J. Glob. Innov. Agric. Soc. Sci., 2017, 5(4);159-164
ISSN (Online): 2311-3839; ISSN (Print): 2312-5225
http://www.jgiass.com

PERFORMANCE OF MAIZE YIELD AND QUALITY UNDER DIFFERENT IRRIGATION REGIMES AND NITROGEN LEVELS

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Optimum uses of irrigation water and nitrogen resources are most important factors in agricultural systems due to limitations of agricultural inputs especially water. The less availability of resources in agriculture sector particularly available water and nitrogen needs to be utilized on optimum bases. An experiment was performed to judge the influence of various levels of irrigation water and nitrogen on the yield and oil quality in maize at Agronomic research area, University of Agriculture Faisalabad, in spring 2015. The study was conducted under Randomized Complete Block Design (RCBD) with split plot arrangement and replicated thrice. The net size of experimental plot was 5 m × 1.8 m having four rows in every plot. Levels of irrigation were assigned in main plot and nitrogen levels in subplots. The study was having sixteen treatments; I_1 (eight number of irrigation levels), I_2 (50 mm potential soil moisture deficit), I_3 (75mm potential soil moisture deficit), I_4 (100 mm potential soil moisture deficit) and nitrogen levels were N_1 (100 kg N ha^{-1}), N_2 (125 kg N ha^{-1}), N_3 (150 kg N ha^{-1}), N_4 (175 kg N ha^{-1}). The interactions was found to be significant and recommended full irrigations with N_4 (175 kg N ha^{-1}) produced highest1000-grain weight (g), economical yield, total dry matter production (t ha^{-1}) and harvest index. Oil content (%)was significantly affected by nitrogen levels.
Keywords: Optimum, Irrigation, Nitrogen, potential soil moisture deficit, harvest index .

INTRODUCTION

Maize is major staple cereal crop due to its high value as it has high nutritional status; its **stover** demand for livestock feed and for various purposes (Abebe *et al.*, 2016). Maize has its vital significance because it has wide environmental range and biological efficacy (Ahmad *et al.*, 2007) and grown at large area of the world (Farhad *et al.*, 2009). Maize requires 550-650 mm irrigation water for proper growth and development depending upon environmental conditions (Reddy, 2006). Water stress in maize decreases the productivity of crop (Paudyal *et al.*, 2001). Water stress solely affects the maize productivity equal to all environmental factors. It decreases leaf area index (Pandey *et al.*, 2000) and phenology (Soler *et al.*, 2007) by reducing leaf expansion and cell division (Reymond *et al.*, 2003). Climate of Pakistan is highly suitable for maize production but poor management strategies limit its higher production. Irrigation and nitrogen are major abiotic components that reduce worldwide maize production (Araus *et al.*, 2002). Irrigation deficiency globally causes heavy crop losses (Shirazi *et al.*, 2011). Production of maize was greatly disturbed due to water deficit and high nitrogen dose (Moser *et al.*, 2006). There is a strong correlation between soil moisture and nitrogen availability (Aynehband *et al.*, 2011).

Limited amount of nitrogen decrease light interception by reducing leaf area index that ultimately leads to reduce yield (Basso & Ritchie, 2005). By increasing the level of nitrogen, leaf area duration increased and crop growth rate increased (Yang *et al.*, 2001). In semi-arid regions, production of maize greatly depends upon optimum application of nitrogen (Semenov *et al.*, 2007). Use of nitrogen in optimum amounts is mandatory for obtaining higher production of maize (Ryan *et al.*, 2008). Equitable balance between demand and supply of irrigation water and nitrogen is important to attain higher yield (Abbas and Fares, 2009). However, it can tolerate limited nitrogen supply in earlier stages as compared to reproductive stages (Islam *et al.*, 2010).

So, this experiment was planned to investigate the impact of water stress and variable nitrogen rates on yield and quality of maize under Faisalabad conditions.

MATERIALS AND METHODS

***Experimental site, climate and soil*:** The field experiment was conducted at Agronomic Research Area, University of Agriculture (73° 06′ E, 31° 26′ N and at altitude of 184.4 m), Faisalabad, Punjab, Pakistan during spring season of 2015. Before conducting the experiment, soil samples up to depth of 0-30 cm were taken from experimental unit with the help of augur. Analysis of soil sample is represented in (Table 1) which shows the soil properties of site. According to FAO soil classification system (FAO, 2014). Soil of experimental site is Lyallpur soil series and classified as Haplic Yermosol. While, according to USDA soil classification system (USDA, 2014) is an aridisol-fine-silty, mixed, Haplagrid and hyperthermic Ustalfic. Experimental period weather data in Fig. 1.

Table 1: Soil physio-chemical properties.

Characteristic	Unit	Value	Status
Physical analysis			
Sand	%	41	
Silt	%	43	
Clay	%	16	
Texture class			Sandy Loam
Chemical analysis			
pH		7.8	Medium alkaline
EC	dSm^{-1}	0.18	Non-saline
Organic Matter	(%)	0.46	Low
Total Nitrogen	(me/L)	0.05	Low
Available Phosphorus	(ppm)	13.9	Low
Available Potassium	(me/L)	175	Medium

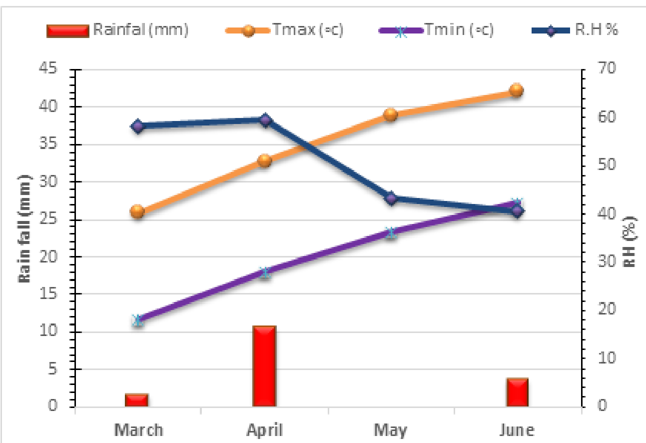

Figure 1:Experimental station Weather data obtained from Agricultural Meteorology Cell, Department of Agronomy, University of Agriculture, Faisalabad.

***Experimental design and treatments*:** The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement using net plot size of 5 m × 1.8 m having three replications for collection data, while randomizing irrigation regimes (I_1: 8 irrigations, I_2: 50 mm potential soil moisture deficit, I_3: 75 potential soil moisture deficits and I_4: 100 mm potential soil moisture deficit) in the main plot and nitrogen levels(N_1:100 kg N ha^{-1}, N_2:125 kg N ha^{-1}, N_3:150 kg N ha^{-1} and N_4:175 kg N ha^{-1}) in sub plots.

***Seed bed preparation, fertilizer application and sowing*:** The experimental site was ploughed (2 times) and planked then using ridger 75 cm apart ridges were formed to provide suitable seed bed for sowing. The seed of maize hybrid DK-6142 dibbled using seed rate 25 kg ha^{-1}in the field on 15thMarch 2015 keeping plant to plant distance 25 cm. Phosphorous (Single Super Phosphate) and potash (Sulphate of Potash) were applied at the rate of 150 and 100 kg ha^{-1} at the time of seed bed preparation. Nitrogen was applied in the form of Urea. Nitrogen applied in two splits at sowing and 1st irrigation was side dressed at 5 cm depth and 10 cm away from the plant row with the help of single row hand drill. Thinning of crop was done at three leaf stage to maintain the optimum plant population.

***Irrigation*:** Maximum potential soil moisture deficit was used as a criterion for irrigation application at 50 mm, 75 mm and 100 mm moisture deficit (French and Legg, 1979). Daily Penman's potential evapotranspiration (PET) was calculated by using standard software "CROPWAT" (FAO, 1992; FAO, 1993). Daily sum of PET values over time gives a cumulative potential soil moisture deficit (D) as suggested by French and Legg (1979). The amount of water applied was equal to the difference between PET and rainfall + irrigation. Irrigation was applied manually by watering cane. All other agronomic practices were kept normal and uniform for all the treatment combinations.

***Harvesting and threshing*:** Harvesting was done on June 15, 2015 and kept in the respective plots for sun drying. Each plot biological yield was tied in bundle and weighed. The cobs were removed from the dry stalks, unsheathed and threshed mechanically with the help of corn sheller.

***Data collection and analysis*:** Observations regarding plant height (cm) ten plants from each experimental unit were randomly selected and averaged, cob length (cm) (ten cobs were taken and averaged their length), number of grains per cob randomly selected 5 cobs and their grains were counted using grain counter, random sample from produce of each plot were taken for 1000-grain weight (g), the whole plot produce tied in bundle and weighed for biological yield (t ha^{-1}) and threshed grain of each plots were weighed and adjusted 14% moisture for grain yield (t ha^{-1}). Oil contents (%) of each experimental unit sample were recorded by Soxhlet method by Low (1990).

***Statistical analysis*:** Data collected on all parameters will be analyzed statistically by using computer software Statistix 8.1the Fischer analysis of variance (ANOVA) technique. Post ANOVA mean comparison of each parameter the least significantly difference (LSD) test at 5% probability level will be applied (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

***Plant height at maturity (cm)*:** Nitrogen rates and irrigation levels significantly affected the plant height; however their interaction was non-significant for plant height. It was observed that N_4 showed maximum plant height (165.35 cm), while minimum plant height (137.90 cm) was found in N_1. In case of irrigation levels, $I_1$and I_4 showed highest (154.33 cm) and lowest (146.67) plant height, respectively as shown in table 2.These conclusions are in line with Pandey *et al.* (2001) who observed that irrigation reduction decreased plant height and Silva *et al.* (2000) found that nitrogen application with different rates enhanced plant height significantly.

***Number of grains per cob*:** Number of grains per cob was influenced significantly by nitrogen and irrigation treatments, while interaction was non-significant. Maximum (504.19) and minimum (462.92) number of grains per cob were observed in case of $I_1$and I_4, respectively as shown in table 2. These results are in agreement with Pandey *et al.* (2000) and Andrade *et al.* (2002) who found that irrigation levels significantly impacted the grains per cob. In case of nitrogen levels, N_4showed maximum grains per cob (553.06) followed by N_3 and N_2, however, minimum number of grains per cob (409.22) was found in case of N_1. These outcomes are in accordance with those of Sabir *et al.* (2000), Silva *et al.* (2000), Hussaini *et al.* (2001) and Mahmood *et al.* (2001) who reported that by increasing nitrogen rate, number of grains also increased.

***1000-grain weight (g)*:** Nitrogen rates and irrigation levels significantly affected the 1000-grain weight and their interaction was also significant for 1000-grain weight. It was found that N_4 showed highest1000-grain weight (228.78 g), while minimum 1000-grain weight (213.81 g) was found in N_1 as shown in table 2. This conclusion is supported by Silva *et al.* (2000) who found that 1000-grain weight enhanced significantly by increasing application of nitrogen. In case of irrigation levels, I_1 and I_4 showed highest (243.94 g) and lowest (189.64 g) 1000-grain weight, respectively. These conclusions are in line with Pandey, (2000) who observed that more irrigation efficiency significantly enhanced 1000-grain weight. Their interaction showed that highest 1000-grain weight (255.11 g) was observed in case of I_1 and N_4 andlowest1000-grain weight (181.11 g) was found in case of $I_4$and N_1. Similar findings were concluded by Mohsan, (1999).

***Grain yield (t ha^{-1})*:** Grain yield was influenced significantly by nitrogen and irrigation treatments. Similarly, interaction

Table 2: The response of yield and yield components of maize to moisture deficits and nitrogen levels during 2015.

Treatments	Plant height at maturity (cm)	Number of grains per cob	1000-grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)	Oil contents (%)
Irrigation							
I_1	154.33 A	504.19 A	243.94 A	8.40 A	17.16 A	49.90 B	3.61
I_2	151.98 AB	487.53 B	231.00 B	8.17 B	16.48 B	50.67 B	3.53
I_3	149.68 BC	476.21 B	215.56 B	7.76 C	15.89 C	49.79 B	3.41
I_4	146.67 C	462.92 C	189.64 C	7.49 D	15.15 D	52.35 A	3.19
LSD 5%	3.23	7.01	13.76	0.18	0.29	0.99	
Nitrogen							
N_1	137.90 D	409.22 D	213.81 D	7.46 C	13.40 D	56.83 A	3.07
N_2	146.90 C	464.42 C	216.44 C	7.53 C	15.44 C	49.46 B	3.34
N_3	154.52 B	504.14 B	221.11 B	8.12 B	16.81 B	48.91 BC	3.55
N_4	163.35 A	553.06 A	228.78 A	8.91 A	19.03 A	47.51 C	3.79
LSD 5%	3.83	16.52	3.28	0.45	0.32	1.60	
Interaction							
I_1N_1	142.53	435.31	238.11 bc	7.64 d-g	14.66 j	52.86 bc	3.17
I_1N_2	149.53	480.05	238.78 bc	7.76 d-g	15.97 gh	49.33 d-g	3.46
I_1N_3	157.07	513.81	243.78 b	8.74 abc	17.34 de	51.07 cde	3.74
I_1N_4	162.80	587.57	255.11 a	9.48 a	20.68 a	46.34 g	4.06
I_2N_1	139.33	420.64	228.67 de	7.58 efg	13.74 k	56.04 b	3.24
I_2N_2	148.13	469.44	229.56 d	7.58 efg	15.68 hi	48.98 d-g	3.42
I_2N_3	156.00	509.32	232.22 cd	8.36 b-f	17.02 ef	49.76 c-f	3.66
I_2N_4	164.40	550.71	233.56 cd	9.18 ab	19.49 b	47.91 efg	3.80
I_3N_1	135.93	406.13	207.33 h	7.34 g	13.51 k	55.30 b	3.08
I_3N_2	146.33	455.73	214.00 g	7.29 g	15.25 ij	48.33 d-g	3.31
I_3N_3	154.07	501.84	218.67 fg	7.87 c-g	16.55 fg	48.19 d-g	3.50
I_3N_4	162.40	541.12	222.22 ef	8.53 bcd	18.26 c	47.32 fg	3.76
I_4N_1	133.80	374.80	181.11 j	7.28 g	11.70 i	63.12 a	2.78
I_4N_2	143.60	452.44	181.11 ij	7.49 fg	14.87 j	51.21 ed	3.16
I_4N_3	150.93	491.60	189.78 i	7.53 fg	16.33 f	46.63 fg	3.28
I_4N_4	158.33	532.83	204.22 h	8.46 b-e	17.68 cd	48.46 d-g	3.52
LSD 5%			6.56	0.90	0.64	3.21	

was also significant. Maximum (8.40 t ha^{-1}) and minimum (7.69 t ha^{-1}) grain yield were observed in case of $I_1$and I_4, respectively as shown in table 2. These results are in line with Bogdan, (1999) who found that grain yield was enhanced significantly by enhancing irrigation frequency. In case of nitrogen levels, N_4showed highest grain yield (8.91 t ha^{-1}) however, lowest grain yield (7.46 t ha^{-1}) was found in case of N_1 which was statistically at par with N_2. These outcomes are in accordance with those of Sabir *et al.* (2000), Silva *et al.* (2000) who reported that by increasing nitrogen rate, grain yield was also enhanced.Their interaction showed that highest grain yield (9.48 t ha^{-1}) was observed in case of I_1 and N_4 andlowestgrain yield (7.28 t ha^{-1}) was found in case of $I_4$and N_1. Similar findings were concluded by Jacob and Pearson (1991).

***Biological yield (t ha^{-1})*:** Nitrogen rates and irrigation levels significantly impacted the biological yield and their interaction was also significant for biological yield. It was found that N_4 showed maximum biological yield (19.03 t ha^{-1}), while minimum biological yield (13.40 t ha^{-1}) was found in N_1 as shown in table 2. These conclusions are supported by Sabir *et al.* (2000) and Mahmood *et al.* (2001) who observed that biological yield enhanced with increase in N rates. In case of irrigation levels, I_1 and I_4showed highest (17.16 t ha^{-1}) and lowest (15.15 t ha^{-1}) biological yield, respectively. These conclusions are in line with Banga *et al.* (1998) and Hussaini *et al.* (2001) who reported that biological yield enhanced by more irrigation. Their interaction showed that highest biological yield (20.68 t ha^{-1}) was observed in case of I_1 and N_4 and lowest biological yield (11.70 t ha^{-1}) was found in case of $I_4$and N_1. These findings are in line with Edalat *et al.* (2009), Compos *et al.* (2004) who observed that biological yield enhanced significantly by both nitrogen and irrigation enhancement.

***Harvest Index (%)*:** Harvest index was significantly affected by nitrogen rates and irrigation levels while interaction also significantly affected harvest index of maize. Individual comparison of treatment means showed that maximum harvest index (52.35) was observed in case of irrigation treatment I_4 (100 mm potential soil moisture deficit) followed by irrigation treatment I_2 (50 mm potential soil moisture deficit) that produced harvest index of (50.67 %). The minimum harvest index (49.90 %) was observed in case of I_1 (8 irrigation) as shown in table 2. These results are in against of Banga *et al.* (1998) and Shah (2001) who observed that harvest index increased with increase in irrigation levels. Individual comparison of treatment means revealed that maximum harvest index 56.83 % was observed in case of N_1 100 kg N ha^{-1} which was followed by N2 125 kg ha^{-1} that produced harvest index of 49.46 %. The minimum harvest index (47.51 %) was observed when nitrogen applied @ 175 kg ha^{-1}. These findings are in not agreement with those of Sabir *et al.* (2000), Mahmood *et al.* (2001) and Waqas (2002) who reported that harvest index increased considerably with the increase in nitrogen rates. Interaction between irrigation levels and nitrogen rates was also found to be significant. Maximum harvest index (63.12 %) was observed in case of I_4 (100 mm potential soil moisture deficit) when nitrogen was applied @ 100 kg N ha^{-1}. Statistically minimum harvest index (46.34 %) was obtained in case of I_1 (8 irrigation) when fertilized with 175 kg Nha^{-1}. The results are not in agreement with that of Pandey *et al.* (2001a)

***Oil contents (%)*:** Oil contents were significantly affected by nitrogen rates while irrigation levels and interaction non-significantly affected the oil contents of maize. Individual comparison showed that maximum oil contents (3.79%) were observed in case of nitrogen treatment N_4 (175 kg N ha^{-1}) which was followed by N_3 (150 kg N ha^{-1}) which produced (3.55%) oil contents as shown in table 2. The minimum oil contents (3.07%) were observed when nitrogen applied @ 100 kg ha^{-1}. These results are in agreement with Hussain (2000) who reported that nitrogen application significantly increased grain oil contents of maize. In nutshell, application of nitrogen at the rate of 175 kg ha^{-1} with recommended full irrigations may improve the yield and quality of maize.

***Conclusion*:** Nitrogen rates and irrigation levels significantly affected the plant height; however, their interaction was non-significant for plant height. It was observed that N_4 showed maximum plant height (165.35 cm), while minimum plant height (137.90 cm) was found in N_1. Number of grains per cob was influenced significantly by nitrogen and irrigation treatments, while interaction was non-significant. Maximum (504.19) and minimum (462.92) number of grains per cob were observed in case of $I_1$and I_4, respectively. Nitrogen rates and irrigation levels significantly affected the 1000-grain weight and their interaction was also significant for 1000-grain weight. It was found that N_4 showed highest1000-grain weight (228.78 g), while minimum 1000-grain weight (213.81 g) was found in N_1. Grain yield was influenced significantly by nitrogen and irrigation treatments. Similarly, interaction was also significant. Maximum (8.40 t ha^{-1}) and minimum (7.69 t ha^{-1}) grain yield were observed in case of $I_1$and I_4, respectively. Harvest index was significantly affected by nitrogen rates and irrigation levels while interaction also significantly affected harvest index of maize. Individual comparison of treatment means showed that maximum harvest index (52.35) was observed in case of irrigation treatment I_4 (100 mm potential soil moisture deficit) followed by irrigation treatment I_2 (50 mm potential soil moisture deficit) that produced harvest index of (50.67 %). The minimum harvest index (49.90 %) was observed in case of I_1 (8 irrigation).

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