

Original Paper



Growth, yield, WUE and NUE of maize under various irrigation application methods and nitrogen application timing

Mahmood-Ul-Hassan¹, Riaz Ahmad² and Muhammad Saqib³

1 Sugarcane Research Institute, Ayub Agricultural Research Institute (AARI), Faisalabad-38850, Pakistan

2 Department of Agronomy, University of Agriculture, Faisalabad-38040, Pakistan

3 Institute of Soil & Environmental Sciences, University of Agriculture, Faisalabad-38040, Pakistan

Received: 16 September, 2019. Accepted: 17 October, 2019

First published on the web December, 2019

Doi: 10.26545/ajpr.2019.b00043x

Abstract

It has been an increasing global interest in adopting new agro-management techniques in crop production to attain improved agro-physiological crop response and resource economization. A field study for two consecutive years was carried out on sandy clay loam soil to ascertain the productivity of Zeamays L. (maize) hybrid with having three irrigation methods viz. irrigation to flat sowing, irrigation to all ridges and irrigation to alternate ridges and four nitrogen application timing viz. control, ½ N at sowing and ½ at 1st irrigation, ½ N at sowing and ½ at 45 days after sowing (DAS) and 1/3 N at sowing + 1/3 at 1st irrigation and 1/3 at 45 DAS. Results of both years revealed that irrigation to all ridges exhibited significantly highest grain yield and yield attributes along with more leaf area index (LAI), dry matter accumulation (TDM), crop growth rate (CGR) and nitrogen and water use efficiencies (WUE and NUE). Three equal splits of nitrogen application resulted in highest grain yield and yield parameters accompanied with maximum LAI, TDM, CGR, WUE and NUE. The results suggested that irrigation to all ridges and applying nitrogen in three equal splits to ridge sowing maize hybrid proved the superior option for maximizing productivity and resource utilization.

Key-words: Maize hybrid, NUE, WUE, Grain Yield

Introduction

The yield potential of crop is not only dependent upon its genetic makeup, but also the environment in which it is grown. However, genetic potential can be exploited to the maximum by providing a favorable growth environment and maize responds differently to varying environments (Javed et al., 2006) under various agro-management practices due to its high yielding potential. Ecological conditions have significant effects on maize yield (Li. et al., 2019). Nitrogen (N) fertilization is a substantial source and key component to high grain yield and optimum economic return in maize. It is a constituent of all proteins and enzymes in plant metabolism, and integral part of chlorophyll (Brady, 1990). Most agricultural soils are deficient in nitrogen for growth of crops, and this deficiency can be overcome by the judicious use of N fertilizers. Urea is a major form of

N used in the world. However, the efficiency of using urea-N for crops is a major concern due to its losses like runoff, erosion, leaching and gaseous emission. Thus, application timing of N fertilizer has key role in efficient utilization and bio-chemical transformation. It is desirable to apply nitrogen in split doses to the crop (Ahmad and Rashid, 2003). The NUE can also be increased by reducing nitrate by splitting application of fertilizer and judicious water application.

Irrigation water is an important input of crop production as it is associated with many factors of the plant environments, which influence growth and development. There is still hot debate among the hydrologists and agronomists about the efficient use of water thus devised various methods of water application. The irrigation requirement of maize varies with soil type and agro-climatic conditions.

✉ Mahmood-Ul-Hassan

E-mail: muh.agr@gmail.com

Usually small quantity of irrigation water may be needed for maize in most part of the country as the best suitable time for sowing is mid June to mid July, which is the peak time of monsoon rainfall. Over irrigation lowers not only the quality and quantity of yield but also cause waterlogging and salinity problems. However, the method, time and amount of irrigation water are the key components in maize production in arid and semi arid areas of the country. Method of irrigation application plays a key role in moisture economizing. Efficient use of scarce water resources using improved irrigation techniques has been the focus of investigations during the past two decades. Furrow-bed method of irrigation save significant quantities of water and improve the fertilizer use efficiency due to line source application (Chaudhary et al., 1994). The irrigation to flat sowing may cause temporary wilting or suffocation to roots, which may result in stoppage of N uptake and other nutrients (Benjamin et al., 1998). Therefore,

irrigation should be scheduled carefully to maximize NUE.

Keeping in view the above facts, this study was designed to determine the impact of nitrogen management on productivity of maize hybrid, and to explore its maximum potential with regard to water and nitrogen use efficiencies under varying irrigation and nitrogen management regimes in semi arid conditions of Faisalabad, PAKISTAN.

Material and methods

The study was carried out on a sandy clay loam soil at the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during 2006 and 2007. Experimental site is located at 31.30 N latitude, 73.060 E longitude and 184 m altitude. Meteorological data for both years were collected from the meteorological observatory of the Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan (Table 1).

Table 1. Metrological data during growing season 2006 and 2007.

MONTH	Temperature (C°)						R.H (%)		Total Rainfall (mm)	
	Maximum		Minimum		Average		2006	2007	2006	2007
	2006	2007	2006	2007	2006	2007				
July	38.82	36.37	29.27	27.42	34.05	31.9	43	55	36	149.7
August	38.13	37.16	28.15	28.11	33.14	32.64	47	51	79.2	19.5
September	36.82	34.97	24.92	25.38	30.87	30.18	41	51	76.2	12.2
October	34.34	32.77	19.72	16.9	27.03	24.84	49	33	7.4	0
November	27.17	27.42	14.62	13.27	20.89	20.34	47	47	12.8	0

Table 2. Physio-chemical analyses of the soil samples from experimental site

DETERMINATION	2006	2007
A. Physical characteristics		
Sand (%)	63.25	65.10
Silt (%)	15.05	15.65
Clay (%)	21.70	19.25
Textural class	Sandy clay loam	Sandy clay loam
B. Chemical analysis		
pH	7.15	7.90
EC (dSm ⁻¹)	0.35	0.42
Organic matter (%)	0.69	0.70
Total N (%)	0.053	0.053
Available P (ppm)	6.05	6.00
Available K (ppm)	147	154

I₁: Irrigation to all ridges (irrigation to ridge sowing) and I₃: Irrigation to alternate ridges (alternate furrow irrigation)

Physio-chemical analysis of the site was done before sowing. Composite soil samples were collected from the experimental area at a depth of 15-30 cm (Table 2). The experiment was laid out in randomized complete block design (RCBD) with a split plot arrangements and three replications. Method

of irrigation was assigned to main plots and N application timing to sub plots. The experiment treatments were I₁: Irrigation to flat sowing (flooding), I₂: Irrigation to all ridges (irrigation to ridge sowing) and I₃: Irrigation to alternate ridges (alternate furrow irrigation).

Nitrogen application timings were N0: Control, N1: ½ N at sowing and ½ at 1st irrigation, N2: ½ N at sowing and ½ at 45 DAS and N3: 1/3 N at sowing + 1/3 at 1st irrigation and 1/3 at 45 DAS. The net plot size of smallest experimental unit (sub plot) was 3 m x 7.5 m. Maize single cross hybrid Monsanto DK-922 was sown on 6 July 2006 and 12 July 2007. The seed bed was well prepared and ridges were made using tractor mounted rigder. A dibbler was used for sowing of crop seed in plots of flat sowing treatments while sowing on ridges was done manually using seeding rate of 30 kg ha⁻¹. The row to row distance of 75cm and plant to plant distance of 20cm was maintained both in flat and ridge sowing.

The NPK fertilizers were applied at 200-150-100 kg ha⁻¹ in the form of urea, diammonium phosphate (DAP) and sulphate of potash (SOP), respectively. A full dose of phosphorus and potassium were applied at the time of seed bed preparation. Nitrogen was applied in patterns as per treatments by band placement / side dressing to ensure maximum availability to crop plants. During the crop growing period, each experimental unit was irrigated seven times with measured quantity of water using a cut-throat flume in both years.

Thinning was carried out at the four-leaf stage of crop and same plant population (66666 plants ha⁻¹) was maintained for all treatments. Standard plant protection measures were adopted to control insect pests and weeds.

Measurement of irrigation water processing

Irrigation water to each experimental unit was applied using a cut throat flume (3''x8''), installed in water course. The time required to irrigate an experimental unit and flow rate was recorded to estimate the amount of water applied. The depth of water applied to each plot was calculated by the formula:

$$d = Q t / A$$

where d=depth in inches, Q=discharge in cusecs, t=time in hours and A=area in acre.

Harvesting

Maize was harvested at physiological maturity, as indicated by the appearance of a black abscission layer at the base of grains (about 30-35% grain moisture content), on 18th and 29th of November 2006 and 2007, respectively. Then after, crop plants

were sundried and tied into small bundles. Afterwards, ears were separated from stalk and further sundried for a few days before shelling, which was done at 14% seed moisture contents.

Growth observations

To determine the leaf area, sampling was initiated 30 DAS (days after sowing) and continued at regular intervals of fifteen days until 105 DAS. Leaf area was measured by a portable leaf area meter (Model CI-202) and total leaf area was calculated by selecting ten plants randomly from each experimental unit and then averaged. Thereafter, leaf area index (LAI) was calculated by the Watson (1947) formula:

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Land area}}$$

Total dry matter was recorded at 15 days intervals by selecting ten plants from each experimental unit. Sampling was initiated 30 DAS and terminated at 105 DAS. Each sample was weighed to determine the fresh weight and then chopped into small pieces. A 100-gram sub-sample from each experimental unit was taken in muslin cloth bags, oven dried at 75 ± 5°C to a constant dry weight, and then dry weight per plant was calculated. The crop growth rate (CGR) was calculated by the formula of Hunt (1978):

$$\text{CGR} = \frac{W_2 - W_1}{T_2 - T_1} \quad (\text{g m}^{-2} \text{ day}^{-1})$$

Where T₂ - T₁ = 15 days

Yield and yield attributes

Grains from ten randomly selected ears of each treatment were shelled, counted and converted into grains ear⁻¹. Thousand-grain weight was determined from three randomly selected samples of 1000 grains from each experimental unit, weighed on an electric balance, and then averaged. Grain yield was determined after sun drying the ears for 15 days, shelling was done with mechanical maize sheller. Grain yield of each plot was recorded and converted into tons per hectare (t ha⁻¹).

Water use efficiency (kg ha⁻¹ mm⁻¹)

$$\text{WUE} = \frac{\text{Economic yield (grain yield)}}{\text{Amount of water applied}}$$

Nitrogen use efficiency (kg kg-1)

$$NUE = \frac{\text{Yield of fertilized plot (kg)} - \text{Yield of non-fertilized plot (kg)}}{\text{Amount of fertilizer applied (kg)}}$$

Statistical Analysis

Data were analyzed using Fisher’s analysis of variance in the computer statistical package “MSTAT-C” (Freed and Eisensmith, 1986), and treatment means were compared using least significant difference (LSD) test at 5% level of probability (Steel et al., 1997).

Results and discussion

Leaf area index (LAI)

It is a dimensionless variable and was first defined as the total one-sided area of photosynthetic tissue per unit ground surface area (Watson, 1947). The LAI in all treatments increased progressively with the advancement of crop growth period, reached maximum at 75 DAS, and then declined at 90 DAS during both years of study (Figure 1). The LAI of maize was significantly affected by irrigation methods and N application timings. It was higher in plots received irrigation to all ridges (I2) and was lowest in irrigation to alternate ridges (I3) during both years (Table 3).

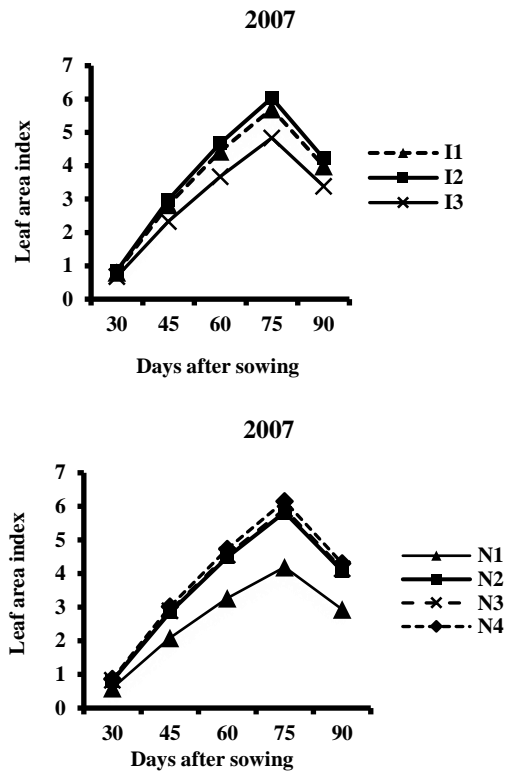
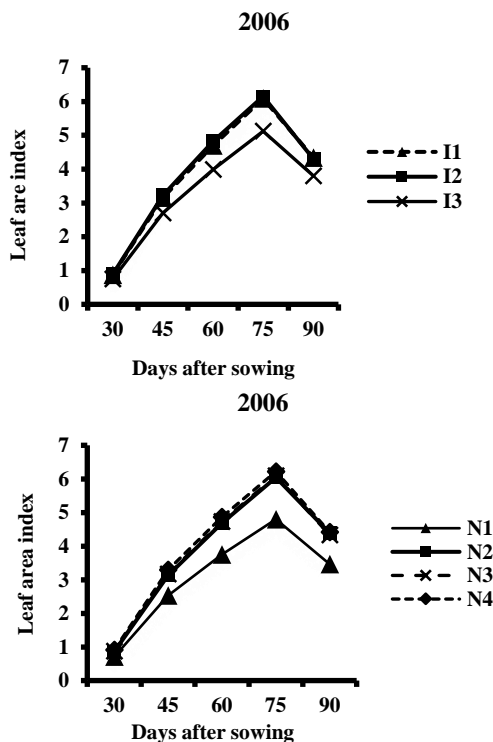


Fig. 1. Periodic leaf area index ($\text{g m}^{-2}\text{day}^{-1}$) of maize as influenced by irrigation method and nitrogen application timing during 2006 and 2007.

The highest LAI in I2 was probably due to better soil moisture available to crop plants during the growing period and led to progressive crop growth. Ahmad et al (2002), Shah et al. (2003) and Patel et al. (2006) also confirmed similar results by concluding that LAI in maize varied significantly among various irrigation application methods. The treatment N3 produced maximum LAI whereas the lowest was recorded in N0 during 2006 and 2007, respectively (Table 4).

The increase in LAI by splitting N application might be due to better uptake and utilization of N by crop plants to produce more photosynthates and partitioning to leaves. These results are partially supported by Amanullah et al. (2009). The interaction between irrigation application methods and N application timing for LAI was not significant in 2006 and significant in 2007 (Table 5). A positive and linear relationship between maize grain yield and LAI was observed which indicated the corresponding increase in grain yield with the increase in LAI (Figure 3).



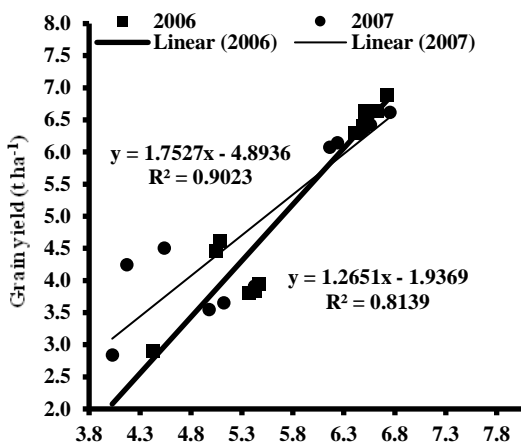


Fig. 3. Relationship between leaf area index.

Total dry matter (TDM)

The TDM of maize was increased with the progress in crop growth period during each year of study (Figure 2). Maize exhibited higher TDM for irrigation to all ridges than other irrigation methods compared with lowest in irrigation to alternate ridges during 2006 and 2007, respectively (Table 3).

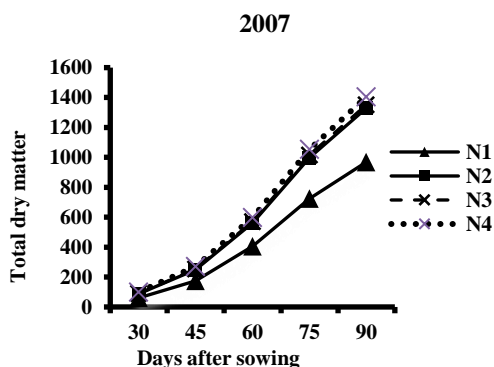
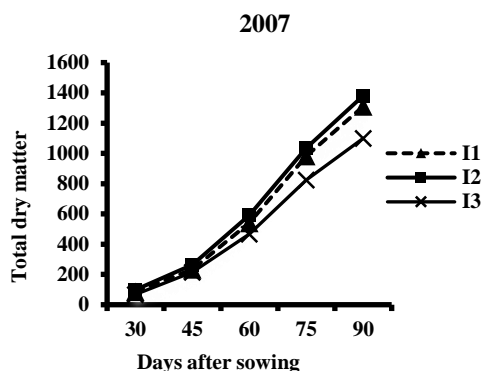
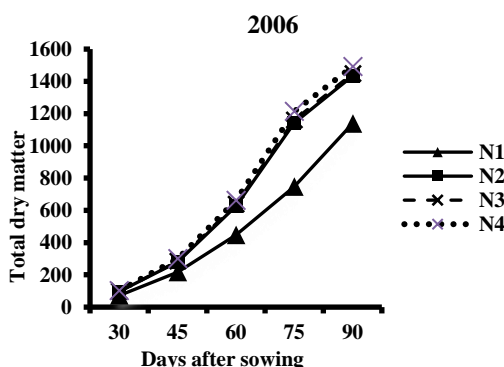
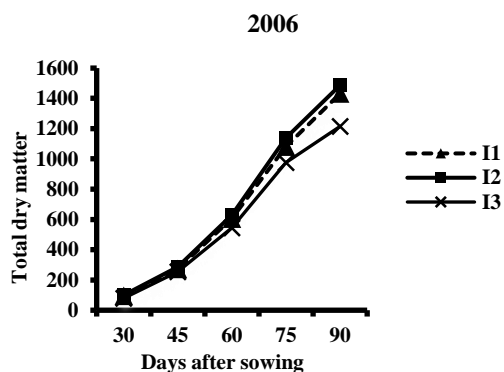


Fig. 2. Periodic total dry matter accumulation (g m^{-2}) as influenced by irrigation method and nitrogen application timing during 2006 and 2007.



The higher TDM in (I2) might be due to more availability of moisture to the crop plants having synergistic effect on nutrients absorption to speed up plant growth by accelerating physiological functions. Patel et al. (2006) reported the similar results for TDM of maize under various irrigation methods. The N application on three variable times (N3) resulted in maximum TDM whereas minimum in control (N0) during both years. The maximum TDM in I2 was probably due to more N supply at critical growth stages of the crop to produce LAI. These results are supported by the findings of Amanullah et al. (2009).

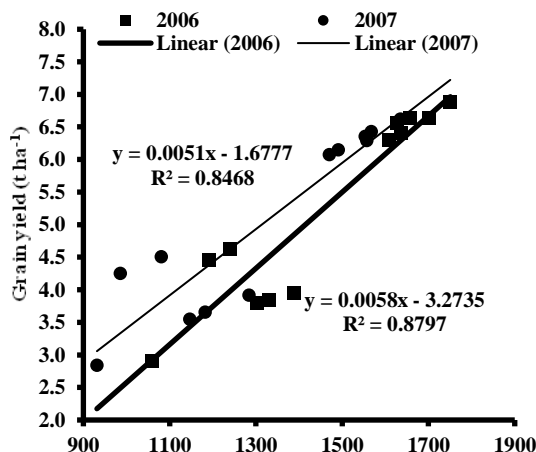


Fig. 4. Relationship between total dry matter.

The interactive effect of irrigation method and N application timing on TDM was non-significant in 2006 and significant in 2007. There was a positive and linear correlation between maize grain yield and TDM showing corresponding increase in grain yield with increase in TDM during both years (Figure 4).

Crop growth rate (CGR)

It is a measure of growth rate of plant per unit land area and time. The CGR of maize varied significantly by irrigation methods and N application timings in both years. In 2006, the highest CGR was recorded for irrigation to all ridges which was at par with irrigation to flat sowing whereas, the lowest was resulted in irrigation to alternate ridges. The same trend was exhibited in 2007. The CGR depends on the amount of intercepted photosynthetically active radiation (PAR), hence the LAI is a key factor in dry matter production (Girardin and Tollenaar, 1994). Similarly, the highest CGR recorded in I2 was due to high LAI and TDM. These results are confirmed by the findings of Patel et al. (2006) and Ahmad et al. (2003).

The N application in three splits (N3) resulted in maximum CGR of maize which was at par with N2 and N1 over the lowest in N0. A similar trend was

noticed during 2007. This increase in CGR by splitting N in thrice was likely due to extended crop growth period because of continuous N supply and uptake besides the minimum losses in the field due to its greater exposure to crop roots.

The interactive effect of I x N on CGR of maize was non-significant in 2006 but significant in 2007. There was a positive and linear correlation between grain yield and CGR of maize in both years showing the interdependence between these two parameters (Figure 5).

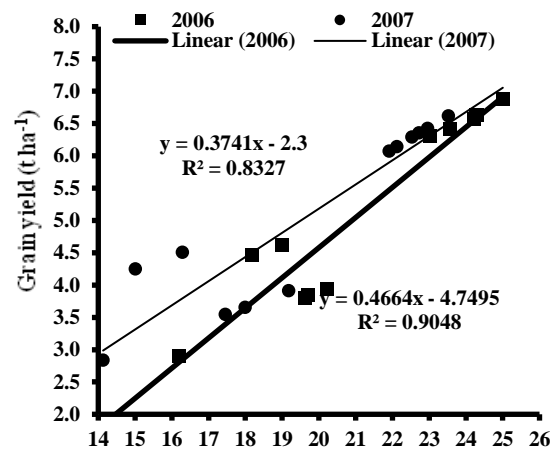


Fig. 5. Relationship between crop growth rate and and grain yield.

Table 3. Impact of irrigation methods on growth characteristics, yield attributes, grain yield, water and nitrogen use efficiency in hybrid maize.

Irrigation method (I)	Leaf area index (g m ² day ⁻¹)	Total matter (g m ⁻²)	dry	CGR (gm ² day ⁻¹)	Grains ear ⁻¹	1000-Grain weight (g)	Grain yield (t ha ⁻¹)	WUE (kg ha ⁻¹ mm ⁻¹)	NUE (kg kg ⁻¹)
2006									
I ₁ : Irrigation to flat sowing	6.09 a	1534 a		22.3 a	284 a	266.9 a	5.95 a	12.31 b	7.47 a
I ₂ : Irrigation to all ridge	6.15 a	1569 a		23.1 a	296 a	277.1 a	6.18 a	15.13 a	7.77 a
I ₃ : Irrigation to alternate ridges	5.12 b	1270 b		18.9 b	240 b	228.5 b	3.62 b	10.75 c	3.58 b
LSD (P ≤ 0.05)	0.4576	167.1		2.227	34.64	27.45	0.61	1.404	1.203
2007									
I ₁ : Irrigation to flat sowing	5.7 b	1376 b		20.4 b	266 b	248.8 b	5.69 b	11.34 b	7.21 a
I ₂ : Irrigation to all ridges	6.03 a	1459 a		21.4 a	280 a	262.3 a	5.98 a	14.77 a	7.35 a
I ₃ : Irrigation to alternate ridges	4.84 c	1136 c		17.2 c	221 c	208.5 c	3.49 c	10.80 c	3.25 b
LSD (P ≤ 0.05)	0.1930	51.1		0.6104	8.983	8.734	0.1897	0.4087	1.535

Means followed by same letter do not differ significantly (P < 0.05)

Grains ear⁻¹

The grains ear⁻¹ was significant under various irrigation methods and N application timing in both years. The irrigation to all ridges was superior which resulted in highest number of grains ear⁻¹ whereas the lowest in irrigation to alternate ridges during 2006. The similar data pattern was observed in 2007. The more number of grains ear⁻¹ produced I₃ was

attributed to adequate moisture supply to plant roots, having synergistic effect on nutrients uptake and to prolong reproductive phase of the crop. The similar findings were opined by Ahmad et al. (2002).

The maximum number of grains ear⁻¹ was recorded in N₃ which was at par with N₂ compared with minimum in N₀ during 2006. The same trend was noticed in 2007. The more grains ear⁻¹ in N₃ was probably attributed to more uptake and utilization of

N by crop plants which led to more photosynthates production. Similar results were reported by Saleem et al. (2009), and Vetsch and Randall (2004).

The interactive effect of irrigation methods and N application timing on grains ear⁻¹ was non-significant in 2006 and significant in 2007. A positive linear relationship between grain yield and grains ear⁻¹ was observed in both years (Figure 6).

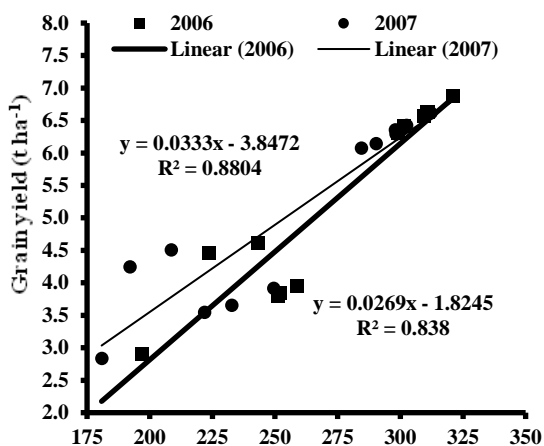


Fig. 6. Relationship between grain ear⁻¹ and grain yield.

1000-Grain weight

The grain weight is one of the major yield contributing factors, which reflects the photosynthetic potential of a crop plant and its capacity to transport assimilates into economically valuable plant organs (Rizwan et al., 2003). The maize irrigated to all ridges exhibited higher test weight than other irrigation methods whereas lowest was noticed in irrigation to alternate ridges. The heavier grains produced in I2 could be due to sufficient supply of soil moisture to crop plants couple with more nutrients uptake which increased the growth and yield characteristics of maize, and resulted in more assimilates production and partitioning. The lowest 1000-grain weight in I3 was because of water stress which induced temporary wilding at growth and reproductive phase of the crop. These results are in conformity with the findings of Ahmad et al. (2002) and Shah et al. (2003).

Three equal splits of N application (N3) to maize was superior compared with minimum in control (N0) during 2006 and 2007, respectively. The increase in test weight in N3 was due to better physiological response of the crop to enhance plant growth because of sufficient N supply and uptake around the grain filling period of the crop. Similar results were reported by Sangoi et al. (2007) and Saleem et al.

(2009). The interaction between irrigation method and N application timings was not significant in 2006 and significant in 2007. A highly significant positive linear correlation was found between grain yield and 1000-grain weight which reflect the interdependence of two characters (Figure 7).

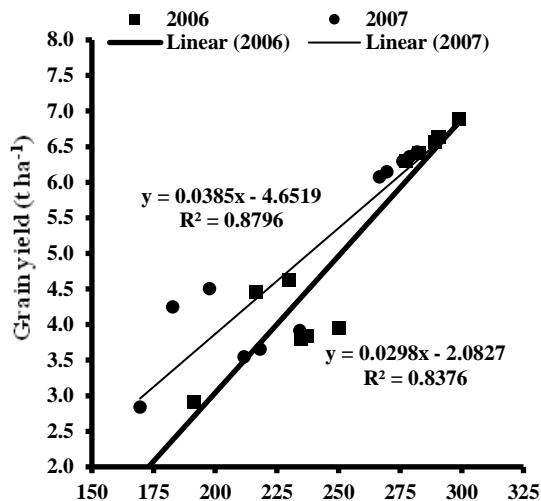


Fig. 7. Relationship between 1000- grain weight and grain yield.

Grain yield

The grain yield per unit area is a function of interaction among various yield contributing factors, which are usually affected differently by the growing conditions and crop management practices. The statistical results revealed that grain yield of maize varied significantly by irrigation methods and N application timing in both years.

The maize irrigated to all ridges (I2) produced highest grain yield compared with the lowest in irrigation to alternate ridges (I3) (Table 3). This increase in grain yield for I2 was 4 to 41 and 5 and 42% higher than I1 and I3 respectively, during 2006 and 2007. The highest grain yield for irrigation to all ridges was probably due to better crop establishment because of efficient utilization of irrigation water as better soil moisture maintained in readily available range which might have favored the progressive growth of crop plants for growth characteristics, and consequently brought out more grains ear⁻¹, grain weight ear⁻¹ and 1000-grain weight, which contributed to higher grain yield. These results are confirmed by the findings of Patel et al. (2006), Shafiq et al. (2003) and Shah et al. (2003).

The N application in there splits (N3) to maize exhibited higher grain yield (5.82 and 5.61 t ha⁻¹) than others which was at par with N2, respectively, in 2006

and 2007, respectively. The lowest grain yield was recorded in control plots (Table 4).

Table 4. Impact of nitrogen application timing on growth characteristics, yield attributes, grain yield, water and nitrogen use efficiency in hybrid maize

Nitrogen application timing (N)	Leaf area index (g m ⁻² day ⁻¹)	Total dry matter (g m ⁻²)	CGR (gm ⁻² day ⁻¹)	Grains ear ⁻¹	1000-Grain weight (g)	Grain yield (t ha ⁻¹)	WUE (kg ha ⁻¹ mm ⁻¹)	NUE (kg kg ⁻¹)
2006								
N ₀ : Control	4.8 b	1163 c	17.8 b	221 b	212.8 b	4 b	9.74 b	0.00 b
N ₁ : ½ N at sowing and ½ at I st irrigation	6.04 a	1513 b	22.3 a	286 a	267.1 a	5.56 a	13.48 a	7.80 a
N ₂ : ½ N at sowing and ½ at 45 DAS	6.09 a	1542 ab	22.5 a	288 a	270.1 a	5.63 a	13.62 a	8.16 a
N ₃ : ⅓ N at sowing + ⅓ at I st irrigation and ⅓ at 45 DAS	6.22 a	1613 a	23.2 a	297 a	279.9 a	5.82 a	14.09 a	9.13 a
LSD (P ≤ 0.05)	0.3823	88.48	1.371	17.97	14.9	0.352	0.9099	1.757
2007								
N ₀ : Control	4.19 c	999 c	15.1 c	194 c	183.3 c	3.87 c	9.48 c	0.00 c
N ₁ : ½ N at sowing and ½ at I st irrigation	5.82 b	1390 b	20.7 b	268 b	252.4 b	5.33 b	12.99 b	7.31 b
N ₂ : ½ N at sowing and ½ at 45 DAS	5.92 ab	1414 b	21 ab	275 ab	256.6 b	5.41 ab	13.09 b	7.72 ab
N ₃ : ⅓ N at sowing + ⅓ at I st irrigation and ⅓ at 45 DAS	6.16 a	1492 a	21.8 a	287 a	267 a	5.61 a	13.65 a	8.72 a
LSD (P ≤ 0.05)	0.2766	57.47	0.7923	11.91	10.23	0.2215	0.5259	1.103

Means followed by same letter do not differ significantly (P < 0.05)

The increase in grain yield of maize for N₃ might be due to timely N supply and its uptake during the growing period, and to increase all physiological characteristics which resulted in more yield attributes towards grain yield. Sangoi et al. (2007), Saleem et al. (2009) and Macharia et al. (2010) reported the

similar results by concluding that splitting of nitrogenous fertilizer increased the grain yield of maize. The interactive effect of irrigation methods and N application timings on grain yield of maize was non-significant in 2006 and significant in 2007 (Table 5).

Table 5. Irrigation method x nitrogen application timing (I x N) interaction for growth characteristics, yield attributes, grain yield, water and nitrogen use efficiency in hybrid maize

Interaction (I x N)	Leaf area index (g m ⁻² day ⁻¹)	Total dry matter (g m ⁻²)	CGR (gm ⁻² day ⁻¹)	Grains ear ⁻¹	1000-Grain weight (g)	Grain yield (t ha ⁻¹)	WUE (kg ha ⁻¹ mm ⁻¹)	NUE (kg kg ⁻¹)
2006								
I ₁ x N ₀	4.99	1191	18.2	224	216.7	4.46	9.22	0.00
I ₁ x N ₁	6.36	1608	23	299	277.4	6.3	13.06	9.22
I ₁ x N ₂	6.43	1636	23.6	301	282.7	6.41	13.29	9.77
I ₁ x N ₃	6.57	1701	24.3	311	290.7	6.64	13.69	10.88
I ₂ x N ₀	5.03	1240	19	243	229.9	4.62	11.36	0.00
I ₂ x N ₁	6.45	1627	24.2	309	289.2	6.57	16.09	9.72
I ₂ x N ₂	6.46	1658	24.3	311	290.5	6.63	16.22	10.05
I ₂ x N ₃	6.67	1751	25	321	298.8	6.88	16.86	11.30
I ₃ x N ₀	4.38	1058	16.2	197	191.6	2.91	8.66	0.00
I ₃ x N ₁	5.32	1302	19.6	251	234.9	3.8	11.28	4.48
I ₃ x N ₂	5.38	1332	19.7	252	237.2	3.84	11.36	4.65
I ₃ x N ₃	5.42	1388.6	20.22	258.8	250.25	3.95	11.7	5.20
LSD (P ≤ 0.05)	-	-	-	-	-	-	-	-
2007								

I ₁ x N ₀	4.12 ef	985 fg	15.0 fg	192 fg	182.8 fg	4.25 cd	8.47 f	0.00
I ₁ x N ₁	6.11 b	1470 b	21.9 b	284 b	266.6 b	6.08 b	12.14 bc	9.13
I ₁ x N ₂	6.19 b	1491 b	22.1 b	290 b	269.7 b	6.15 b	12.26 b	9.48
I ₁ x N ₃	6.4 ab	1557 ab	22.5 ab	298 ab	276.1 ab	6.29 ab	12.50 b	10.22
I ₂ x N ₀	4.49 de	1081 ef	16.3 ef	209 ef	197.7 ef	4.51 c	11.16 de	0.00
I ₂ x N ₁	6.44 ab	1554 ab	22.7 ab	298 ab	278.9 ab	6.36 ab	15.78 a	9.25
I ₂ x N ₂	6.51 ab	1568 ab	23 ab	302 ab	282 ab	6.43 ab	15.73 a	9.60
I ₂ x N ₃	6.7 a	1635 a	23.5 a	312 a	290.5 a	6.62 a	16.39 a	10.57
I ₃ x N ₀	3.98 f	931 g	14.1 g	181 g	169.5 g	2.84 f	8.8 f	0.00
I ₃ x N ₁	4.93 cd	1147 de	17.5 de	222 de	211.8 de	3.55 e	11.04 e	3.54
I ₃ x N ₂	5.07 c	1183 d	18 cd	233 cd	218.2 cd	3.66 e	11.29 cde	4.08
I ₃ x N ₃	5.37 c	1284 c	19.2 c	249 c	234.4 c	3.92 de	12.05 bcd	5.38
LSD (P ≤ 0.05)	0.4791	99.53	1.372	20.62	17.72	0.3836	0.9109	-

Means followed by same letter do not differ significantly (P < 0.05)

Water use efficiency (WUE)

It is a function of multiple factors including physiological characteristics of maize, genotype, oil characteristics, meteorological conditions and agronomic practices. The WUE of maize was significantly affected by various irrigation methods and N application timing during both years.

The higher WUE was recorded in crop plots irrigated to all ridges (I₂) whereas the lowest for irrigation to alternate ridges (I₃) during 2006 and 2007, respectively. The higher WUE in maize for I₂ was attributed to better crop stand, and efficient utilization of irrigation water in transpiration and other metabolic processes. Huang et al., (2006) and Shah et al. (2003) confirmed the similar results by concluding that maize exhibited higher WUE for irrigation to all ridges than other methods.

The N application in three splits was superior with maximum WUE compared with the minimum was noticed in control plots during both years. More WUE for N₃ was probably due to better N supply, uptake and utilization besides efficient use of available water in physiological process during growth and development of the crop. The interaction between irrigation methods and N application timings was non-significant in 2006 and significant in 2007.

Nitrogen use efficiency (NUE)

The irrigation to all ridges exhibited the highest NUE in maize and was at par with irrigation to flat sowing over the lowest in irrigation to alternate ridges during both years (Table 3).

The increase in NUE might be due to continuous supply of moisture to plant roots which resulted in more nutrients absorption from the soil during

growing period of the crop. The NUE in maize was increased for all N application timings over control but the plots received N in three equal splits (N₃) resulted in highest NUE which was at par with N₂ during 2006 and 2007, respectively (Table 4).

The highest NUE in maize for N₃ might be due to uniform N supply at peak demands of the crop which led to better performance at vegetative and reproductive stage, and resulted in improved growth and yield attributes. Macharia et al. (2010) reported the similar variation in NUE of maize under various N application timing. The interaction between irrigation methods and N application timing for NUE of maize was non-significant in both years (Table 5).

Conclusion

It is concluded from the results that maize should be sown on ridges facilitating the irrigation water to all furrows for getting maximum grain yield and water economy. Similarly, the splitting of nitrogen application in three equal splits could be the better option for getting higher grain yield and nitrogen use efficiency.

Conflict of interest: All authors declare no conflict of interest.

References

- Ahmad, N. and M. Rashid. 2003. Fertilizers and their use in Pakistan. Extension Bulletin. NDFC. Islamabad
- Ahmad, R., A. Mahmood, M. Ikraam and B. Hassan. 2002. Influence of different irrigation methods and band placement of nitrogen on maize productivity. Int. J. Agric. Biol 4: 540-543

- Amanullah, K.B.; Marwat, P.; Shah, N.; Maula and S. Arifullah. 2009. Nitrogen levels and its time of application influence leaf area, height and biomass of maize planted at low and high density. *Pak. J. Bot* 41(2):761-768
- Benjamin, J.G., L.K. Porter, H.R. Duke, L.R. Ahuja and G. Butters. 1998. Nitrogen movement with furrow irrigation method and fertilizer band placement. *Soil Sci. Soc. Am. J* 62(4):1103–1108
- Brady, N.C. 1990. The nature and properties of soils. 10th Ed. New York: Macmillan Publishing Company, USA
- Chaudhry, M.R., A.D. Chaudhry, S. Akbar, M. Iqbal and M. Asif. 1994. Water and fertilizer conservation by improved irrigation methods. *Pak. J. Agric. Sci* 31 (1): 87-90
- Freed, R.D., and S.P. Eisensmith. 1986. M. Stat. Micro Computer Programme, Michigan State University Agric. Michigan, Lansing, USA
- Girardin, P.H. and M. Tollenaar, 1994. Effects of intra-specific interference on maize leaf azimuth. *Crop Sci* 34: 151–155
- Huang, R., C. J. Birch and D. L. George. 2006. Water use efficiency in maize production – the challenge and improvement strategies. 6Th Triennial conference 2006. Maize association of Australia
- Hunt, R. 1978. Plant growth analysis. *Studies in biology. Edward Arnold* 96: 26-38
- Javed, H.I., M.A. Masood, S.R. Chughtai, H.N. Malik, M. Hussain and A. Saleem. 2006. Performance of maize genotypes on the basis of stability analysis in Pakistan. *Asian J. Plant Sci* 5(2): 207-210
- Macharia C.N., C.M. Njeru, J.W. Kamundia, L.S. Nafuma, A. Gichangi and M.S. Shiluli. 2010. Nitrogen use efficiency and maize yield response to rate and mode of nitrogen application in the Kenya highlands. *Proceedings of 12th KARI Biennial Scientific Conference. 8-12 November, 2010*
- Patel, R.G., G.B. Shah, B.S. Patel and S. Raman. 2006. Effect of depth and method of irrigation on yield and water economy sugarcane. *Ind. J. Agron* 34(1):80-84 (Irri. and Drain. Absts., 18(1):311;1992)
- Q. Li, F. Kong, W. Long, Y. Wu, Q. Cheng, P. Dou, X. Ma, J. Yuan, and X. Guo. 2019. Effects of planting density and cropping pattern on the dry matter accumulation and yield of maize (*zea mays* l.) in southwest China. *J. Anim. Plant Sci* 29(1):182-193
- Rizwan M., M. Maqsood, M. Rafiq, M. Saeed and Z. Ali. 2003. Maize (*Zea mays* L.) response to split application of nitrogen. *Int. J. Agri. Biol.*, 5(1):19-21
- Saleem, M. F., S. Randhawa, S. Hussain, M. A. Wahid and S. A. Anjum. 2009. Nitrogen management studies in autumn planted maize (*Zea mays* L.) hybrids
- Sangoi, L., P.R. Ernani and P.R.F., Silva. 2007. Maize response to nitrogen fertilization timing in two tillage systems in a soil with high organic matter content. *R. Bras. Ci. Solo* 31:507-517
- Shafiq, M., I. Hassan and Z. Hussain. 2003. Maize crop production and water use efficiency as affected by planting methods. *Asian J. Plant Sci* 2(1):141-144
- Shah, S.H., F. Ahmad, M.F. Saleem and S.I. Zamir. 2003. Effect of planting patterns on water use efficiency and agronomic characteristics of maize (*Zea mays* L.). *Pak. J. W. Resources* 7(2):11-14
- Steel, R.G.D., J.H. Torrie and D.A. Dickey. 1997. Principles and Procedures of Statistics. A Biometrical approach, 3rd Ed. McGraw Hill Book Co., New York, 172-177
- Vetsch, J.A., and G.W. Randall. 2004. Corn production as affected by nitrogen application timing and tillage. *Agron. J.*, 96(2): 502–509
- Watson, D.J. 1947. Comparative physiological studies on the growth of field crops. Variation in net assimilation rate and leaf area between species and varieties and within and between years. *Annals of Botany* 11: 41-76

Cite this article as:

Hassan, Mahmood-UI.; Ahmad, Riaz.; Saqib, Muhammad. 2019. Growth, yield, WUE and NUE of maize under various irrigation application methods and nitrogen application timing. **Amaz. Jour. of Plant Resear.** 3(3): 343-352.

Submit your manuscript at

[https:// www.ajpr.online](https://www.ajpr.online)