrogen used. This positive relationship on the process results in increasing the number of grains per cob due to increasing nitrogen consumption. Mishra et al. (1995) also stated that increasing nitrogen consumption results to increase in the number of grains per head. The was no significant effect of nitrogen on number of rows per ear (Table 32). This shows that the relative stability of this component is to yield result, and this is in line with the study of (Alizadeh et al., 2007). Number of grains per row was significantly affected by nitrogen levels and this in tendon with the study reported by Costa et al (2002) and Hamidi et al (2000) who reported that nitrogen treatment increased the number of kernels per row. The highest number of grains per row was obtain under the highest nitrogen dose treatment per hectare which is significantly different from the other treatments (Table 32). Aktinoye et al, (1997) concluded that, high rates of nitrogen nutrition and low competitive intensity and aborted flower in determining the number of eggs in a row, grain number per row increases as well.

Persad and Singh (1990) increased the number of grains per ear in proportion to increasing the rates of nitrogen fertilizer was registered. From this research, reducing nitrogen dose will result a significant decrease in the number of grains per ear. It emerges that the conditions resulting in the exhaustion of nitrogen deficiency in the allocation of leaves, leaf area index and its durability factor is reduced and thus, it is less of grains per ear assimilate necessary for the formation. In other respect, Sinclair et al, (1990) stated that, the number of grains per ear is determined at the time of pollination and lack of assimilates for growing embryonic stem cells, has a negative effect on the number of grains per ear.

Nitrogen effect on seed weight in this study was significantly influence at $P<0.05$ level of probability (Table 32). Treatment of $NPK_{180:135:135}$ seed weight was obtained. The lowest seed weight, of nitrogen fertilizer treatments was not significantly different from other treatments in the non-irrigated plot (Table 32). Because these reactions appear to meet the growing needs of the next increase in nitrogen level of 180 kg N ha had no significant impact on grain weight. The study of Majdam, (2012), reported that, the amount of nitrogen increased grain weight was significant. Uhart and Andrade (1995) reported that average grain weight per ear at a rate of transfer of material between flowering and grain filling depends on other factors like cultivars. Tollenaar (1977) and Uhart and Andrade (1995) argue that the increase in seed yield due to nitrogen use may increase the number of grains per ear and grain weight gain is associated. Muchow (1994) believes that the loss of nitrogen is lower grain weight; however, Purcino et al, (2000) argue that seed weight is not affected by nitrogen.

Nitrogen is an important element for maize plants physiological and biochemical processes that in due course alters maize growth parameters and grain yield. Shrestha (2015) found out that, application of nitrogen dose (200, kg N/ha) gave the highest cob length, cob per plant, cob diameter, number of grains per cob and grain weight per cob which is in line with this current study. Nitrogen deficiency shows an increase in barren crop plant (Singh, 1988). Barrenness in maize plants has been reported by Kamprath et al, (1982) as a result in reduction in nitrogen dose. A high level of nitrogen application enhances grain weight as reported by (Gökmen et al., 2001; Wajid et al., 2007).

Table 33: Effect of NPK-level on grain quality in maize monoculture (Debrecen-Latokep, 2019)

Treatment	Monoculture Irrigated			Monoculture Non-Irrigated		
	Moisture %	Protein %	Starch %	Moisture %	Protein %	Starch %
$NPK_{O:O:O}$	15.97a	7.06a	76.88a	15.83a	7.13a	75.54a
$NPK_{60:45:45}$	15.99a	7.37b	79.34b	15.88a	7.52b	76.31b
$NPK_{180:135:135}$	16.31a	8.48c	79.53b	16.18a	8.64c	80.39c

Note: Same letters within each column do not differ significantly at P<0.05

Maize grain quality in the 2019 crop year is presented in (Table 33) above in the monoculture field under irrigated and non-irrigated plots. Nitrogen effect was pronounced on grain protein and starch content in both the irrigated and non-irrigated plots, but grain moisture content was not influence by nitrogen levels.

In the irrigated plot, there was a statistically significant effect on maize grain protein content. The higher the nitrogen level, the higher the protein content. The maximum grain protein content was recorded under the highest dose of nitrogen $NPK_{180:135:135}$ (8.48 % and 8.64 %) and the minimum protein was registered under the control $NPK_{O:O:O}$ (7.06 % and 7.13 %) in both irrigated and non-irrigated plots, respectively. There was also a significant difference between the $NPK_{180:135:135}$ dose and $NPK_{60:45:45}$ at P< 0.05 as indicated in Table 33 in the irrigated and non-irrigated, respectively.

Maize grain starch in this study was also significantly affected by different nitrogen levels or doses. The highest starch content was observed under the $NPK_{180:135:135}$ (79.53 % and 80.39 %) whereas the lowest starch content was recorded under the control $NPK_{O:O:O}$ (76.88 % and 75.54 %) for both irrigated and non-irrigated plots, respectively. In the irrigated plot however, there was no significant difference between the $NPK_{180:135:135}$ dose and $NPK_{60:45:45}$ at P< 0.05 as indicated in Table 31 above. In the non-irrigated plot, there was significant difference between all the three levels of nitrogen doses as shown in Table 33.

Grain moisture content was not significantly affected by nitrogen level in both irrigated and non-irrigated plots although the $NPK_{180:135:135}$ dose treatment produced the highest grain moisture content; this was statistically not significant at P< 0.05 level (Table 33).

Maize grain is comprised of almost about 72% starch, 10% protein, 5% oil, 2% sugar, and 1% ash with the remainder being water according to (Perry, 1988). The application of nitrogen fertilizers results in higher biomass and protein yield and increases the absorption of protein in the plant tissue. The increased in protein concentration of maize grain, leads to an increase in zein making up an increasing proportion of the protein (Tsai et al., 1992). Nitrogen usually influences the amino acid composition of the protein, and thus the quality of nutrients. Nitrogen synchronizes the efficiency of the use of nutrients in the plant. Nitrogen influences many physiological and biochemical processes in plant cells and affects growth and development (Brady, 1990). In proteins, alkaloids, nucleic acids, coenzymes, porphyrins, nitrogen is the main ingredient. The porphyrins are responsible for the inheritance, metabolic process, and growth of plants. Porphyrins are the main component of cytochrome and chlorophyll (Jain, 2000). The protoplast of plant cells contains mainly nitrogen. It plays an essential role in the growth and proper development of the plant. The lack of nitrogen reduces the growth of the plants and lower yields.

Maize plants height and stem diameter were measured just before harvest in the monoculture field and the results presented in Table 34 shows a significant difference between the different levels of nitrogen doses in both the irrigated and non-irrigated plots. The tallest plants were seen under the highest dose of nitrogen in both the irrigated and non-irrigated plots (256.20cm and 275.80cm) respectively which was significantly different at $P<0.05$ (Table 32), whereas the shortest plants height was observed under the control treatment with zero nitrogen dose (233.45cm and 258.85cm) for the irrigated and non-irrigated plots, respectively. There was no significant difference between the control $NPK_{O:O:O}$ and $NPK_{60:45:45}$ dose in the irrigated treatment. In the non-irrigated plot, no significant difference was observed between the $NPK_{180:135:135}$ and $NPK_{60:45:45}$ and also no difference was seen between $NPK_{O:O:O}$ and $NPK_{60:45:45}$ dose, but significant difference was registered between the $NPK_{180:135:135}$ and $NPK_{O:O:O}$ dose at $P<0.05$ level (Table 34).

Maize stem diameter results were not different from that of the height results as shown in Table 34 below. Nitrogen dose affected maize stem diameter. The maximum stem diameter was recorded under the highest nitrogen dose of $NPK_{180:135:135}$ (2.95mm and 2.49mm) for both irrigated and non-irrigated plots respectively, whiles the lowest stem diameter was seen under the control treatments $NPK_{O:O:O}$ (2.25mm and 2.24mm). respectively. No significant difference was seen between $NPK_{O:O:O}$ and $NPK_{60:45:45}$ dose but significant difference was registered between the $NPK_{180:135:135}$ and $NPK_{O:O:O}$ dose at $P<0.05$ level (Table 34) in the irrigated plot treatment. In the non-irrigated plot, no significant difference was observed between the maize stem diameter $NPK_{180:135:135}$ and $NPK_{60:45:45}$ and also no difference was seen between $NPK_{O:O:O}$ and $NPK_{60:45:45}$ dose, but significant difference was registered between the $NPK_{180:135:135}$ and $NPK_{O:O:O}$ dose at $P<0.05$ level (Table 34).

Maize plants need a lot of plants nutrients due to its great nutrient using ability. A lot of nitrogen fertilizer is needed if higher yields are expected because it is required in a more significant amount than other nutrients. The significant increase in maize plant height with application of nitrogen at $NPK_{180:135:135}$ dose might be due to increase level of cell division, cell elongation, and nuclear formation. The studies of (Siddiqui et al.,2006; Kamara et al.,2014; Sen et al., 2015) reported that the application of higher dose of nitrogen produced the maximum emergence in maize and also increased plant elongation and yield.

Table 34: Effects of NPK-levels on plant height and stem diameter in monoculture maize (Debrecen-Latokep, 2019)

Treatment	**Monoculture Irrigated**		**Monoculture Non-Irrigation**	
	Plant Height (cm)	**Stem Diameter (mm)**	**Plant Height (cm)**	**Stem Diameter (mm)**
$NPK_{O:O:O}$	233.45a	2.25a	258.85a	2.24a
$NPK_{60:45:45}$	238.20a	2.36a	265.55ab	2.39ab
$NPK_{180:135:135}$	256.20b	2.95b	275.80b	2.49b

Note: Same letters within each column do not differ significantly at $P<0.05$

Data in Table 34 show that the stem diameter was significantly increased in both irrigated and non-irrigated treatments. The highest stem diameter was noticed at the highest nitrogen dose and this could be explained as application of nitrogen promotes plants growth and on the other hand, increased in maize plant stem diameter due to application nitrogen could be attributed the quality or quantity of sulphur as reported by Elmar (2001).

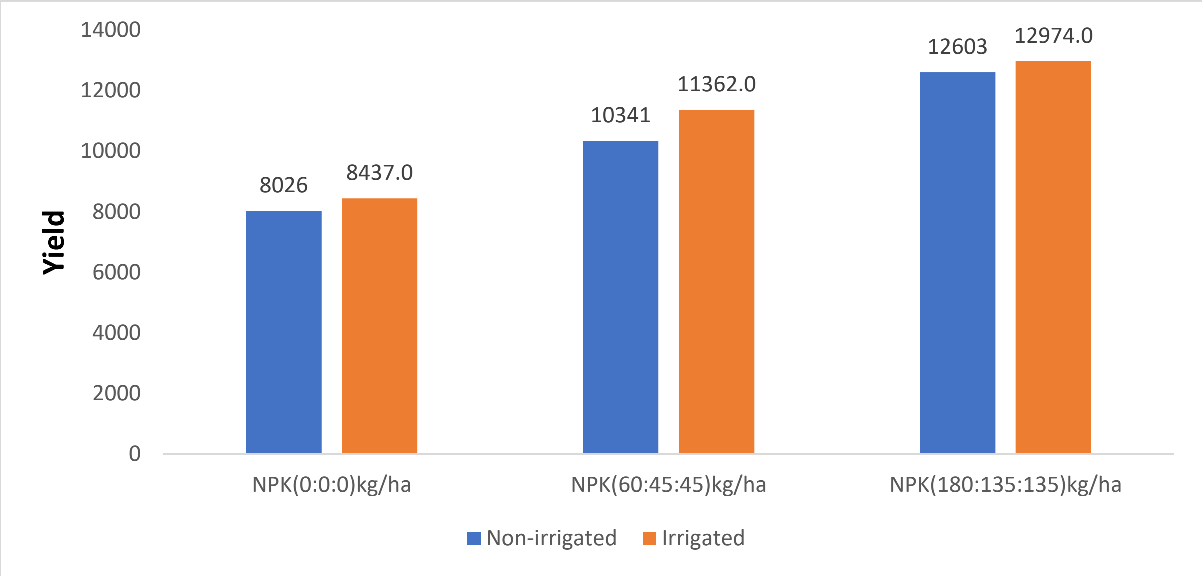

Figure 6: Irrigation effect on grain yield in monoculture maize

Source: Debrecen-Latokep, 2019

Figure 6 represents analysis of irrigation effects on maize grain yield in the 2019 cropping season in the monoculture crop rotation. Irrigation did not have a significant effect on grain yield in this cropping season. From the figure, irrigated treated plants had the highest grain yield under all the three nitrogen treated levels but this yield is not statistical different from the non-irrigated treated plants at $P<0.05$.

Maize grain yield responds positively to irrigation, but the rate of responds varies from year to year. Non-irrigated maize plants yielded less grains compared to the irrigated plants in this study. The considerable yield reduction in the non-irrigated treatment could primarily be due to reduction in carbon assimilation rate, leading to leaf number reduction which affects yield components thus reducing the grain yield (Kresovic et al., 2015). Other researchers like (Dolferus et al., 2011; Bhimireddy et al., 2017) reported an increase in grain yield with irrigation over rainfed treated maize plants. Precipitation in July was very high and probably provided enough moisture for the non-irrigated plants to made up for the water stressed lost there by making use of these moisture to develop the grains. The low yield recorded under the non-irrigated treatment indicates that when absences of soil moisture in the field passes a certain level, plants performance decreases. Kramer (1983) and Levitt (1980) also reported a significant reduction of fresh yield under drought condition in maize.

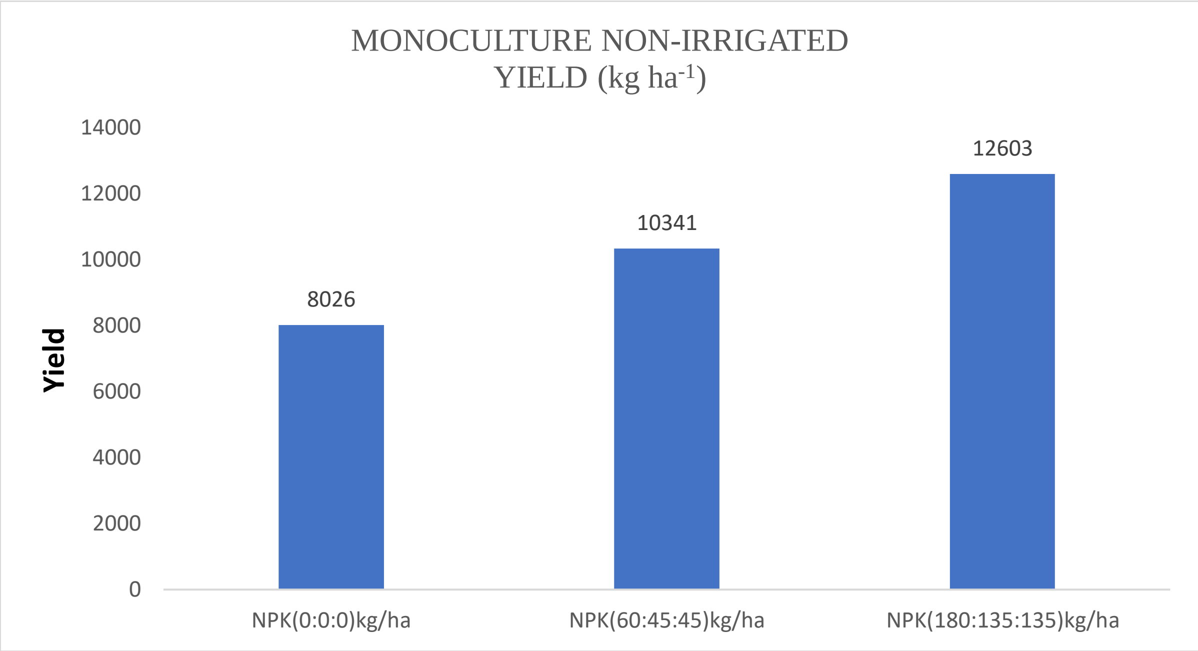

Figure 7: Nitrogen effect on grain yield in monoculture non-irrigated field (Debrecen-Latokep, 2019)

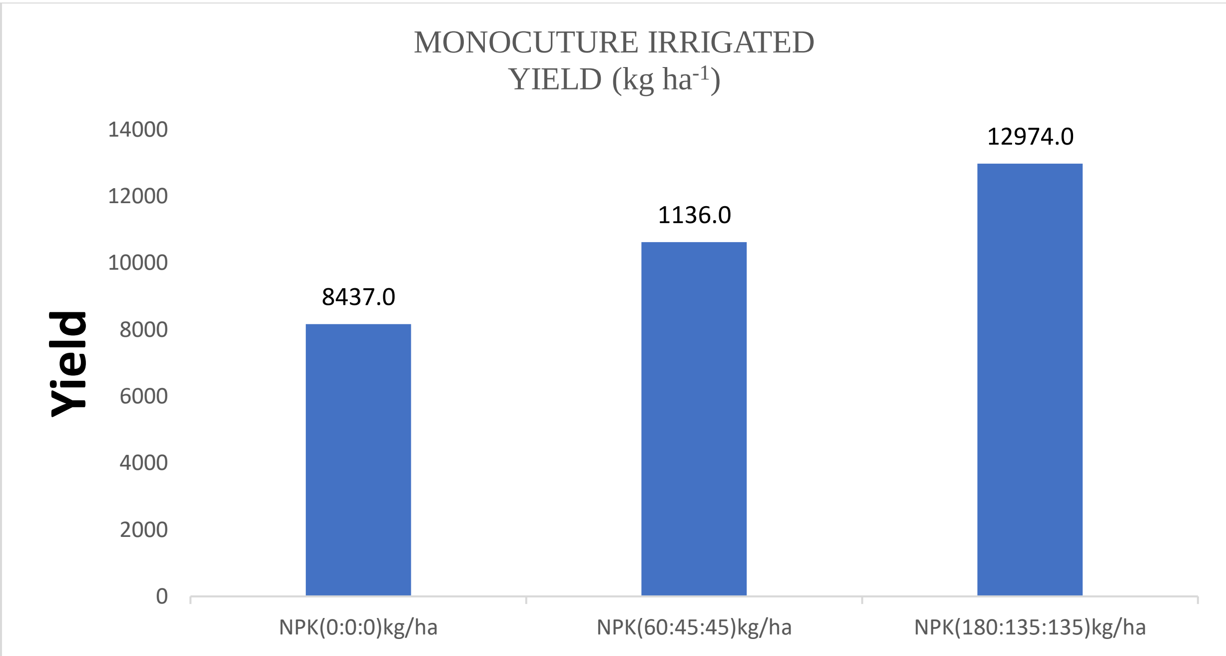

Figure 8: Nitrogen effect on grain yield in monoculture irrigated field

Source: Debrecen-Latokep, 2019

Figure 7 and 8 above present nitrogen effect on grain yield in monoculture non-irrigate and fully- irrigated fields, respectively. Nitrogen levels significantly influenced maize grain yield in both plots. The highest grain yield in both non-irrigated and full irrigated plots were recorded under the highest dose of nitrogen NPK_{180} (12603 kg ha^{-1} and 12974.0 kg ha^{-1}), whereas the lowest grain yield was observed under the control experiment NPK_0 (8026 kg ha^{-1} and 8437.0 kg ha^{-1}) respectively for non-irrigated and fully irrigated (Figure 7 and 8) which was statistically significant at P<0.05. Again, in both plots, there was a significant difference between the NPK180 dose and the NPK60 as shown in the (Figure 7 and 8).

Nitrogen effect on grain has been reported and the current study coincide with Marshner (1995) when he reported that, nitrogen plays a vital role in maize plant life and contribute to increasing the grain yield and that nitrogen is important for cell division and elongation as well as the root growth and dry matter content of maize. The result obtain in this study agrees with those reported by (Hokmalipour et al., 2010; El-Gizaw, 2009; Loecke et al., 2004).

Table 35: Effects of NPK on photosynthetic parameter in biculture maize (Debrecen-Latokep, 2019)

Biculture Treatment	**First Measurement**			**Second Measurement**			**Third Measurement**		
	Fully Irrigated								
	SPAD	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**	**SPAD**	**NDVI**	**LAI (m^2/m^2)**
$NPK_{O:O:O}$	57.12a	0.55a	2.32a	63.53a	0.78a	2.43a	38.02a	0.50a	2.02a
$NPK_{60:45:45}$	58.02a	0.57a	2.32a	62.30a	0.79a	2.81a	38.20a	0.57a	2.18a
$NPK_{180:135:135}$	58.99a	0.58a	2.40a	65.73b	0.81b	3.72a	39.54a	0.58a	2.51a
Non-Irrigated									
$NPK_{O:O:O}$	57.05a	0.81a	2.59a	63.99a	0.79a	3.04a	40.76a	0.52a	1.94a
$NPK_{60:45:45}$	57.06a	0.83b	3.02a	64.23a	0.80ab	3.53a	44.07a	0.50a	2.20a
$NPK_{180:135:135}$	58.52a	0.83b	3.24a	63.17a	0.81b	3.47a	42.33a	0.54a	2.25a

Note: Numbers with the same letter in same column, have no significant difference (P<0.05)

This research presents measurements and analysis of different NPK doses on the photosynthetic parameter on maize in the biculture field for the 2019 cropping season in Table 35. From the table, different NPK treatment did not have any influence on the parameters measured in the first and third measurements in the biculture fully irrigated plot. In the second measurement, SPAD and NDVI were affected by nitrogen dose, where the maximum means of SPAD and NDVI were recorded under the $NPK_{180:135:135}$ and the minimum SPAD and NDVI mean values were registered under the $NPK_{0:0:0}$ which were statistically significantly different. There was however difference between $NPK_{0:0:0}$ and

$NPK_{60:45:45}$ for both SPAD and NDVI in second measurement in fully irrigated plot in the bicuture field (Table 35) at P<0.05.

In non-irrigated plot in the biculture field, only NDVI in the first and second measurement was significantly affected by different nitrogen doses where in both cases, the highest nitrogen dose corresponds to the maximum NDVI mean value as shown in table 35 above.

The impact of nitrogen fertilizer on photosynthetic characteristics of maize in this study is presented in Table 35 showed that maximum chlorophyll content in ear leaf (65.73 SPAD-units) and minimum of this trait (63.53 SPAD-units) were obtain under the highest nitrogen and lowest nitrogen doses respectively. Varvel et al (1997) demonstrated nitrogen fertilizer significantly increased SPAD reading. Nitrogen increases leaf area index as reported by Valadabadi and Aliabadi (2010) but the current study shows otherwise.

Table 36: Effects of NPK-levels on plant height and stem diameter in biculture maize plots (Debrecen-Latokep, 2019)

Treatment	Biculture Irrigated		Biculture Non-Irrigated	
	Plant Height (cm)	**Stem Diameter (cm)**	**Plant Height (cm)**	**Stem Diameter (cm)**
$NPK_{O:O:O}$	260.95a	2.54a	275.30a	2.03a
$NPK_{60:45:45}$	272.80ab	2.58ab	278.90a	2.17ab
$NPK_{180:135:135}$	282.50b	2.88b	298.95b	2.48b

Note: Numbers with the same letter in same column, have no significant difference (P<0.05)

Plant height and stem diameter were both affected by different nitrogen doses in both biculture fully irrigated and non-irrigated plots as indicated in Table 36. The highest maize plant height was recorded under the highest nitrogen dose in both irrigated and non-irrigated plots (282.50 cm and 298.95 cm) respectively whereas the minimum plant height was observed under the control experiment with zero nitrogen dose (260.95 cm and 275.30 cm) for both irrigated and non-irrigated respectively. Maize stem diameter was significantly affected as the maximum stem mean diameter was seen under the highest dose of nitrogen in both irrigated and non-irrigated plots as recorded in table 36 above. The positive effect of nitrogen on maize plant height and maize stem diameter has been reported my other researchers. The increase in maize plant height with more nitrogen would be due to proper amount of nitrogen at different growing stages of maize which promotes plants growth, increases the number of and length of internodes which result in progressive increase in the plant height. Adhikary et al (2004) reported that plant height could significantly be affected due to plant population densities and growing environment.

Nitrogen levels effects on maize grain quality was analyzed in table 37 in the 2019 crop season for biculture irrigated and non-irrigated plots and it was noticed that grain protein content was significantly influenced by nitrogen dose for both irrigated and non-irrigated treatments. Maize grain moisture and starch content was not significantly affected by different nitrogen treatments in this study although the mean of moisture and starch under $NPK_{180:135:135}$ dose had the maximum values in both the irrigated and non-irrigated treatments, these means were statistically not significant at $P<0.05$ compared to the other treatments as shown in Table 37. The maximum protein content mean values were recorded under $NPK_{180:135:135}$ dose (9.49 % and 9.09 %) for both irrigated and non-irrigated treatments respectively whereas the minimum grain moisture and starch content were observed under the control experiment $NPK_{0:0:0}$ (7.86 % and 7.02 %) for both irrigated and non-irrigated treatments respectively (Table 37). Nitrogen effect on maize grain protein has been reported by some researchers; Increasing nitrogen supply to corn generally resulted in increased grain and protein yield and grain protein concentration (Olson et al., 1976; Cromwell et al., 1983; Tsai et al., 1983; Anderson et al., 1984; Kniep and Mason, 1991).

Research finding of Tsai et al., (1983) reported that protein concentration of maize grain increases with nitrogen supply due to preferential deposition of zein over the other endosperm proteins. Kniep and Mason (1991) found that irrigation increased grain yield, reduced protein concentration, had no effect on percent lysine per sample, and increased percent lysine of protein of normal corn. Nitrogen application increased grain yield, protein concentration and percent lysine of sample, but decreased percent lysine of protein.

Table 37: Effect of NPK-levels on grain quality in biculture maize (Debrecen-Latokep, 2019)

Treatment	**Biculture Irrigated**			**Biculture Non-Irrigated**		
	Moisture %	**Protein %**	**Starch %**	**Moisture %**	**Protein %**	**Starch %**
$NPK_{O:O:O}$	14.59a	7.86a	75.20a	14.52a	7.02a	75.82a
$NPK_{60:45:45}$	14.92a	8.74b	75.24a	14.80a	8.33b	75.64a
$NPK_{180:135:135}$	15.06a	9.49b	75.89a	15.11a	9.09c	76.18a

Note: Numbers with the same letter in same column, have no significant difference ($P<0.05$)

In table 38, this study presents the effects of NPK levels on maize grain yield and yield components in a biculture filed for non-irrigated and fully irrigated treatment. Yield components were not significantly influenced by different nitrogen doses in both the non-irrigated and the fully irrigated plots. It is however clear from the non-irrigated plot (Table 38) that the $NPK_{180:135:135}$ dose had the maximum mean values in all the yield parameters measured whereas the control ($NPK_{O:O:O}$) measured the minimum mean values (Table 38). Grain yield in this study was significantly influenced by nitrogen levels as the maximum grain yield recorded under the $NPK_{180:135:135}$ (13102kg/ha) was significantly different compared to the control experiment (10858kg/ha). No significant difference was however noticed between $NPK_{180:135:135}$ and $NPK_{60:45:45}$ as shown in the table below.

The reduction in yield at little of nitrogen consumption was reported by other authors (Singh *et al.*, 1995; Hasanzade, 2002). In this study, at greater dose of nitrogen, accumulation of photosynthates increased at stem and leaf parts which resulted in increased gathering of nutrients in grains. The reduction in nitrogen dose can causes leaf size reduction which in turn can result in the reduction in the amount of sun light absorption and light usage for plant photosynthesis which finally leads to reduced maize grain yield as seen in this study in Table 38. Uhart and Andrade (1995) reported that decreasing nitrogen use decreased the number of maize grains and gran weight which in turn results to yield reduction.

Table 38: Effects of NPK-levels on maize yield and yield components in biculture crop rotation (Debrecen-Latokep, 2019)

Biculture	**Non-irrigated**								
Treatment	**Cob-Diameter (mm)**	**Cob-Length (cm)**	**No. of row/ Cob**	**No. of grain/ row**	**Empty Cob weight (g)**	**Grain weight/cob (g)**	**Cob weight (g)**	**No. of grain/cob**	**Yield (kg ha^{-1})**
$NPK_{O:O:O}$	48.8a	21.4a	15.3a	43.4a	36.1a	236.5a	273.8a	627.3a	10858a
$NPK_{60:45:45}$	48.8a	21.6a	15.3a	44.1a	39.5a	247.3a	288.9a	648.8a	12947b
$NPK_{180:135:135}$	49.9a	21.8a	15.8a	44.9a	41.5a	247.8a	290.9a	674.4a	13102b
Biculture							Fully Irrigated		
$NPK_{O:O:O}$	49.9a	21.7a	15.8a	45.7a	36.6a	242.4a	280.9a	693.9a	11441a
$NPK_{60:45:45}$	50.8a	22.7a	15.7a	45.2a	38.3a	254.9a	300.0a	690.1a	13133b
$NPK_{180:135:135}$	47.9a	21.7a	15.7a	43.9a	41.1a	234.1a	274.8a	656.7a	12192b

Note: Numbers with the same letter in same column, have no significant difference ($P<0.05$)

Figure 9 represents the effects of water treatment on the yield of maize grain in the biculture crop rotation. In this study, irrigation did not have a significant effect on maize yield although the irrigated treatment in the control $NPK_{0:0:0}$ and $NPK_{60:45:45}$ had a maximum yield under the fully irrigated (figure 9). In the $NPK_{180:135:135}$ dose, the highest yield was observed under the non-irrigated treatment suggesting that, under the current conditions, $NPK_{60:45:45}$ dose is sufficient to get the maximum yield in an efficient use of nitrogen under irrigation conditions in a biculture filed. Irrigation impact on grain yield has been reported by some researchers. Maize grain yield increases in reaction to irrigation, but the rate of increase differs between years and cultivars. Maize plants that received less water (rainfed) recorded less yield as seen in (figure 9). The lower grain yield under deficit water may be chiefly due to carbon dioxide assimilation area and net assimilation rate, leaf number and yield components (Kresovic et al., 2015). Bhimireddy et al, (2017) reported that grain yield of no-till maize increased with increases in water input from 75% pan evaporation to 100% pan evaporation irrigation schedule in drip irrigation but could not reach the level of significance at 125% in a semi-arid environment in India. Like the result of the current study, Aydinsakir et al. (2013) reported the highest grain yields with full irrigation and lowest yield with no irrigation. Yield reduction in maize grains due to lack of soil water very much depends on some factors such as soil, climate conditions, cultivars sensitivity to water stress etc.

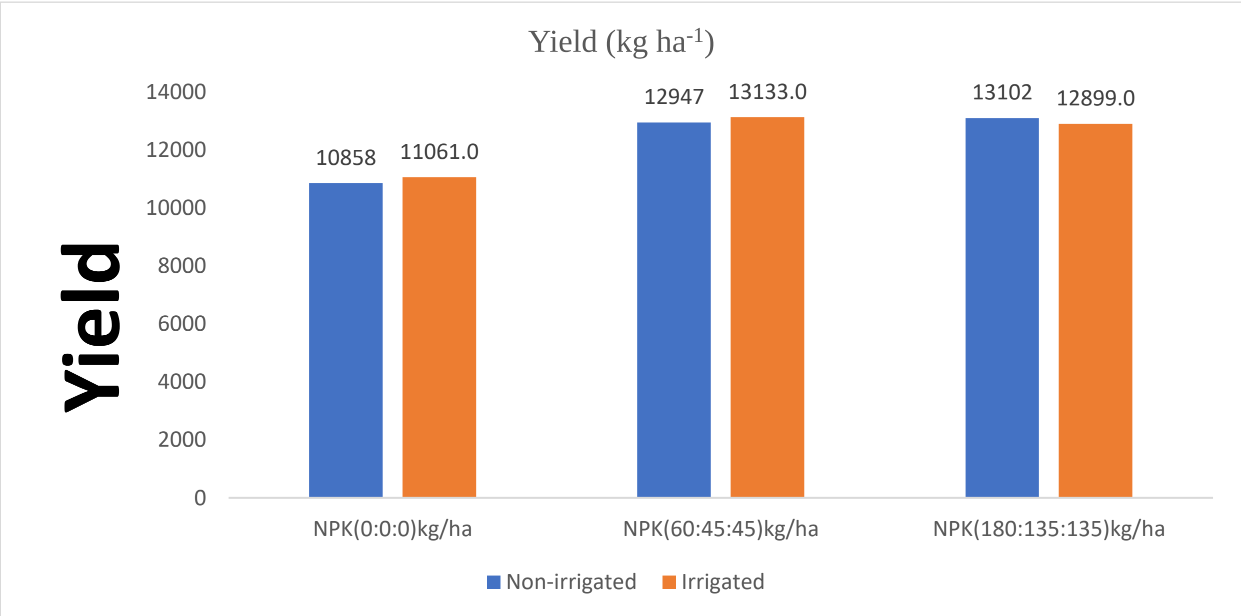

Figure 9: Effect of water treatment (Irrigation) on maize yield in biculture crop rotation

Source: Debrecen-Latokep, 2019

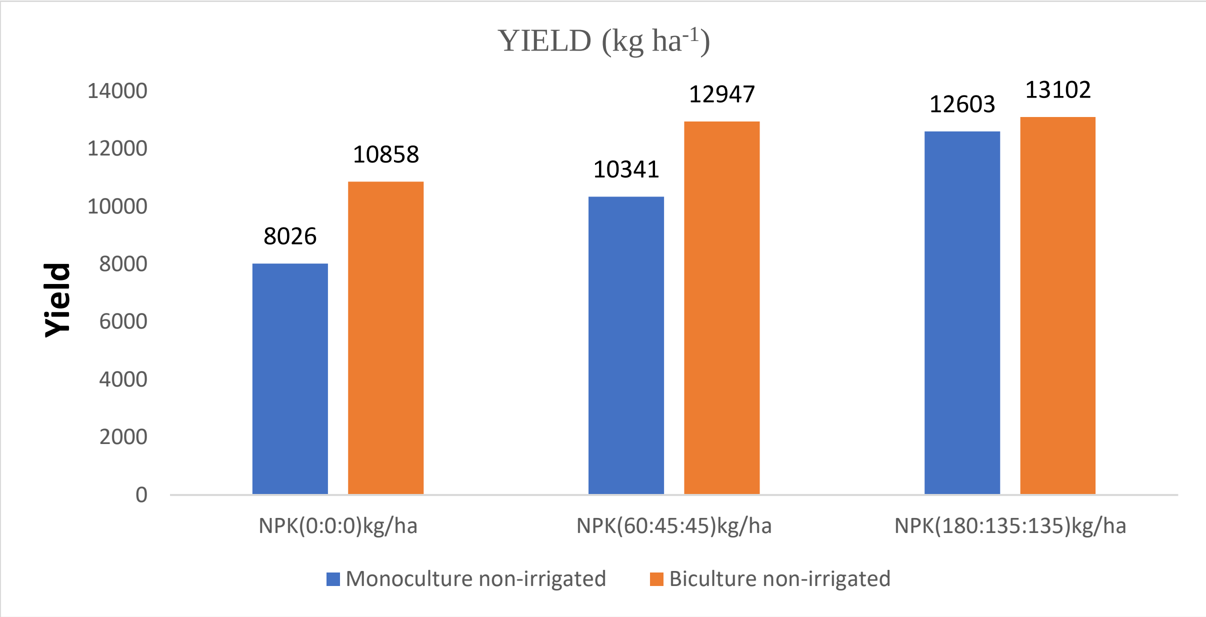

Figure 10: Effect of crop rotation on grain yield of maize in non-irrigated plots

Source: Debrecen-Latokep, 2019

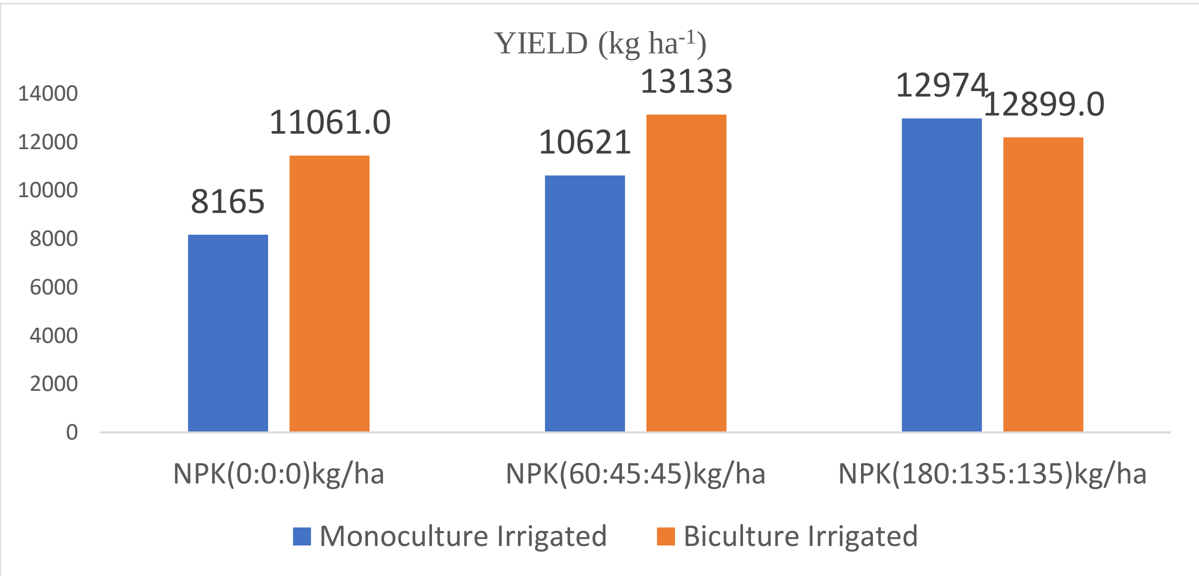

Figure 11: Effect of crop rotation on grain yield of maize in full irrigated plots (Debrecen-Latokep, 201)

Crop rotation is one of the effect crop production management systems used to improve crop yield and figures 10 and 11 above present the crop rotation effect on maize grain yield in the monoculture non-irrigated and full irrigated plots in the 2019 cropping year. From the data, crop rotation had a significant effect on grain yield at a nitrogen level NPK_O and NPK_{60} doses, but difference was not observed between the monoculture and biculture treatment at the nitrogen dose of NPK_{180} kg ha^{-1} in both the non-irrigated and fully irrigated plots at $P<0.05$ (Figure 10 and 11). The maximum grain yield was achieved under the biculture field under similar nitrogen doses of NPK_0 and NKP_{60}. Under the non-irrigated plot at a zero-nitrogen dose (NPK_0), the highest maize grain yield was recorded under the biculture (10858 kg ha^{-1}) whereas the lowest was observed under the monoculture field (8026 kg ha^{-1}) and at a nitrogen dose of (NPK_{60}), grain yield of the biculture field was (12947 kg ha^{-1}) whereas the minimum yield was recorded under the monoculture field (10341 kg ha^{-1}) (figure 10).

In the irrigated plots under the zero-nitrogen dose (NPK_0), the monoculture field recorded the minimum grain yield of (8165 kg ha^{-1}) whereas the biculture field recorded the highest yield of (11061.1 kg ha^{-1}). Under the application rate of (NPK_{60}), monoculture field registered the lowest grain yield of (10621 kg ha^{-1}) whiles the maximum yield was observed under the biculture field (13133 kg ha^{-1}) (figure 11).

The yield of maize grain cultivated under the monoculture field in the study was significantly lower compared to the biculture field under zero-nitrogen dose and NPK_{60} dose. The yield reduction was due to a lower number of grain number per cob and low grain weight in the monoculture treated crops. Cereals grown in the monoculture fields are usually accompanied by weeds having similar characteristics and development cycle thus competing with the main crop for every plant nutrient and available water (Wozniak and Soroka , 2015). Monoculture cropping system has an advert effect on crop production and habitats of the soil. These negative effect outcomes include low grain yield and grain quality (Rachon et al., 2015; Woźniak and Makarski, 2013). Decrease in grain quality as a result of monoculture cultivation of cereals was also reported. This is due to wrinkled grain which is produced under unfavourable cultivation conditions. The positive effect of biculture has been reported by Crookston et al (1988) in their trail, corn yielded significantly better when rotated with soybean or fallow.

Nutrition absorption of crops in crop rotation system differs because of many factors like, depth of plant roots and breadth, crop genotypes, and abiotic factors. Generally, crops may be characterized as having low, medium, or high nutrient demands based on their nutrient uptake efficiency. Different varieties within any crop may be efficient at taking up nutrients. Those crops with a high nutrient demand (Nitrogen) require higher levels of those nutrients to be present in the soil solution. This high demand could be related to large vegetative plant growth just before fruiting set in. Soil fertilization timing have the most benefit when it targets the crops with high nutrient demands. On fertile soils, crops with low nutrient demand often have good yields from residual soil fertility from previous crops in a biculture system alone.

Crop rotation depth and frequency can have important implications for nutrient availability in the soil as well as soil physical characteristics. Crop rotations that integrate deep-rooting crops with less nutrient-efficient crops can help cycle nutrients in the soil profile thus to the advantage of the next crop. Deep-rooted crops also create channels into the soil that later can improve water infiltration.

4.2 GENOTYPE EXPERIMENT

4.2 .1 Effects of water stress and irrigation on photosynthetic parameters between maize genotypes

Photosynthetic parameters (SPAD, LAI, NDVI) in this study were measured at three different stages of the maize development and Table 39 presents an analysis of the first measurement of the photosynthetic parameters among maize genotypes under this study in both non-irrigated and full irrigated treatments.

Table 39: Effects of water stress and irrigation on photosynthetic parameters of maize genotypes (Debrecen-Latokep, 2018)

GENOTYPES	Non-irrigated			Full irrigation		
	SPAD	LAI (m^2/m^2)	NDVI	SPAD	LAI (m^2/m^2)	NDVI
DKC4943	67.0b	4.1b	0.7920a	66.3a	4.4c	0.8113a
P9903	64.7ab	3.8ab	0.8073a	62.8a	3.5ab	0.8200a
P9911	64.1ab	3.4ab	0.8173a	62.5a	3.7ab	0.8247a
KWS4484	65.8b	3.3a	0.8147a	64.7a	3.8bc	0.8240a
S.Y ZEPHIR	61.2a	3.5ab	0.7993a	63.0a	3.2a	0.8213a

Note: Means with the same letter within columns are not significantly different at P<0.05

From the Table 39 above, SPAD measurement between genotypes in the non-irrigated treatment shows a significant difference between maize genotypes. Genotype DCK4943, KWS4484, P9903 and P9911which had the maximum SPAD mean measurements (67.0, 65.8, 64.7 and 64.1) respectively did not show any significant difference between them. There was however significant difference between the genotypes DCK4943 and KWS4484 as against S.Y Zephir which recorded the minimum SPAD measurement of (61.2). There were no significant differences between the genotypes P9903, P9911, and S.Y Zephir at P<0.05 (Table 39).

In the irrigated treatment, there were no significant SPAD value readings between genotypes. The DKC4943 had the maximum SPAD reading of (66.0) whiles P9911 recorded the minimum SPAD value of (62.5). Water deficiency in maize crop production is one of the main factors limiting photosynthetic activities of the plant (Malakouti, 2005). Findings of Zobayed et al. (2005) has it that, chlorophyll concentration is an index for evaluation and there, a decrease of its concentration could be considered as non-stomata limiting factor under drought stress conditions. Kuroda et al., 1990 also reported a decline in chlorophyll content mean value under drought stress condition. The reduction in chlorophyll in the drought stressed treatments could be as a result the proline in the plant tissues which has missed water since water is needed for by plants for their physiologically and biochemical activities. Plants need a maximum amount of water to maintain their chlorophyll activities (Bohrani and Habili, 1992).

Leaf Area Index (LAI) analysis from Table 39 above in the non-irrigated treatment, shows significant difference between maize genotypes. There is significant difference between the genotype DKC4943 and KWS4484 at P<0.05. There was however no LAI difference between DKC4943, P9903, P9911 and S.Y. Zephir at P<0.05 (Table 39). In the fully irrigated, the genotype DKC4943 shows a significant mean (4.4) LAI measurement against the other genotypes. No significant LAI differences were observed among the P9903, P9911 and KWS4484 genotypes and, no difference was recorded between P9903, P9911 and S.Y. Zephir genotypes. Water stress significantly reduced leaf area index in this research in some genotypes due to reduction in cell division and this may reduce plant turgor pressure and cell expansion, thus resulting in dry mass being contain within a smaller leaf area and increasing the density of leaves (Hsiao, 1973; Rascio et al.,1990). Means comparison as seen in Table 39 shows an increase in the drought stress resulted in a significant decrease in the leaf area index in some genotypes and this finding coincided with other research finding such as that of (Nouri and Ehsanzadeh, 2007; Saberali et al., 2007; Pandey et al., 2000) all reported significant reduction in maize under drought stress condition. Ritchie, 1987 also reported that, there was difference between irrigated and drought stress crops at the end of the growing season whereby plants under drought stress conditions lost the leaf area. The genotype LAI means comparison showed that the DKC4943 had the highest LAI (4.1) and the KWS4484 genotype had the lowest LAI (3.3) under the non-irrigated regime whereas under the irrigation treatment, DKC4943 had the highest LAI (4.4) and S.Y Zephir genotype had the lowest mean value of LAI (3.2) (Table 37). NDVI measurements in both non-irrigated and irrigated treatments did not show a significant difference between genotypes in this study in the first measurement of the photosynthetic characteristics as shown in Table 39 above.

Table 40: Effects of water stress and irrigation on photosynthetic parameters of maize genotypes (Debrecen-Latokep, 2018)

Genotypes	**Non-irrigation**			**Full irrigation**		
	SPAD	**LAI (m^2/m^2)**	**NDVI**	**SPAD**	**LAI (m^2/m^2)**	**NDVI**
DKC4943	53.9c	5.6b	0.83ab	56.0c	6.8b	0.82ab
P9903	50.9bc	5.2b	0.84b	53.0bc	5.8ab	0.85b
P9911	52.5c	5.4b	0.82a	54.9c	5.6ab	0.80a
KWS4484	50.9bc	5.1b	0.83ab	54.5c	5.1a	0.84b
S.Y ZEPHIR	42.9a	3.6a	0.81a	47.9a	5.0a	0.82ab

Note: Means with the same letter within columns are not significantly different at $P<0.05$

In the second measurement of the photosynthetic parameters as recorded in Table 40 above, significant difference was noticed between the SPAD readings of the different genotypes. DKC4943 and P9911 genotypes were significantly different from the other genotypes at $P<0.05$ (Table 40). No significant difference was noticed between the genotypes P9903 and KWS4484, however, these two genotypes was significantly different from the S.Y. Zephir genotype which recorded the minimum (42.9) SPAD reading among the measured genotypes in this study in the non-irrigated treatment. In the fully irrigated treatment, S.Y. Zephir genotype was negatively different from the other genotypes as it measured lease (47.9) as against the maximum mean of DKC4943 (56.0).

Leaf Area Index (LAI) analysis in the second measurement in the non-irrigated treatment shows there was no difference between four genotypes (DKC4943, P9903, P9911 and KWS4484) but however, these genotypes were significantly different from the S.Y. Zephir genotype which had the minimum LAI (3.6). In the full irrigation treatment, DKC4943, P9903, and P9911 genotypes were not significantly different between themselves however, they were significantly different from KWS4484 and S.Y. Zephir genotypes as these two genotypes had the least minimum LAI readings (5.1 and 5.0) respectively (Table 40).

NDVI measurement and analysis did not show any difference between DKC4943, P9903 and KWS4484 genotypes in both non-irrigated and fully irrigated treatments. In the non-irrigated treatment, P9911 and S.Y. Zephir genotypes were negatively significant to the other genotypes as seen in Table 40 above as they recorded the minimum NDVI values (0.82 and 0.81) respectively.

Table 41: Effects of water stress and irrigation on photosynthetic parameters of maize genotypes (Debrecen-Latokep, 2018)

Genotypes	Non-irrigation			Full irrigation		
	SPAD	**LAI (m^2/m^2)**	**NDVI**	**SPAD**	**LAI (m^2/m^2)**	**NDVI**
DKC4943	60.47c	2.62c	0.847ab	59.50c	2.23a	0.822ab
P9903	56.30ab	2.04abc	0.880b	56.35ab	2.00a	0.850b
P9911	57.09ab	2.46bc	0.827a	56.88b	1.86a	0.809a
KWS4484	60.46c	1.99ab	0.837ab	62.03d	2.06a	0.843b
S.Y ZEPHIR	54.68a	2.15abc	0.819a	54.54a	1.82a	0.829ab

Note: Means with the same letter within columns are not significantly different at $P<0.05$

Table 41 shows data on the third measurements of photosynthetic parameters of the maize genotypes in this study. Significant difference was noticed between maize genotypes in the SPAD readings in the third measurement in the non-irrigated treatment. DKC4943 and KWS4484 genotypes were significantly different from the other measured genotypes and they recoded the maximum SPAD mean values (60.47 and 60.46) respectively. No significant difference was noticed between P9903 and P9911genotypes and P9903, P9911 and S.Y. Zephir genotypes were not statistically different. In the fully irrigated treatment, SPAD values among genotypes were very much different from each other. KWS4484 was statistically different from the genotype DKC4943 which was also significantly different from P9903, P9911 and S.Y. Zephir. No significant difference was seen between the P9903 and P9911 and no difference was recorded between P9903 and S.Y. Zephir.

Leaf Area Index in the non-irrigated treatment, the DKC4943 genotypes had the maximum LAI value of (2.62) which is statistically not different from P9903, P9911 and S.Y. Zephir genotypes but significantly different from KWS4484 genotype which had the minimum LAI value mean. Genotypes P9903, P9911 and S.Y. Zephir were not statistically different and genotypes P9903, KWS4484 and S.Y. Zephir were not significantly different between them. In the irrigated treatment, no significant difference was recorded between maize genotypes at $P<0.05$ (Table 41). According to Table 41, water stress showed significant difference between genotypes on leaf area index and researcher like Nouri and Ehsanzadeh, (2007), Saberali et al., (2007) Pandey et al., (2000) all reported significant reduction in leaf area index during drought stress.

NDVI in the third measurement shows significant difference in both non-irrigated and fully irrigated treatments. In the non-irrigated treatment, the genotypes P9903, DKC4943 and KWS4484 were not significant different among themselves but were statistically different from P9911 and S.Y. Zephir genotypes. No difference was found between DKC4943, P9911, S.Y. Zephir and KWS4484 genotypes. In the irrigated treatment, genotypes P9903 and KWS4484 is statistically different from the other genotypes. DKC4943 and S.Y. Zephir were not different statistically. The maximum and minimum NDVI mean values are P9903 and P9911 respectively. Leaf chlorophyll of different genotypes shows significant difference ($P<0.05$) but the interaction between the irrigated treatments. Water deficiency causes plant pigment and plastid damage and drought stress also decrease chlorophyll carotenoids (Duysen and Freman, 1975).

4.2.2 Effects of water stress on yield components of different maize genotypes

Table 42 presents an analysis of the effect of water stress on yield components of maize genotypes. Generally, in the non-irrigated treatment in this study, there was no statistically significant difference between yield components of the maize genotypes. Measurement of cob diameter between genotypes shows that P9903 (55.1 mm) had the maximum whiles S.Y Zephir had the least cob diameter of (50.4 mm) among the genotypes and did not show any significant differences as recorded in (Table 42).

Cob length in the water stress treatment shows no significant difference between genotypes. The maximum cob length was recorded under KWS4484 (22.2) whiles the minimum cob length was seen under P9911 (20.5) (Table 42). Number of rows per cob shows P9903(16.7) genotype had the maximum number of rows per cob whereas DKC4943(15.6) genotype had the minimum row number per cob. There was no difference between the genotypes. Grain number per row in this study did not show any difference between genotypes and DKC4943(45.8) had the maximum grain number per row whiles the KWS4484 (43.1) genotype recorded the minimum grain number per row. Finding from this study on yield components did not agree with that of (Bozkurt et al., 2006, Cakir, 2004; Otegui et al., 1995) who all reported significant difference between genotypes they used in their research, and this could be true in that, different genotypes respond to different environmental factors. Maize is very sensitive to water stress in during joining and flowering stage as reported by (Rhoads and Bennett, 1990; Pandey et al., 2000 and Kuscu and Demir, 2013). If water stress can be avoided during silking and early ear developing stage, high grain yields could be expected in maize production. But recent climate changes in many parts of the world is obvious and increase in temperature and reduction in precipitation mean is becoming unpredictable thus, resulting in low yields.

Table 43: Effects of water stress on yield components of different maize genotypes (Debrecen-Latokep, 2018)

Genotypes	Cob diameter (mm)	Cob length (cm)	No. of Row/Cob	No. of grain/Row	Grain weight/cob (g)	Cob weight (g)	Grain no/Cob
DKC 4943	50.9a	21.9a	15.6a	45.8a	262.8a	290.3a	687a
P 9903	55.1a	22.0a	16.7a	45.6a	285.2a	316.2a	730a
P 9911	53.9a	20.5a	16.0a	45.0a	275.6a	313.7a	714a
KWS 4484	50.5a	22.2a	16.4a	43.1a	253.0a	287.8a	679a
S.Y ZEPHIR	50.4a	22.1a	16.6a	44.2a	250.1a	284.5a	709a

Note: Means with the same letter within columns are not significantly different at P<0.05.

Grain weight per cob was not significantly different between maize genotypes in this study under the water stress treatment. Genotype P9903 (285.2g) weighed higher whiles S.Y. Zephir (250.1g) genotype was the least weighed grain weight per cob. Cob weight of genotypes were not statistically different between maize genotypes in this study as can be shown in (Table 43). The maximum cob weight was seen under the genotype P9903 (316.2g) whereas the minimum cob weight was observed under the genotype S.Y. Zephir (284.5g). Grain number per cob between genotypes was not different among the genotypes. The maximum mean grain number was recorded under the genotype P9903 (730) and the minimum grain number per cob was seen under DKC4943 (687).

Table 43 present analysis of effects of water treatment on yield components of different maize genotypes. Cob diameter, cob length and Grain number per cob in this treatment did not record any significant difference between genotypes in this study (Table 43). The maximum cob diameter among the genotypes was observed under the genotype P9911 (55.2 mm) whiles the lowest mean of cob diameter was seen under the genotype S.Y Zephir (50.9 mm). Cob length between the genotypes did not show significant difference between genotypes in this study. S.Y. Zephir genotype had the maximum cob length of (22.4 cm) as against the genotype P9903 (19.9 cm) which had the minimum cob length. Grain number per cob was not different between genotypes. The genotype P9911 (730) had the maximum grain number per cob as against the KWS4484 (644) genotype which measured the minimum grain number per cob in the study. (Table 43). The reduction in kernel/grain number does not suggest a reduction in grain yield in this experiment and the reduction in cob diameter or size per plant in this treatment suggest that grain yield is due to moisture deficit stress at tasselling had a pronounced impact on grain yield. Number of rows per cob under the water treatment shows significant difference between maize genotypes in this study. The genotype P9903(17.3) measured the highest mean of row number per cob which is significantly different from the other genotypes. The genotypes P9911, KWS4484 and S.Y. Zephir did not show any statistical difference between them. The minimum genotype measured was seen under DKC4943 (15.7) (Table 43). The row number per ear was statistically affected by irrigation between the genotypes. Sampathkumar et al., 2013 reported similar findings. Number of grains per row was statistically different between genotypes and as recorded in (Table 43) above, S.Y Zephir (45.5) genotype which had the maximum grain number but not different from the DKC4943 (45.2) were both significantly different from the other genotypes. P9903 and KWS4484 genotypes are not significantly different (Table 43).

Table 44: Effects of water treatment on yield components of different maize genotypes (Debrecen-Latokep, 2019)

Genotypes	**Cob diameter (mm)**	**Cob length (cm)**	**No. of Row/Cob**	**No. of grain/Row**	**Grain weight/cob (g)**	**Cob weight (g)**	**Grain no/Cob**
DKC 4943	51.1a	22.3a	15.7a	45.2c	244.5a	285.3a	681a
P 9903	53.7a	19.9a	17.3b	41.7ab	317.5cd	365.2b	697a
P 9911	55.2a	20.3a	16.8ab	44.5bc	290.4bc	328.3ab	730a
KWS 4484	53.4a	20.3a	16.6ab	40.2a	258.5ab	300.1a	644a
S.Y ZEPHIR	50.9a	22.4a	16.4ab	45.4c	264.2ab	295.0a	722a

Note: Means with the same letter within columns are not significantly different at P<0.05

Grain weight per cob in this study also showed significant difference between genotypes. The minimum grain weight per cob was observed under the DKC4943 (244.5 g) which was not significantly different from the KWS4484 and S.Y. Zephir genotypes whiles the maximum mean grain weight per cob was recorded under P9903 (317.5 g) which was not statistically different from the genotype P9911 (290.4 g) but were both statistically different from the other genotypes as shown in Table 44 above at P<0.05.

Cob weight shows a significant difference between maize genotypes and the genotype P9903 (365.2 g) which had the maximum mean cob weight is not statistically different from P9911 (328.3 g) genotype, however, these two genotypes are significantly different from the other measured genotypes at P<0.05 as recorded in Table 44 above. The analysis of mean indicated that growing season significantly affected maize grain yield characters under the irrigated treatment except cob diameter and cob length between the genotypes. Similar experiment reported by Istanbulluoglu et al., 2002 and Otegui et al., 1995 saw significant difference under full irrigation, which agrees with our results of the current study. Ear length of maize affects the number of grains per ear and its one of the important yield components that affect grain yield and could probably be affected by yearly precipitation levels as reported by Ertek and Kara (2013) that, ear length reduced with decreased irrigation levels.

4.2.3 Effects of water stress and irrigation on maize grain quality and yield of genotypes.

Table 45 presents an analysis of effects of water stress (non-irrigation) and irrigation on maize grain quality and yield between genotypes. Moisture content in grains between genotypes after harvest were significantly different. In the non-irrigated treatment, there were no significant difference between the P9911 (15.8 %) and S.Y. Zephir (15.6 %) genotypes, however, these two genotypes were statistically different from the other genotypes (DKC4943, P9903, and KWS4484) which were not significantly different among themselves at $P<0.05$ (Table 45).

Maize grain protein content measured shows significant difference between maize genotypes in the non-irrigated treatment. The maximum mean of protein was seen under S.Y. Zephir (9.8 %) genotype which was not statistically different from (P9911 and KWS4484) genotypes but were significantly different from the DKC4943 (8.5 %) genotype which had the minimum mean and P9903 genotype. The P9903 (9.2 %) genotype significantly differ from the DKC4943 (8.5) genotype at $P<0.05$ (Table 45). Farhad et al., (2013) and Aydinsakir et al., (2013) who worked on different irrigation regimes on different maize cultivars also reported that, grain protein content was significantly influenced. They attributed these differences due to cultivar variation, soil, and ecological difference.

Maize starch content in genotypes were significantly different between the maize genotypes. Three genotypes (DKC4943, P9911 and S.Y. Zephir) were not statistically different from each other. The P9903 and KWS4484 genotypes were not significantly different. The maximum starch content was recorded under the genotype P9911(74.7 %) which was significantly different from P9903 and KWS4484 genotypes at $P<0.05$ (Table 45). In this study, starch gradually differ between genotypes with deficit irrigation indicating that grain filling rate was similar between genotypes. The increase was not large but statistically very significant at ($P<0.05$). The justification for these variations could be modifications in starch biosynthetic enzyme activity and build-up of starch in the grains. Zhao et al., (2009) also stated in his work that, mild drought stress increased could lead to a decreased in the starch content in maize. Water stress during grain development according to Thitisaksakul et al., (2012) can result to a reduction in starch mass due to alterations in the enzyme activity accountable for starch biosynthesis. Lu et al., (2015) also reported that, moisture deficit had no consequence on starch content of fresh waxy maize.

Grain yield of maize genotypes in this study under the non-irrigated treatment was significantly different between maize genotypes. The maximum genotype grain yield was observed under the P9911 (16517.7 kg/ha) genotype which was not statistically different from the DKC4943 (15945.6 kg/ha) but was however statistically different from the other genotypes as recorded in Table 42 below. Genotypes DKC4943, P9903 and S.Y. Zephir were not significantly different between them. P9903 and S.Y. Zephir genotypes were statistically not different among them. The minimum grain yield was seen under the KWS4484 (14134.9 kg/ha) genotype. The lower grain yield demonstrated under drought stress may mainly be because of reduction in carbon dioxide assimilation area, leaf number and total leaf size covered. Dolferous et al., (2011) observed that, grain number is an important yield component that is clearly associated with increased in yield in cereal crops. Maize grain yield reduction of genotype could be attributed to absence of soil water, or other environmental factors like climatic conditions in the growing season, drought intensity and or genotype sensitivity to soil drought (Ertek and Kara, 2013).

Under the fully irrigated treatment, grain moisture content was significantly different between maize genotypes. Genotype P9911 (16.4 %) had the maximum moisture content at harvest which was statistically different at $P<0.05$ from the other genotypes as recorded in Table 45.

Grain protein content was significantly different between maize genotypes. S.Y. Zephir (10.3 %) genotype which had the maximum protein content percentage is not statistically different from KWS4484 (10.1 %), but significantly different from DKC4943(8.9 %) genotype which recorded the minimum protein percentage among the genotypes. P9903 and P9911 genotypes were not significantly different, but they were significantly different from the DKC4943 genotype at $P<0.05$ (Table 45). The effect of irrigation on genotypes protein content was statistically important as seen in Table 45 above. Vartanli and Emeklier (2007) reported that crude protein content of some maize cultivars was between 6.21 and 8.65%. Aydinsakir et al (2013) who worked on different maize cultivars reported significant influence of different irrigation treatment on grain protein content. The possible difference in grain protein content of genotypes could be due cultivars response of different water utilization and soil or ecological conditions.

Table 46: Effects of water stress and irrigation on maize grain quality and yield of genotypes (Debrecen-Latokep, 2018)

GENOTYPES	**Non-Irrigated**				**Full-Irrigation**			
	Moisture %	**Protein %**	**Starch %**	**Yield (kg ha^{-1})**	**Moisture %**	**Protein %**	**Starch %**	**Yield (kg ha^{-1})**
DKC4943	14.9a	8.5a	74.2ab	15945.6cd	14.8a	8.9a	74.5c	15351.0b
P9903	15.0a	9.2b	73.4a	15237.0bc	15.5bc	9.3b	73.7abc	16011.2bc
P9911	15.8b	9.7c	74.7b	16517.7d	16.4d	9.5b	74.3bc	16651.4c
KWS4484	14.9a	9.7c	73.5a	14134.9ab	15.2b	10.1c	73.1a	14129.9a
S.Y ZEPHIR	15.6b	9.8c	74.2ab	14834.7bc	15.8c	10.3c	73.8abc	15292.6b

Note: Means with the same letter within columns are not significantly different at $P<0.05$

Maize grain starch content after harvest in the full irrigated treatment shows significant difference between the genotypes. The maximum starch content percentage is seen under the genotype DKC4943 (74.5 %) is not significantly different from the other genotypes except KWS4484 (73.1 %) which had the minimum starch percentage at $P<0.05$ (Table 46). Starch content is not greatly influenced by irrigation between genotypes but however, average mean values differed between genotypes and could be because of difference in cultivar enzyme processing of grains of maize genotypes. Liu et al (2013) stated that, maize grain starch content experiments grown with less irrigation was 3.0% reduced to that with high irrigation.

Grain yield under the full irrigation treatment had significant difference between the genotypes. The highest grain yield was recorded under the genotype P9911 (16651.4 kg ha^{-1}) which was statistically not different from P9903(16011.2 kg ha^{-1}) but significantly different from (KWS4484, DKC4943 and S.Y. Zephir). No significant difference was noticed between DKC4943, P9903 and S.Y Zephir genotypes, but they were significantly different from KWS4484 (14129.9 kg ha^{-1}) genotype which had the minimum grain yield. Maize grain yield increases in response to water availability; however, the level of increase varies within genotypes. Many authors reported increase in yield as a result of irrigation. Bhimireddy et al., 2017 observed that, grain yield of no-till maize increased with increase in water input from 75% pan evaporation to 100% pan evaporation irrigation plan in drip irrigation but could not achieve the level of 125% pan evaporation in semi-arid environment in India. Like this current study, Aydinsakir et al., 2013 related the highest grain yield was recorded under full irrigation whiles the lowest grain yield was in no irrigation. A drop in maize grain yield because of lack of soil water hangs on some factors such as the soil, climate conditions the season, drought duration, period of growth, and hybrid sensitivity to soil drought.

4.2.4 Effects of water stress and irrigation on maize grain quality and yield of genotypes.

Table 47 presents an analysis of effects of water stress and irrigation on maize grain quality and yield between genotypes in the 2019 cropping year.

Table 47: Effects of water stress and irrigation on maize grain quality and yield between genotypes (Debrecen-Latokep, 2019)

Genotypes	Non-Irrigation				Full-Irrigation			
	Moisture %	**Protein %**	**Starch %**	**Yield (kg ha^{-1})**	**Moisture %**	**Protein %**	**Starch %**	**Yield (kg ha^{-1})**
DKC4943	16.1a	8.4a	75.47b	15022.2ab	17.0ab	7.5a	76.30b	16103.9c
P9903	16.8ab	8.8ab	74.82ab	15469.3b	16.5a	8.3b	75.05a	15156.4bc
P9911	17.8b	9.1b	75.45b	15349.2b	18.2c	9.0c	75.45a	14720.3ab
KWS4484	16.5ab	9.0ab	74.13a	13648.9a	16.4a	9.2c	75.00a	14084.2a
S.Y ZEPHIR	16.6ab	9.0ab	75.30b	14959.4ab	17.6bc	8.8c	75.15a	14916.7ab

Note: Means with the same letter within columns are not significantly different at P<0.05

Moisture content in the non-irrigated treatment was significantly different between genotypes. There was not statistically difference between genotypes P9903, KWS4484, and S.Y. Zephir. Genotype P9911 (17.8 %) had the maximum grain moisture content which is significantly different from the DKC4943 (16.1 %) genotype which had the minimum moisture content (Table 47). According to Porter et al. (1997), the chosen hybrid and weather conditions of the given vegetation period have the most expressed effect on the harvest grain moisture content. Moisture in grains of maize is natural and its influence on the physiognomic handling in maize grains enhances grain quality and economic yield at harvest. The water movement dynamism in maize during flowering stage is transfer of materials to the grain during grain filling stage through the ear which add up to the dry matter composition accompanied by physiological changes in the moisture content of maize seeds at harvest.

Maize grain protein content in the non-irrigated plot shows statistical difference between genotypes. The genotype P9911 (9.1 %) recorded the maximum protein percentage which is significantly different from the DKC4943 (8.4 %) genotype which had the minimum grain protein content. P9903, KWS4484, and S.Y. Zephir. genotypes were not significantly different between them. The quality of forage value of maize is chiefly determined by maize grain protein and other quality parameters like oil content. Quality characteristics of maize grain are genetically determined and may sometime be manipulated by ecological and agrotechnical factors (Izsaki, 2009). The study of Feng et al. (1993) and that of Singh et al. (2005) established that protein content of maize grain can be increased in a non-irrigated field by increasing the nitrogen rate in maize hybrids. Weather condition in an area has a substantial impact on the raw protein content of grains (*Szász G*, 1977) and this adjustment correlates with yield fluctuations and could be ascribed to the quality of precipitation distribution in the growing season.

Grain starch content shows difference between genotypes. Genotypes P9903, P9911, DKC4943 and S.Y. Zephir did not show difference among them but were significantly different from KWS4484 (74.13 %) genotype except P9903 genotype at $P<0.05$ (Table 47). Maize grain starch is an important raw material of various seafood products and can also be used in pharmacy as excipient drugs. Bosnjak et al. (2008) reported similar results when they conducted their research applying three levels of irrigation treatment.

Maize grain yield under the irrigated study did not show much difference between maize genotypes except for KWS4484 (13648.9 kg ha^{-1}) genotype which had the minimum grain yield which negatively marched the other genotypes in the study. P9911, P9903, DKC4943, and S.Y. Zephir. Genotype were not statistically different and the genotypes DKC4943, KWS4484, and S.Y. Zephir did not show any difference between them. The highest grain yield was observed under the genotype P9903 (15469.3 kg ha^{-1}) is significantly different from KWS4484 (13648.9 kg ha^{-1}) genotype which had the minimum grain yield. Maize grain yield is affected by abiotic factors during its growth, thereby deciding productivity of maize. High yield losses are due to water shortage and drought in the vegetative stage and in maize flowering. Reports from Quatter et al. (1987), has it that, drought during grain filling period of maize was responsible for yield losses. Tolleneaar and Lee, (2002) reported that drought stress during grain filing greatly decreases yield. There was no considerable difference between genotypes as elucidated based on drought easiness and other researchers like Brar et al., (2001); Fallah et al., (2007) also argue that grain yield greatly reduced because of water stress.

In the fully irrigated treatment, P9911(18.2 %) genotype recorded the maximum grain moisture content which was significantly different from all the measured genotypes except S.Y Zephir. Genotypes DKC4943 and S.Y Zephir were not statistically different and genotypes DKC4943, P9903 and KWS4484 were not significantly different among themselves. The genotype KWS4484 (16.4 %) recorded the minimum grain moisture content among the measured genotypes.

Maize grain protein content percentage did not show any significant difference between three maize genotypes in the full irrigated treatment (P9911, KWS4484 and S.Y Zephir), however, they were significantly different from genotype DKC4943 and P9903. Significant difference was also noticed between genotype DKC4943 and P9903 at $P<0.05$ (Table 47). Svecnjak et al. (2007) reported their experiment of four maize hybrids under intensive and extensive soil and crop management and found out that, lower yield of maize was under less favourable weather condition whiles grain protein and oil content of grain were associated with extensive crop management. (Hegyi and Berzy, 2009) also reported high yielding hybrid had high starch and low protein and oil content in grains. Also, higher protein and low starch in grains were found under both irrigated and dry year conditions.

Grain starch content recorded the maximum starch in the DKC4943 (76.30 %) genotype which was statistically different from the other genotypes (P9903, P9911, KWS4484 and S.Y Zephir) which did not show any significant difference among themselves. Sipos et al., (2009) assessed the impact of nutrient supply and irrigation on yield and starch content in maize hybrids at different maturation stages on calcareous chernozem soil of the eastern part of Hungary. Apart from nutrient supply to maize, yield and starch contents primarily depends on the hybrid and other environmental factors, such as irrigation. In general, growing of maize hybrids of the earlier maturity group grain and starch yields are the lower but more stable compared to those of the longer vegetation period. Saleem et al, (2008.) found considerable differences of protein, starch, and oil contents in maize grain among maize hybrids in Pakistan. In general, low positive correlation was found between grain yield and starch contents and low negative correlation between grain yield and protein contents in grain.

Maize grain yield in the full irrigation treatment shows significant difference between maize genotypes. The highest grain yield was observed under genotype DKC4943 (16103.9 kg ha^{-1}) which is not significantly different from the P9903 genotype, but considerably different from the other genotypes. No meaningful difference was noticed between P9903, P9911 and S.Y Zephir genotypes. The genotype KWS4484 (14084.2 kg ha^{-1}) which recorded the minimum grain yield among the genotypes is not significantly different from P9911 and S.Y Zephir genotypes at $P<0.05$ (Table 47). The findings of this study coincide with that of Pepo et al. (2008) in eastern Hungary when they reported considerable influence of irrigation on maize grain yields.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary on Ruzsanyi experiment

Three-year research study took place in the experimental crop science centre of at Latokep experimental station in Debrecen, Hungary. From the research, the following conclusions can be inferred; Water treatment (irrigation) and nitrogen fertilizer had a substantial influence on the maize grain nutrient quality in all the three growing seasons particularly protein and moisture content. Fertilization has a great impact on the starch content rather than water treatment (irrigation).

Maize grain yield was not significantly influenced by nitrogen and water treatment in both monoculture and biculture fields, but it however influences the yield components in the monoculture field. The yield components in the biculture field were not significantly affected by nitrogen and irrigation treatment.

The individual impact of irrigation and nitrogen dose on yield components in both monoculture and biculture was significant (Table 7, 8, 9). The influences of water treatment on yield were not felt in both monoculture and biculture fields (Table 10).

Crop rotation significantly affected maize physiological parameters but did not influence maize grain quality (Table 13).

Generally, in this study, nitrogen did not have influence on photosynthetic parameters except maize leaf area index. Nitrogen significantly increased yield in both monoculture and biculture (Table 20). Irrigation did not influence yield in both biculture and monoculture in the 2018 cropping season (Table 21). NPK did not significantly influence yield components in the 2018 season but combine effect of irrigation and NPK treatment significantly influence yield and yield components (Table 23 and 24) respectively. Crop rotation and irrigation significantly affected yield and yield component and yield was affected by crop rotation (Table 26 and 27). NPK significantly affected grain yield in monoculture and biculture except the biculture fully irrigated (Table 28). Nitrogen levels did not have a significant effect on physiology, but the morphology was affected. (Table 29, 30). Nitrogen did not significantly affect physiological characteristic of monoculture plants (Table 33). Irrigation did not influence grain yield (Figure 6 and 7) and grain yield was influence by nitrogen levels but not yield components (31).

Nitrogen significantly affects grain yield in monoculture non-irrigated and fully irrigated (figure 8 and 9). Crop culture significantly influence grain yield at NPK_0 and NPK_{60} dose but did not influence the yield at NPK_{180} dose (figure 10 and 11).

Summary on Genotype experiment

From the analysis of figures from this research, it could be deduced that photosynthetic parameter (SPAD, LAI, NDVI) data between maize genotypes for this study for both non-irrigated and full irrigation, treatment shows significant difference between genotypes with the genotype DKC4943 showing the highest SPAD and leaf area index reading whiles the genotype P9903 recorded the maximum NDVI readings. The impact of water supply levels on maize grain yield components did not significantly influence yield component under the non-irrigated treatment between maize genotypes. However, there was significant influence of irrigation between genotypes under the irrigation treatment between maize genotypes which resulted in significant difference in genotypes (No. of row/cob, No. of grain/row, Grain weight/cob, Tube weight) for the genotypes P9903, S.Y Zephir and DKC4943, P9903 respectively.

Maize grain quality and yield of maize in the 2018 cropping season saw a significant difference between genotypes in both non-irrigated and full irrigated treatments. The maximum moisture content and grain yield in both non-irrigated and full irrigated were recorded under the genotype P9911. The maximum protein content from the genotypes in both non-irrigated and full irrigated was recorded under S.Y Zephir. Starch content under the non-irrigated treatment saw the genotype P9911 whiles, under the full irrigated, DKC4943 genotypes had the maximum starch content.

Maize grain nutritional quality (moisture, protein, starch) and yield saw significant difference between the genotypes under both non-irrigated and full irrigation. Under the non-irrigated, the genotype P9911 recorded the maximum moisture, protein, starch content whiles genotype P9903 registered the highest grain yield among the genotypes under the non-irrigated regime. In the full irrigated treatment, the genotype P9911 recorded the maximum moisture and starch content whiles the genotypes KWS4484 and DKC4943 registered the maximum protein content and grain yield, respectively. Grain quality is an important objective in maize production and a typical genotype contains approximately about 9% protein, 74% starch 4% oil and 14% other constituents mostly fibre. The impact of water levels on maize grain yield and nutritional component in maize genotypes varies between cropping seasons. The environmental climate difference had greater impact on yield and nutrition composition of maize. Water deficit reduced yield significantly between maize genotypes. The results also show that grain nutrient quality depends on drought intensity as soil water decreases beyond the reach of plants roots, maize nutrients losses were higher. The results of the study might be conducive to improving and increasing grain yield and nutrient quality of maize grains under similar ecological and climatic conditions based on appropriate genotype selection.

6. Conclusion

Maize cultivation in any part in the world cannot bring out any profit without sufficient water supply to the maize plants, but regrettably, because of climate changes and its influence on the environment, many crop plants are cultivated in many parts of the world without adequate water supply at important stages of the crop growth and development. It is against this backdrop that this study was conducted to examine the influence or effects of drought stress on the vegetative and reproductive yield process and yield elements of maize plant.

Understanding the physiological and morphological processes of maize to the responses to biotic and abiotic stresses is an important step towards future maize yield improvement which is the key to every research. In this study, the interaction of agronomic technology and environmental factors in terms of drought stress was explored with respect to physiology and morphology of maize plant changes and yield and yield components and grain quality. The hypothesis of this study stated that the effect of drought stress on maize growth and its interaction to reduce or increase grain quality of maize. Maize growth under this study in the conditions of nitrogen levels, irrigation regimes, and crop rotation, the following key observations from the results were made:

1. Variation in response to different nitrogen levels in maize grain yield in drought stress environments occurred between years.
2. Maize growth stages and the severity of drought influence the interaction of nitrogen use efficiency in this study. NUE = $\frac{\text{Grain Yield (kg ha-1)}}{\text{N absorbed at maturity (kg ha}^{-1}\text{)}}$
3. Nitrogen levels effected maize grain protein content nutrient quality in all the observed years.
4. Drought stress reduced aboveground biomass and grain yield.
5. Physiological and morphological characteristics were not influenced by nitrogen levels.
6. Crop rotation influence grain yield and quality.

7. The results presented in this thesis provide an important insight into the potential for the interaction of agro technical and drought stress. Morphological changes which occur in roots caused by drought stress may be critical to understanding the cumulative processes that determine grain yield in maize.

7 New scientific results

1. Drought stress response can be influenced by hybrid selection and plant density. New drought trait technology, for example, will influence the degree to which yield will be lost as result of drought stress. If drought stress increases plant to plant variability, then as maize seedling density increases, intraspecific competition will play a greater role in determining the extent of the interaction of the drought stress. The application of higher plant density 72,000 ha^{-1} leads to an increased in leaf area durability thus producing the maximum yields by application of relatively higher plant density values.
2. Maize yield components are accounted by stored soil moisture in previous precipitation of autumn-winter and precipitation in the critical production season. The water stock and its changings in a chernozem soils is determined by weather situation in given cropping season. The water deficiency of cropping site was 312 – 325 mm, 289 – 333 mm and 211 -245 mm in a highly dry year of 2017, a dry year of 2018 and moderately good water supply year of 2019 in that order.
3. The comparisons of data of two irrigation regimes under similar but identical fields under limited irrigation experience resulted in different degree of water stress, thus influence soil water nitrogen availability and maize plant nitrogen status. It is not possible to evaluate the effects of the irrigation treatments without considering that aspect which has a major influence on the maize crop. The irrigated treated field reacted positively to $NPK_{60:45:45}$ utilization influencing yield by 14.0 t ha^{-1}, 12.6 t ha^{-1} and 15.2 t ha^{-1} for the years 2017, 2018, and 2019 respectively as again 11.5 t ha^{-1}, 12.0 t ha^{-1}, and 13.6 t ha^{-1} respectively in the non-irrigated treated field.
4. In a biculture field, $NPK_{60:45:45}$ dose is required to produce maximum grain yield. Combined effect of irrigation and fertilization produces the best grain nutrition quality in a biculture field condition. Grain Protein was 5.2%, 7.4%, and 9.5% in the cropping years of 2017, 2018, and 2019 respectively as against monoculture non-irrigated 4.5% 6.8% and 7.3% respectively in the same cropping years.
5. Crop rotation is an effective system to improving on the maize crop physiological characteristics which in effect improves crop growth parameters. Crop rotation increased crop yields by 2.3 – 3.8 t ha$^{-1,}$ 2.1 – 2.9 t ha^{-1} and 2.2 – 3.1 t ha^{-1} respectively as against monoculture 1.4 – 2.6 t ha^{-1}, 1.6 – 2.0 t ha^{-1} and 1.5 – 2.9 t ha^{-1} in the years under review.

8. Practical application of scientific results

1. Under drought climatic situations, the main basis of crop production is the development of mechanisms of a technology of water saving to produce an effective and efficient application irrigation and precipitation for plants uptake. Crop yield and water use of maize was largely influenced by water supply.
2. In a water cycle space of crop production in the water supply to maize, the water stock of chernozem soil and amount of precipitation distribution during the cropping season are determining significance influencing the effect of agro technical factors such as irrigation, fertilization, crop rotation etc on water stock of the soil at different stages.
3. The proper timing of water supply to maize crops is proven by the fact that water deficiency values did not change in the periods between water supply dates. If the maize stands receive water supply in proper timing at the jointing stage with high water requirements, then it can be used efficiently and effectively for the vegetative stage of the maize development and yield and yield components formation.
4. The response to drought stress is influenced by hybrid selection and agrotechnical factors such as density of plants. New trait technology will influence the degree to which yield will be lost as a result of drought stress.
5. Grain quality is an important objective in maize production and a typical genotype contains approximately about 9% protein, 74% starch 4% oil and 14% other constituents mostly fiber.

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Candidate: Mahama Salifu
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List of publications related to the dissertation

Foreign language scientific articles in Hungarian journals (1)

1. **Salifu, M.**: Effects of water deficit on the growth and yield formation of maize (Zea mays L.).
   Agrártud. Közl. 72, 143-148, 2017. ISSN: 1587-1282.

List of other publications

Foreign language scientific articles in international journals (5)

2. **Salifu, M.**, Dóka, L. F., Balláné Kovács, A., Juhász, E. K.: The Impact of Nitrogen and Water Stress on Maize Genotypes at the Vegetative Stage.
   Int J Emerg Tech Adv Eng. 10 (5), 141-145, 2020. ISSN: 2250-2459.

3. **Salifu, M.**, Dóka, L. F.: Effects of Water Deficiency on Phosiological Traits, Grain Nutrition Quality and Yield of three Maize (Zea mays L) Genotypes.
   International Journal of Environment, Agriculture and Biotechnology. 4 (5), 1373-1376, 2019.
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4. **Salifu, M.**, Dóka, L. F.: Effects of Water Deficiency on the Physiology and Yield of Three Maize Genotypes.
   International Journal of Environment, Agriculture and Biotechnology. 5 (12), 31-35, 2019.
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5. **Salifu, M.**: The Impact of Crop Rotation and Nutrient Levels on Nutrition Quality, Yield and Yield Components of Maize (Zea maize L).
   International Journal of Environment, Agriculture and Biotechnology. 3 (2), 522-524, 2018.
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6. **Salifu, M.**, Dóka, L. F.: Effects of drought on the yield and yield components of maize (Zea mays l.).
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Foreign language conference proceedings (1)

7. **Salifu, M.**, Dóka, L. F.: Effects of plant density on photosynthetic characteristics and yield of maize under irrigation condition.
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8. **Salifu, M.**: The effect of drought and cropping system on the yield and yield components of maize (Zea mays L.).
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DEDICATION

I dedicate this manuscript to my family, most especially my late mother **Chiraba Abudu** whose prayers and wish for me has been fulfilled posthumously. (May her soul rest in peace).

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DECLARATION

Candidate’s declaration

I prepared this dissertation within the framework of Kálmán Kerpely doctoral school of the University of Debrecen, in order to obtain a doctoral (PhD) degree from the University of Debrecen.

Debrecen, 20……………………….

……………………………………..

Signature of the candidate

Supervisor's declaration

I certify that Mahama Salifu; a doctoral candidate between 2016-2020, and within the framework of the above-mentioned doctoral school, has carried out his work under my guidance / direction. The independent contribution of the candidate to the results included in the dissertation, the dissertation is the independent work of the candidate. I suggest / recommend the acceptance of the dissertation.

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Signature of the supervisor (s)