

Thesis of Doctoral (PhD) Dissertation

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

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Debrecen

2021

1. INTRODUCTION

Maize (*Zea mays* L.) is a major cereal crop worldwide, serving as a major staple for both human consumption and animal feed. It has also become a key resource for industrial applications and bioenergy production. Maize grain is extensively used for the preparation of corn starch, corn syrup, corn oil dextrose, corn flakes, gluten, grain cake, lactic acid and acetone which are used by various industries such as textile, foundry, fermentation, and food industries. With the development of poultry and livestock industry, its consumption in the feeds has also increased tremendously. Maize is one of the earning grains crops and, in the world, it is perhaps the most versatile. It is used in the human diet in both fresh and processed forms. The value added has been an economic driver in the specialty corn markets (Hallauer and Miranda, 1988).

About 80% of maize 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 71% starch, 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.

Global demand for maize will increase from 526 million tons to 784 million tons from 1993 to 2020, with most of the increased demand coming from developing countries (Rosegrant *et al.*, 1999). This is as a result of the over increasing world population and its demand as food and its usage as an industrial raw material for many products.

Drought stress or water deficit is an inevitable and recurring feature of global agriculture. Kramer (1980) reported that about one-third of the world's potentially arable land suffers due to water shortage, and most of the crops production is often reduced by drought. Water being integral part of plants plays a pivotal role in the initiation of growth, subsequent maintenance of developmental process throughout the plant's life and ultimately increases the economy of a country. The maize crops may experience reductions of grain yields when subjected to water deficit during the critical period of crop cycle from tasselling stage to initiation of grain filling.

2. MATERIALS AND METHODS

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 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. The soil from the experimental site is that of calcareous chernozem soil formed from loess with s deep humus content which has medium- heavy soil (plasticity index according to Arany: 43) belonging to the loam soil type.

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 layer ranged between 6.3 to 6.5. The nitrogen supply of the experimental site could be described as medium and the total 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 for the experimental site could be classified into the group IV according to Varallyai's soil 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.

This is a long-term experimental set-up in a four-factorial set up with a plot size of 9.2x5 m, 46m². The studied factors are Crop Rotation, Irrigation, Plant Density and Fertilization.

Factor 1: Crop Rotation, Treatments: Monoculture (Maize) and Biculture (Maize - wheat)

Factor 2: Irrigation Treatments: Non-Irrigation and Irrigated

Factor 3: Plant Density Treatments: 60,000 plants ha^{-1} , 72,500 plants ha^{-1} , 85,000 plants ha^{-1}

Factor 4: Fertilization Treatments: Nitrogen (N) (0, 60, 180), Phosphorus (P_2O_5) (0, 45, 135) and Potassium (K_2O) (0, 45, 135).

2.1 Agrotechnical 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 done with modern farm operational machines. 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, on 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% NH_4NO_3 .

In the Bi-culture 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. While the fertilization in the Spring was 2nd April, 2019 where 50% of the amount of nitrogen fertilizer was applied. Nitrogen fertilizer form: 34% NH_4NO_3 . 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 intercultural Cultivation (May 27, 2019).

2.2 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.

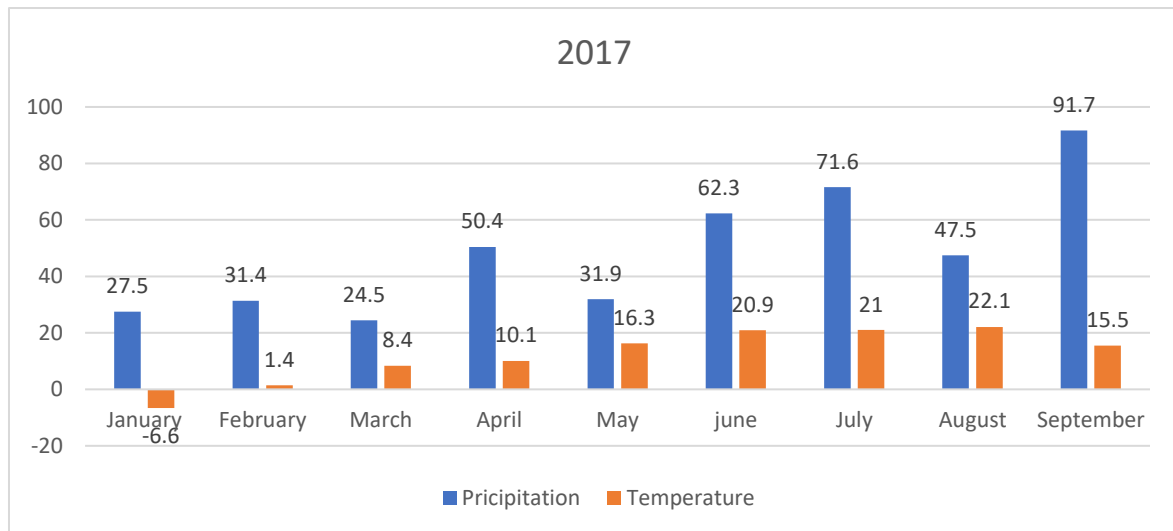


Figure 1: Precipitation and Temperature data. (Debrecen-Latokep 2017)

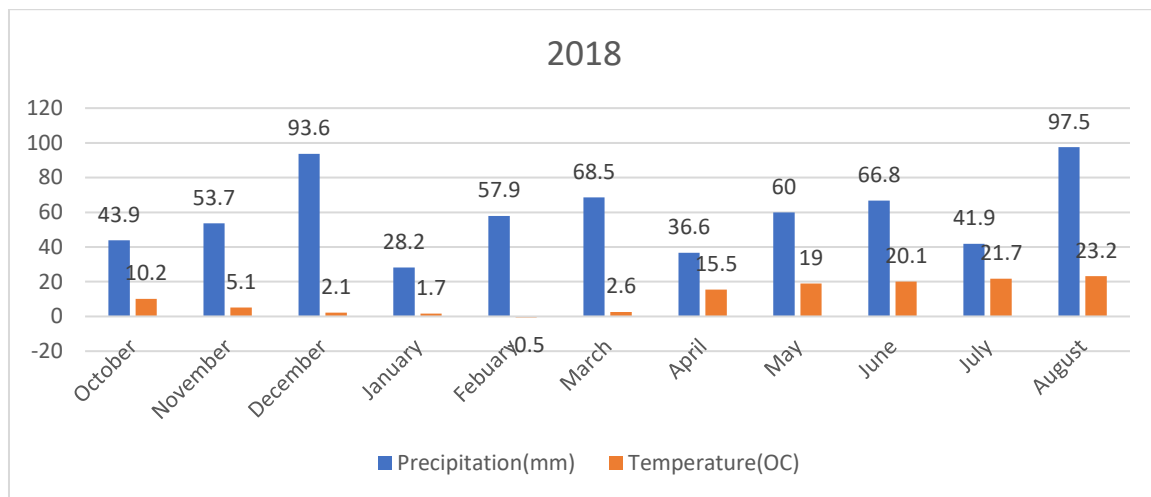


Figure 2: Precipitation and Temperature data. (Debrecen-Latokep 2018)

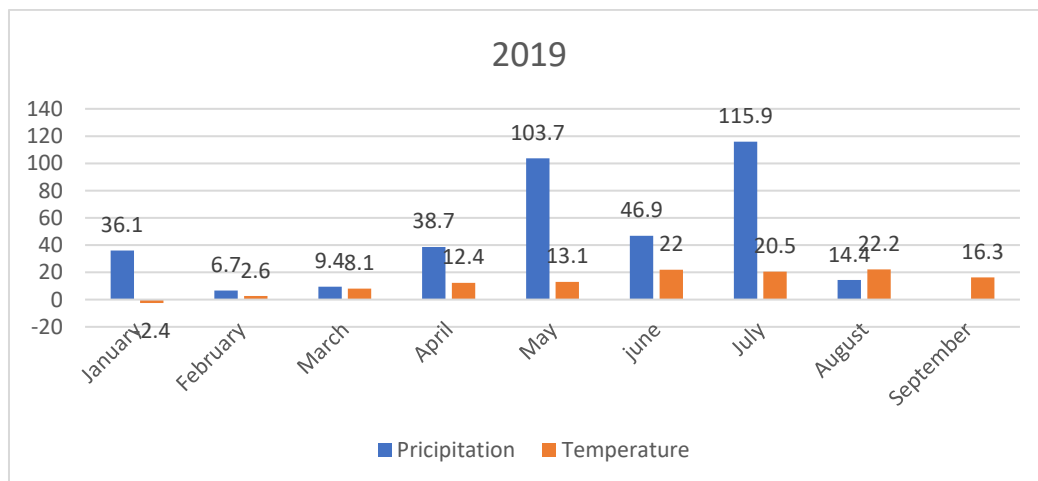


Figure 3: Precipitation and Temperature data. (Debrecen-Latokep 2019)

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 good comparing with the 30-year weather data of the planting area. Precipitation in April was 50.4mm which was significant compared to the 30year 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 (27.5mm and 31.4mm) 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 30year temperature in April was (10.4 °C). There was a significant change in precipitation in the months of May and June (31.9mm and 62.3mm) as against the 30year average of (58.8mm and 79.5mm) respectively and the high temperature recorded in those months of 16.3 °C and 20.9 °C which was far higher than the 30year 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 °C) was about 2 °C above the 30-year average (10.4 °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 °C) was significantly higher than the multi-year average (4.6 °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).

In 2019 cropping season, the weather of the growing year was contradictory regarding the vegetative and generative development of maize. The drought of the autumn-winter-spring months, May was cool and saw an unprecedented precipitation of 103 mm, far way more than the 30year average for that month and August was extremely dry because of high temperature (22.2 °C) above and warm which were significantly unfavourable for maize plants. On the other hand, the heavy rainfall in May and July and the optimum weather conditions in June were promising.

2.3 MATERIALS AND METHODS FOR GENOTYPE EXPERIMENT

2.3.1 Agrotechnical intervention

The agrotechnical interventions used in the experiment met the requirements of modern maize growing. The preproduction of the experiment was winter wheat.

2.3.2 Nutrient supply:

In the autumn of September 14, 2018, 30 kg n, 72 kg P₂O₅ and 72 kg K₂O were delivered in the autumn. During the spring period, n=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

2.3.3 Irrigation dates

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 m². The full irrigation treatment in addition 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 taken. The distance between the soil and the highest point of the male flower was considered.

Cob weight (g) was measured 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 leaf, 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 Granolys (Pfeuffer, Germany).

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

3. RESULTS AND DISCUSSION FOR RUZSANYI EXPERIMENT

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

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, thereby contributing linear increase of maize plant above ground biomass. This study is in tandem 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 of 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 1) below. The influence of nitrogen on the maize crude protein has been reported by (Haque et al 2001) that, inadequate supply of nitrogen could cause a retarded growth in maize owing to be a constituent of protein and nucleic acid. Similarly, according to (Ayuba et al.,2002a), 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 1. The protein content was significantly lower in the fully irrigated treatment of (8.41 g/kg). This shows that the protein content of maize decreases if the amount of irrigated water is above or below a certain level, 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 1: Effect of irrigation and NPK-levels on photosynthetic parameters and grain quality

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 _{0:0:0}	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

Moisture content in grain at the harvest was affected by irrigation. The irrigated treatment had significant mean value of 17.60 against 17.02 for non-irrigated treatment (Table 1). Newton and Eagles (1991) reported differences in grain moisture content at harvest were determined mainly by drying rates after physiological maturity as a result of drought stress and not by silking time. Hard density of endosperm is greater than that of soft endosperm making diffusion of water from the maize grain interior to the exterior more difficult, thus reducing

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 1).

3.2 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 2). 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 the does on Spad. The effects water stress was evident on the photosynthetic characteristic of maize in the biculture plots as NDVI was significantly affected as indicated in Table 2. The warning effect of drought on photosynthesis is clear at the stem elongation stage of maize development and the low level of photosynthesis rate could have a great impact on food construction and impact on dry matter accumulation. (Kisman.,2003; Osborne et a.,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 affected by water 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 2).

Maize plant height was significantly affected by both water stress and NPK levels in the biculture at ($P < 0.05$ in Table 2). 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 (18.50 cm) than the control (17.07cm). 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 2: Effects of Irrigation and NPK-levels on photosynthetic parameters and grain quality in biculture maize (Debrecen-Latokep, 2017)

Biculture	SPAD	NDVI	LAI (m²/m²)	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 _{0:0:0}	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

Source: (Debrecen-Latokep, 2017)

In this biculture field experiment, maize grain nutrient quality content of protein and moisture content 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 2 above. From the analyzed data, irrigated treatment plants had higher protein content and non-irrigated plants had low mean value accounting to 0.33% of the reduction in the protein content while NPK_{0:0:0} levels accounted for about 0.41% loss 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 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 influence 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 (Midorikawa et al., 2014; 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 2. 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 proportion of hard endosperm as indicated by grain hardness and percentage of grit following grinding. Newton and Eagles (1991) reported that, the density of hard endosperm is greater than that of soft endosperm making diffusion of water from the grain of low nitrogen utilized grain from the interior to the exterior more difficult, thus reducing grain dry down.

3.3 Effect of irrigation on yield components of maize on a Biculture plot in 2017

Results in the biculture plot present the effects of water treatment yield components in Table 3 below. From the table, irrigation had a severe impact on the yield parameters measured at $P<0.05$.

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 (43.2500) under the irrigated treatment again (39.2500) for the non-irrigated treatment which was statistically not significant.

Table 3: 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

The analysis of independence T-test show that the effect of water treatment of on maize cob length were significant (Table 3). 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) and the difference was significant at $P < 0.05$ (Table 3).

Grain number per row in this study was influence 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 (37.0833), whereas the non-irrigated treatments had a minimum number of grains per row of (29.4) which was significant at $P < 0.05$ (Table 3)

Number of grains per cob was significantly affected by irrigation treatment in this study at $P < 0.05$ (Table 3). The highest grains number per cob was registered under the irrigated treatment (569.5833), against the lowest grain number per cob which was recorded under the non-irrigated treatment (465.0833) 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 influence 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 et 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 mostly likely to influence by heredity factors rather than by crop management.

3.4 Effect of NPK Treatment on yield in Monoculture and Biculture plots in 2017

Table 4 present 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 4: Effect of NPK Treatment on yield in Monoculture and Biculture plots

Treatment	Monoculture (Yield kg/ha)		Biculture (Yield kg/ha)	
	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 $P < 0.05$

Source: Debrecen-Latokep, 2017

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) 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 4.

In the fully irrigated treatment in the monoculture plot, there was significant differences between all the three levels of NPK doses at $P < 0.05$ as shown in (Table 4). 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) registered under the highest NPK_{180:135:135} rate while 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 4).

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 4 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 decrease (5696.9 kg/ha) compared to the irrigated treatment (6249.9) Table 4. 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 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. 2011b; Anjum et al 2011). 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 reduces plant growth, resulting in reduction in grain yield.

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

Table 5 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 5). 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 influence by cropping system in this study at $P < 0.05$ level (Table 5). 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 5) 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 the shown in (Table 5). The mean value reading from the granulysers 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 5). 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 5 : 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

This study presents in Table 6 an analysis of the Effects of crop rotation and irrigation on yield component parameters. The impact of crop culture 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 6).

Water treatment significantly influence 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 6). The combined effect of crop culture or 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. The negative effect of monoculture is that it reduces leaf area thus resulting in low levels of radiation absorption and its impact on yield resulting in lowering yield performance as observed in (Table 6) and this has been reported by Wozniak A (2008).

Water treatment played a significant role in this study on the yield and yield component parameters as shown in (Table 6) and this finding is in line with other research findings such as (Classen and Shaw, 1970b; 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 production in any location in the world cannot be carry out meaningfully without enough water supply to the crops, but unfortunately, due to climate changes and its impact on the environment, most crops are grown in many parts of the world without enough water supply at some parts of the crop's developmental stages.

Table 6: Effects of crop culture and irrigation on yield component parameters (Debrecken-Latokep, 2018)

Crop Culture(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	ns	ns	ns	*

(A X B)

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

Source: Debrecen-Latokep, 2018

Table 7: 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 _{0:0:0}	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 7), 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 NPK180:135:135 (6249.9 kg/ha) and the lowest grain yield was seen under the control which had a zero dose of nitrogen. Significant difference was also seen between the NPK60:45:45 and NPK180:135:135 as shown in (Table 7). 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 increase 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.

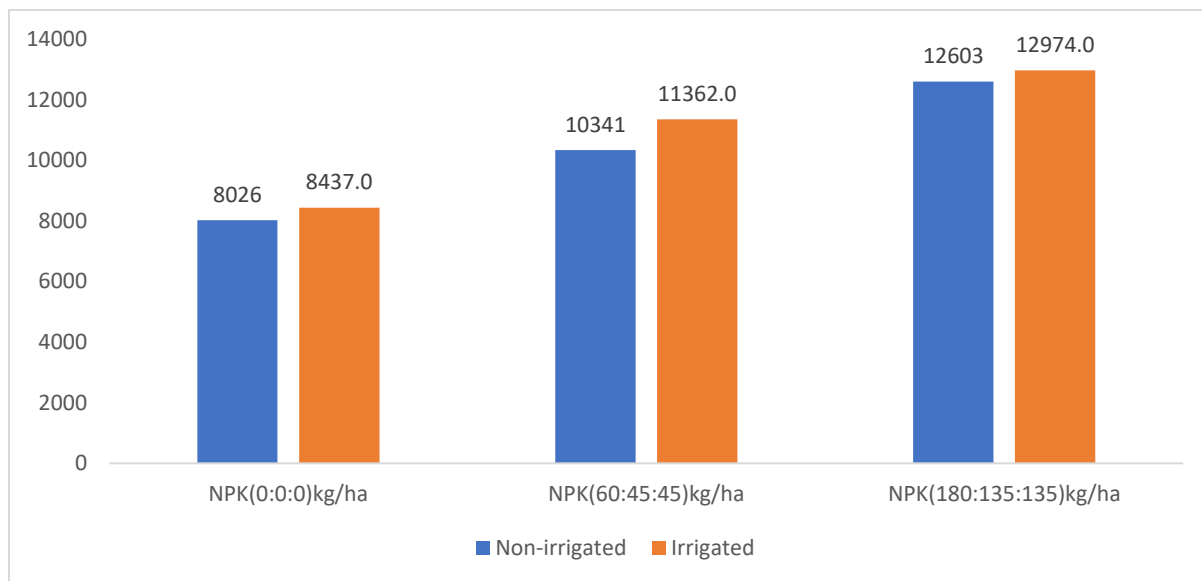


Figure 4: Irrigation effect on grain yield in monoculture maize

Source: Debrecen-Latokep, 2019

Figure 4 represent 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 indicate that when absences of soil moisture in the field passes a certain level, plants performance decreases.

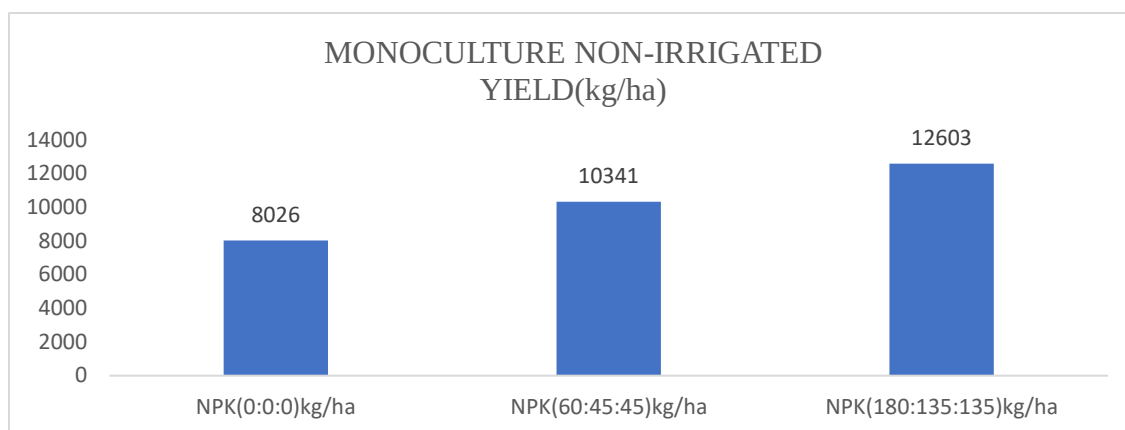


Figure 5: Nitrogen effect on grain yield in monoculture non-irrigated field

Source: Debrecen-Latokep, 2019

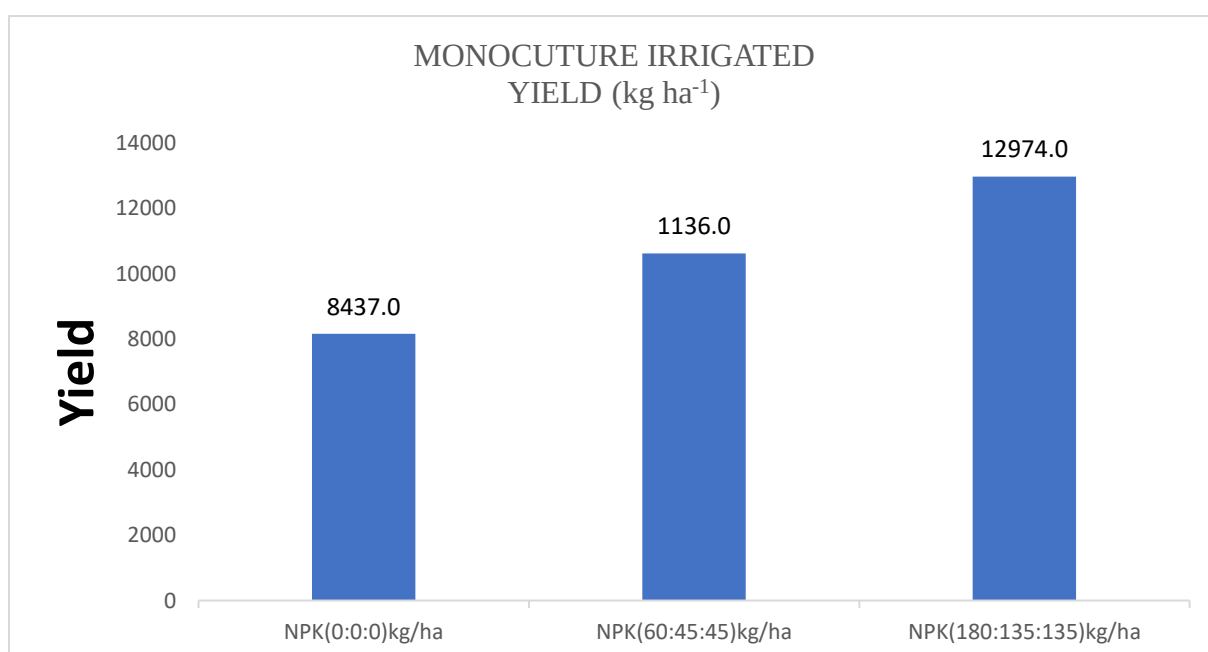


Figure 6: Nitrogen effect on grain yield in monoculture irrigated field

Source: Debrecen-Latokep, 2019)

Figure 5 and 6 above present Nitrogen effect on grain yield in monoculture non-irrigate and fully- irrigated fields, respectively. Nitrogen levels significantly influence 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 NPK₁₈₀ (12603 kg/ha and 12974 kg/ha), whereas the lowest grain yield was observed under the control experiment NPK₀ (8028 kg/ha and 8437.0 kg/ha) respectively for non-irrigated and fully irrigated (Fig 5 and 6) which was statistically

significant at $P < 0.05$. Again, in both plots, there was a significant difference between the NPK_{180} dose and the NPK_{60} as shown in the (Fig 5 and 6).

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-Gedway, 2009).

Figure 7 represent 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 $\text{NPK}_{0:0:0}$ and $\text{NPK}_{60:45:45}$ had a maximum yield under the fully irrigated (fig 7). In the $\text{NPK}_{180:135:135}$ dose, the highest yield was observed under the non-irrigated treatment suggesting that, under the current conditions, $\text{NPK}_{60:45:45}$ dose is sufficient to get the maximum yield in an efficient use of nitrogen under irrigation conditions in a biculture filed. Maize grain yield increases in response 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 7). The lower grain yield under deficit water may be chiefly due to carbo 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.

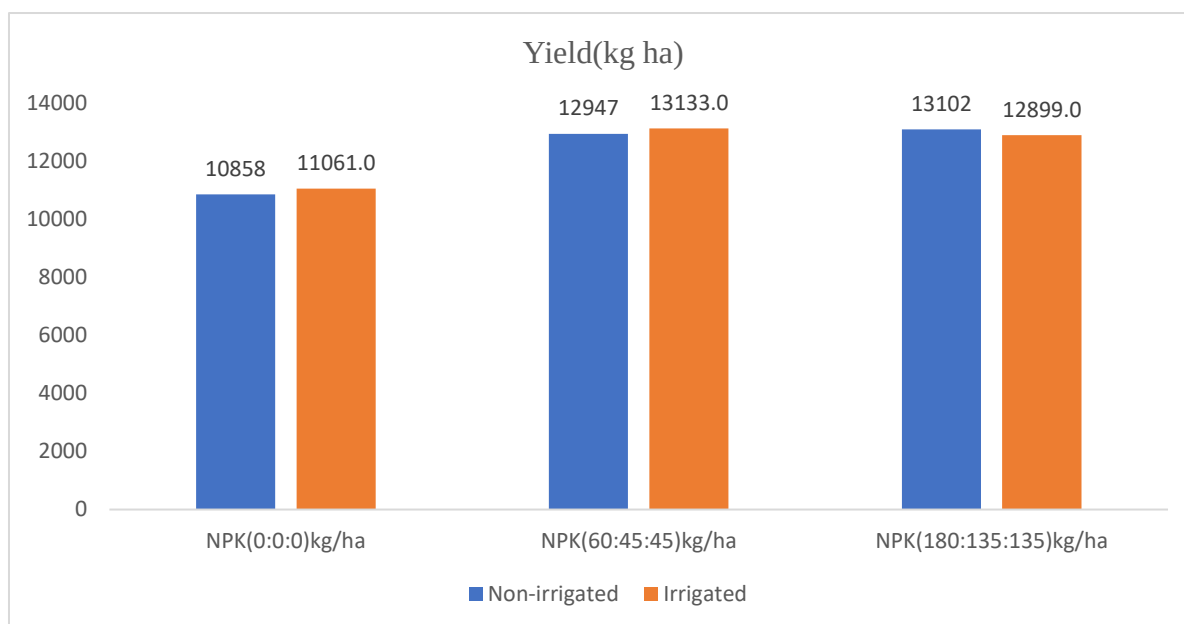


Figure 7: Effect of water treatment (Irrigation) on maize yield in biculture crop rotation

Source: Debrecen-Latokep, 2019

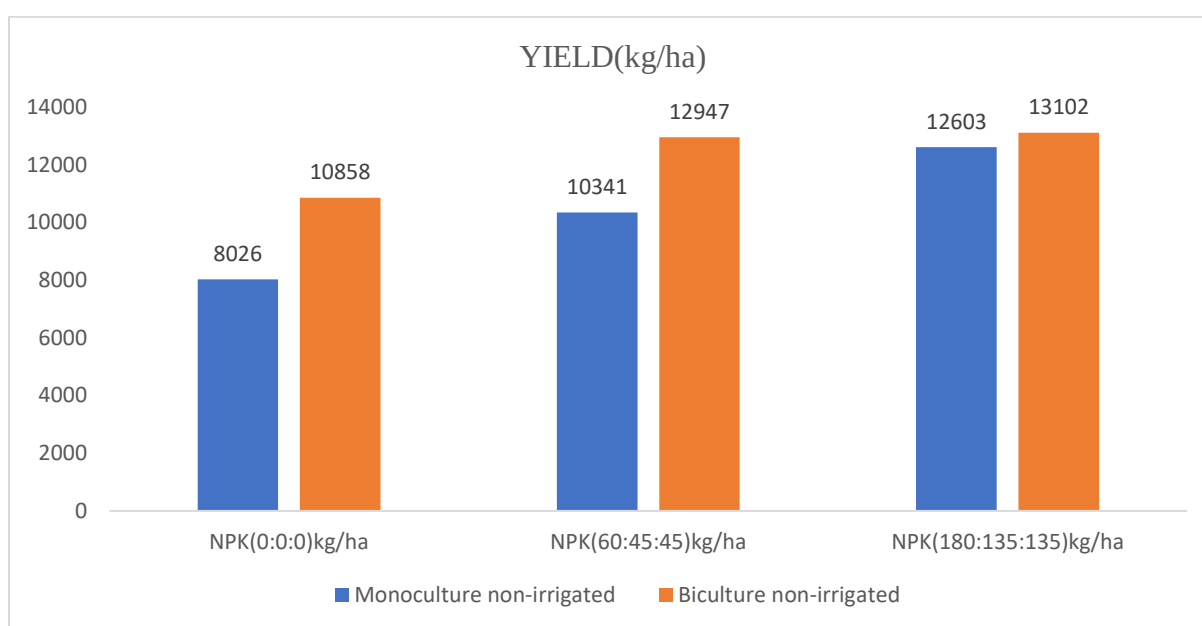


Figure 8: Effect of crop culture on grain yield in non-irrigated plot

Source: Debrecen-Latokep, 2019

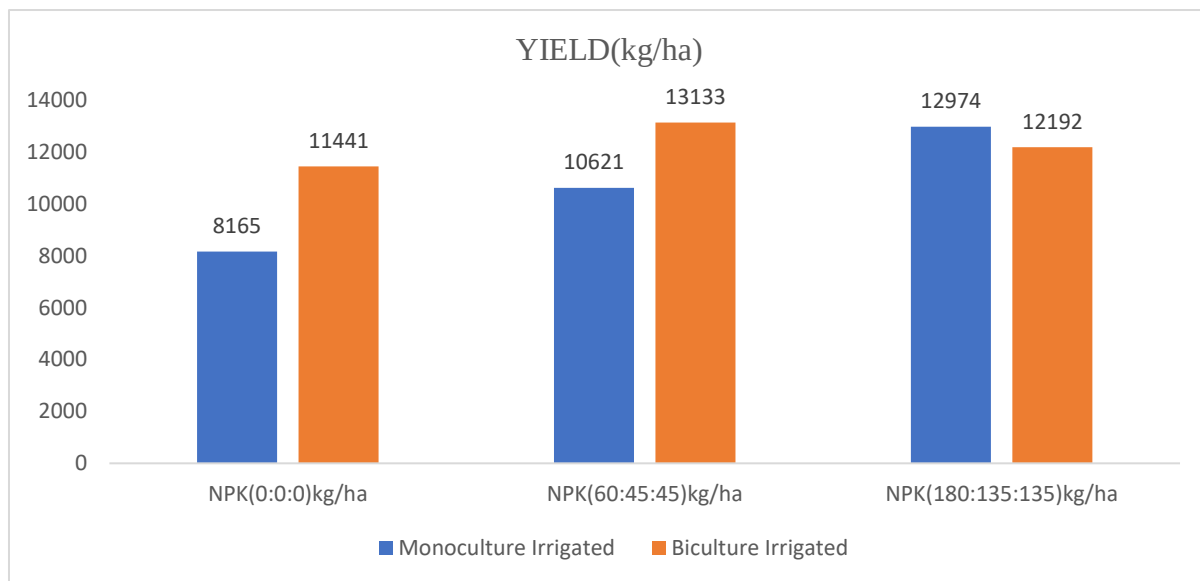


Figure 9: Effect of crop culture on grain yield in full irrigated plots

Source: Debrecen-Latokep, 2019

Crop rotation is one of the effect crop production management system used to improve crop yield and figure 8 and 9 above present the crop culture effect on maize grain yield in the monoculture non-irrigated and full irrigated plots in the 2019 cropping year. From the data, crop culture had a significant effect on grain yield at a nitrogen level NPK_0 and NPK_{60} doses, but difference was not observed between the monoculture and biculture treatment at the nitrogen dose of NPK_{180} kg/ha in both the non-irrigated and fully irrigated plots at $P < 0.05$ (Figure 8 and 9). The maximum grain yield was achieved under the biculture field under similar nitrogen doses of NPK_0 and NPK_{60} . Under the non-irrigated plot at a zero-nitrogen dose (NPK_0), the highest maize grain yield was recorded under the biculture (10858kg/ha) whereas the lowest was observed under the monoculture field (8026kg/ha) and at a Nitrogen dose of (NPK_{60}), grain yield of the biculture field was (12947kg/ha) whereas the minimum yield was recorded under the monoculture field (10341kg/ha) figure 8.

In the irrigated plots under the zero-nitrogen dose (NPK_0), the monoculture field recorded the minimum grain yield of (8165kg/ha) whereas the biculture field recorded the highest yield of (11441). Under the application rate of (NPK_{60}), monoculture field registered the lowest grain yield of (10621kg/ha) while the maximum yield was observed under the biculture field (13133kg/ha) figure 9.

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; Woznial and Kakarski, 2013). Decrease in grain quality because 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 follow.

Crop nutrient uptake in crop rotation system varies due to many factors, including rooting depth and breadth, crop variety, and environmental 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.

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

Table 8 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 8).

Maize grain protein 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 18). 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 to 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 8). 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/h) genotype which was not statistically different from the DKC4943 (15945.6 kg/h) but was however statistically different from the other genotypes as recorded in Table 8 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/h) 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 8).

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 between them, but they were significantly different from the DKC4943 genotype at $P < 0.05$ (Table 8). The effect of irrigation on genotypes protein content was statistically important as seen in Table 18 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.

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 mean percentage at $P < 0.05$ (Table 8). 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.

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Table 8: Effects of water stress and irrigation on maize grain quality and yield between genotypes.

GENOTYPES	Non-Irrigation				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 $P < 0.05$

Source: Debrecen-Latokep, 2018

Grain yield under the under the full irrigation treatment had significant difference between the genotypes. The highest grain yield was recorded under the genotype P9911 (16651.4 kg/h) which was statistically not different from P9903(16011.2 kg/h) 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) 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. Bhimirieddy 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 while the lowest grain 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.

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

Table 9 present an analysis of effects of water stress and irrigation on maize grain quality and yield between genotypes in the 2019 cropping year.

Table 9: Effects of water stress and irrigation on maize grain quality and yield between genotypes.

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 $P < 0.05$

Source: Debrecen-Latokep, 2019

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 9). 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 and fatty amino acids. Quality characteristics of maize grain are genetic 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 (Szirtes et al., 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 19). 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/h) 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/h) is significantly different from KWS4484 (13648.9 kg/h) 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 filling 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 19). Svecnjak et al. (2007) reported in 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 et al. 2008; 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/h) 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/h) 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 9). 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.

4 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.

5 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. 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. 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.

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Subject: PhD Publication List

Candidate: Mahama Salifu

Doctoral School: Kálmán Kerpely Doctoral School

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 Physiological 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.
EISSN: 2456-1878.
DOI: <http://dx.doi.org/10.22161/ijeab.45.12>
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.
EISSN: 2456-1878.
DOI: <http://dx.doi.org/10.22161/IJOEAR-DEC-2019-8>
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International Journal of Environment, Agriculture and Biotechnology. 3 (2), 522-524, 2018.
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Agrártud. Közl. 1, 115-118, 2019. ISSN: 1587-1282.

DOI: <https://doi.org/10.34101/actaagrar/1/2381>

Foreign language abstracts (1)

8. **Salifu, M.**: The effect of drought and cropping system on the yield and yield components of maize (*Zea mays* L.).

Agrártud. Közl. 75, 51-53, 2018. ISSN: 1587-1282.

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

28 October, 2020

