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Effect of Irrigation Schedules and Nitrogen Rates on Yield and Yield Components of Maize

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ABSTRACT

A field study was conducted to assess the effects of irrigation and nitrogen rates on hybrid maize yield. The results revealed that yield parameters like cobs plant^{-1}, grains cob^{-1} and mean grain weight were influenced significantly by different irrigation schedules and nitrogen rates. Generally, the grain yield increased with increasing irrigation or N levels. Maximum grain yield (> 7.0 t ha^{-1}) was recorded with I_3 (-8 bars) irrigation schedule and N_3 rate (200 kg ha^{-1}) of application.

Key Words: Grain yield; Yield components; Irrigation schedules; Nitrogen rate; Maize.

INTRODUCTION

Maize (*Zea mays* L.) occupies an important position in the existing cropping systems of Pakistan due to source of good economic return in a short duration and diversified products such as corn oil, glucose-D, starch etc. The crop is grown on an area of 868.6 thousand hectares giving annual production of 1.25 million tones and average grain yield of 1440 kg ha^{-1} (Anonymous, 2000). The average grain yield of maize is not only substantially lower compared with other important maize growing countries but also less than the production potential of existing genotypes. Main constraints to increase maize productivity are malnutrition, inadequate water supply, weed infestation, pest attack etc. Thus there is a need to develop a site specific agro-technology to increase productivity of maize by making improvement in some basic components of the existing maize production technology in Pakistan.

Maize has high yield potential and responds well to different management practices. Among various management practices, irrigation and nitrogen nutrition play a significant role in realizing the maximum potential of the crop. Irrigation scheduling is the technology for applying the proper amount of water at the right time. Reasons for using irrigation scheduling are to reduce water applications, energy consumption and deep percolation of water below the crop root zone (Ritter & Manager, 1985). Water is further required to provide constant turgor pressure that supports the plant and facilitates cell enlargement after cell division has been initiated. Hence, plant growth and survival depend on adequate water availability. Irrigation also improves the efficiency of fertilizer utilization by the crop. Increases in irrigation frequency increased N, P and K uptake by maize (Prasad & Prasad, 1988). Maximum grain yield and greater water use efficiency were achieved when irrigating to 100% of field capacity (Mbagwu & Osuigwu, 1985). Highest grain yield was obtained with 120 kg K_2O ha^{-1} and irrigation at 25% depletion of available soil moisture (Patel *et al.,* 1985). Crude protein contents increased with increase in irrigation frequency (Pillai *et al.,* 1990).

Management of crop nutrition includes correct manuring at right time, optimum level and appropriate method of application. Nitrogen, being an integral part of structural and functional proteins, chlorophyll and nucleic acids such as RNA and DNA as well as essential for proper carbohydrate utilization, plays a vital role in crop development (Tisdale *et al.,* 1990). Increased application of nitrogen gives faster rate of leaf expansion (Wright, 1982), increased leaf area index, leaf area duration, photosynthetic rate and increased radiation interception and radiation use efficiency (Muchow & Davis, 1988; Sinclair & Horie, 1989; Connor *et al.,* 1993). Both nitrogen deficiency and excess affects assimilate partitioning between vegetative and reproductive organs (Donald & Hamblin, 1976). Crude protein concentration is frequently increased by adequate nitrogen supply (Tisdale *et al.,* 1990).

The present study was therefore, undertaken to determine the optimum level of irrigation schedules and nitrogen rates for enhanced grain yield and its components under semi arid irrigated conditions.

MATERIALS AND METHODS

A field study was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad (31°.26'N, 73°.06'E, 184.4m) during 1997 and 1998 summer seasons.

Experiment was laid out in a randomized complete block design with split plot arrangement four replications.Irrigation schedules were kept as main plots and nitrogen levels as subplots.

Irrigation schedules were I_1 (control, weekly irrigation), I_2 (-4 bars), I_3 (-8 bars) and I_4 (-12 bars) and nitrogen rates were N_0 (control), N_1 (100 kg N ha^{-1}), N_2 (200 kg N ha^{-1}) and N_3 (300 kg N ha^{-1}). Plot size was 3 m x 5 m with four rows in each plot.

Maize cv. Golden was sown in 75 cm spaced rows on 10 August and 5 August during 1997 and 1998, respectively, using a dibble at 15 cm plant to plant distance. A basal dose of 100 kg P_2O_5 ha^{-1}and 100 kg K_2O ha^{-1} was applied. Total P, K and half dose of N in the form of tri-super phosphate, potassium sulphate and urea, respectively was side-dressed at sowing. Remaining half of nitrogen was top-dressed with second irrigation. Irrigation was given according to specified irrigation schedule. Crop was kept free of weeds by hoeing on 9 September 1997 and 24 August 1998 to avoid weed-crop competition. Sunfuran was applied @ 20 kg ha^{-1} on 10 September 1997 and 15 September 1998 against borer control. All other agronomic practices were kept normal and uniform for all the treatments.

Final harvest was done on 21November 1997 and 6 November 1998 by harvesting an area of 3 x 4m. All plants in the respective plots were sun dried in the field for two days; thereafter tied into bundles and stalked for four weeks. A sub sample of 20 plants was randomly taken to determine different yield components. All the cobs were separated from the stalks and allowed to dry in sunshine for further few days before threshing. Then the grain yield was converted into kilograms per hectare.

RESULTS AND DISCUSSION

Biomass. Table I shows the effect of treatments on biomass production at final harvest in both years. The I_2 (-4 bars) treatment gave the maximum biomass yield as compared to all other irrigation treatments in both years, except in 1997 when I_2 (-4 bars) and I_3 (-8 bars) treatments were, however, statistically at par in biomass production. The control and I_4 (-12 bars) treatments produced the lowest biomass in both seasons. In 1997, average biomass yield was 10.84 t, 15.35 t, 15.25 t and 12.08 t ha^{-1} in I_1, I_2, I_3 and I_4 treatments, respectively. Equivalent values of biomass in 1998 were 11.15 t, 15.14 t, 14.45 t and 11.17 t ha^{-1}, respectively. Interaction between irrigation schedules and nitrogen levels affecting total dry matter (Table II) showed that treatments N_3I_2 combination gave the maximum biomass yield at 17.97 t ha^{-1} which was at par with N_2I_2 or N_2I_3 combinations. The positive effect on biomass yield by irrigation schedules (I_2 or I_3 treatments) and increasing N rates (200 or 300 kg ha^{-1}) may be attributed to increased vegetative growth, resulting in more leaf area index (LAI) and thus ensuring better light interception. This favourable environment resulted in greater LAI with higher CGR. Total biomass yield (11-15 t ha^{-1}) achieved in this study is similar to other work (Bangarwa, 1988; Muchow, 1989; Ahmad, 1998; Shah, 2001; Rasheed, 2002), reported elsewhere or in Pakistan.

Grain yield. As shown in Table I the I_2 (-4 bars) irrigation treatment gave significantly higher grain yield than all other treatments in both years. In 1997 both I_2 (-4 bar) and I_3 (-8 bar) treatments were, however, statistically at par in grain yield. The average grain yield in 1997 was 4.48 t, 6.09 t, 6.01 t and 4.99 t ha^{-1} in I_1, I_2, I_3 and I_4 treatments, respectively. Equivalent figures were 4.49 t, 5.94 t, 5.80 t and 4.64 t ha^{-1}, respectively.

The response to increasing nitrogen rates to grain yield was highly significant. Both N_2 (200 kg ha^{-1}) and N_3 (300 kg ha^{-1}) treatments markedly enhanced grain yield than lower rate of nitrogen application (N_1) or control (nil) treatment in both years, and this response was cubic in nature (Table I). The average grain yield was ranged from 3.89t ha^{-1} to 6.40t ha^{-1} among various nitrogen rates. Overall, mean grain yield was at 5.39t ha^{-1} in 1997 and 5.24t ha^{-1} in 1998, respectively. The interaction between irrigation schedules and nitrogen levels on grain yield was significant in both years (Table II). Treatment N_2 I_2 combination gave the maximum grain yield at 7.26 t ha^{-1} which was at par with N_3I_3 (7.09 t ha^{-1}) combination. Lowest grain yield was produced in N_0 treatment, irrespective of irrigation schedules (Table III).

Grain yield in maize like other cereals is the product of number of cobs per unit area, number of grains cob^{-1} and 1000-grain weight. The increased value of three parameters under I_2 and I_3 irrigation schedules or increasing rates of N applications were improved. Therefore, grain production significantly improved under these treatments as compared to lower rates of N application or increasing water stress such as I_4 (-12 bars) treatments. Grain yields found in this study (> 7 t ha^{-1}) are similar to the work of Muchow (1988) who also reported grain yield of maize at 7.9 t ha^{-1} under semi arid tropical environment. Both Ahmad (1998) and Rasheed (2002) also reported grain yield of > 7.0 t ha^{-1} under agro-ecological conditions of Faisalabad with better irrigation and nitrogen management.

Harvest index. In both seasons, irrigation schedules and nitrogen levels showed significant effect on harvest index (HI) (Table I). Both I_1 (Control) and I_4 (-12 bars) irrigation schedules increased harvest index (HI) over I_2 (-4 bars) or I_3 (-8 bars), on average, by 3.91% over other irrigation schedules. The HI between I_2 (-4 bars) and I_3 (-8 bars) treatments did not differ significantly in both years (Table I). On average, HI ranged from 39.51 to 41.17% among various irrigation schedules.

In both years the N_2 (200 kg ha^{-1}) treatment markedly increased HI than other rates of nitrogen application, and this response was cubic in nature (Table I). In 1997 the N_0, N_1 and N_3 treatments were statistically at par in HI. In 1998, the N_3 treatment also gave higher HI over N_0 and N_1 (100 kg ha^{-1}) treatment. Overall, mean HI was 40.35 % in 1997 and 40.40 % in 1998, respectively.

Results showed lower harvest index values in lower nitrogen rates. This could be due to increase in sterile plants and barrenness in ears as noted by others (Bangarwa *et al*., 1988; Rasheed, 2002). The higher HI in N_2 (200 kg ha^{-1}) compared to other treatments was associated with their maximum TDM accumulation due to higher leaf area duration (LAD), which in turn increased interception of radiation and its utilization efficiency. Ahmad (1998) also reported similar effects of nitrogen applications on maize. According to Muchow (1988), higher grain yield in maize was associated with higher HI. Since higher HI depends on the proportion of pre-and post-anthesis growth and its partitioning to grains, the differences in HI may simply be a consequence of their respective growth stage duration.

Components of Grain Yield

Number of cobs plant^{-1}. In both seasons, the I_2 (-4 bars) treatment significantly increased the number of cobs plant^{-1} as compared to all other irrigation treatments. Both I_1 (control) treatment and crop plants stressed at -12 bars (I_4) gave the lowest number of cobs plant^{-1}. The average number of cobs plant^{-1} was 0.90, 0.94, 0.93 and 0.92 in I_1, I_2, I_3 and I_4 treatments, respectively (Table IV).

Table I. Effect of irrigation schedules and nitrogen levels on biomass, grain yield and harvest index of maize

Treatment	Biomass(t ha^{-1})		Grain yield (t ha^{-1})		Harvest index(%)	
Sowing date	**1997**	**1998**	**1997**	**1998**	**1997**	**1998**
Irrigation schedule						
I_1 = Control	10.84 c	11.15 c	4.48 c	4.59 c	41.40 a	40.94 a
I_2 = - 4 bars	15.35 a	15.14 a	6.09 a	5.94 a	39.54 b	39.74 b
I_3 = - 8 bars	15.25 a	14.45 b	6.01 a	5.80 b	39.38 b	39.64 b
I_4 = -12 bars	12-08 b	11.17 c	4.99 b	4.64 c	41.06 a	41.27 a
LSD 5%	0.31	0.54	0.51	0.12	0.63	0.45
Nitroogen levels						
N_0 = Nil	10.23 c	9.89 c	4.07 c	3.70 c	40.00 b	38.82 c
N_1 = 100 kg ha^{-1}	12.09 b	11.67 b	4.81 b	4.58 b	39.82 b	39.10 c
N_2 = 200 kg ha^{-1}	15.58 a	15.50 a	6.39 a	6.41 a	41.29 a	42.33 a
N_3 = 300 kg ha^{-1}	15.63 a	15.20 a	6.30 a	6.28 a	40.28 b	41.33 b
LSD5%	0.26	0.57	0.17	0.14	0.47	0.48
Linear	**	**	**	**	**	**
Quadratic	**	**	**	**	**	**
Cubic	**	**	**	**	**	**
Mean	13.38	12.98	5.39	5.24	40.35	40.40

Means sharing different letters differ significantly at ($P \leq 0.05$)

Table II. The interaction between irrigation schedules and nitrogen levels affecting total dary matter matter (t ha^{-1})

Treatments	I_1	I_2	I_3	I_4
$N_{0 = Nil}$	8.13 g	11.78 d	11.66 d	9.35 f
N_1=100 kg ha^{-1}	9.85 f	13.85 b	13.67 b	10.97 e
N_2=200 kg ha^{-1}	12.65 c	17.78 a	17.84 a	14.05 b
$N_{3 =}$300 kg ha^{-1}	12.74 c	17.97 a	17.84 a	13.97 b
	SX=0.183		LSD5%=0.53	

I_1 = control; I_2 = -4 bars; I_3 = -8 bars; I_4 = -12 bars

Table III. The interaction between irrigation schedules and nitrogen levels affecting grain yield (t ha^{-1})

Treatments	1997	1998	1997	1998	1997	1998	1997	1998
	I_1		I_2		I_3		I_4	
$N_{0 = Nil}$	3.42 f	3.25 f	4.57 d	4.19 e	4.50 d	4.09 e	3.80e	3.27f
N_1=100 kg ha^{-1}	4.00 e	4.00 e	5.41 c	5.19 d	5.34 c	5.07 d	4.70d	4.05e
N_2=200 kg ha^{-1}	5.30 c	5.60 c	7.24 a	7.26 a	7.12 a	7.09 ab	5.89b	5.67c
$N_{3 =}$300 kg ha^{-1}	5.22 c	5.50 c	7.12 a	7.11 ab	7.06 a	6.94 b	5.80b	5.55c
	SX-0.115		LSD% =0.33			SX =0.100		LSD% =0.29

I_1 = control; I_2 = -4 bars; I_3 = -8 bars; I_4 = -12 bars

Increasing rates of nitrogen application also significantly enhanced number of cobs plant^{-1} over control or lower rate (N_1, 100 kg ha^{-1}) of N application, and this response was quadratic in nature (Table IV). The N_3 (300 kg ha^{-1}) treatment gave the maximum number of cobs plant^{-1} than all other rates of nitrogen application. The N_2 (200 kg ha^{-1}) treatment was, however, statistically at par in the number of cobs plant^{-1} with N_3 treatment during 1997. Overall, mean number of cobs plant^{-1} was 0.94 and 0.91 in 1997 and 1998, respectively. Similar results were reported by others who also noted higher number of cobs m^{-2} with higher rates of N application (Ahmad, 1998; Rasheed, 2002), under similar agro-ecological conditions.

Number of cobs m^{-2}. Number of cobs per unit area was significantly influenced by different irrigation schedules. The I_2 (-4 bars) treatment gave maximum number of cobs at 7.80 m^{-2} in 1997 and 7.68 m^{-2} in 1998 as compared to control or I_4 (-12 bars) treatments. Both I_2 (-4bars) and I_3 (-8 bars) were, however, statistically at par in the number of cobs m^{-2} in both the seasons (Table IV).

Increasing rate of nitrogen application significantly ($P<0.01$) enhanced the number of cobs per unit area. This response to nitrogen was highly significant and linear in nature (Table IV). The average number of cobs m^{-2} was 6.86 in N_0, 7.56 in N_1, 7.80 in N_2 and 8.17 in N_3, respectively. Overall, mean number of cobs was 7.67 m^{-2} in 1997 and 7.48 m^{-2} in 1998, respectively. Similar results were reported by others (Pearson, 1994; Ahmad, 1989; Rasheed, 2002) who also found higher number of cobs with N application.

Number of grains cob^{-1}. Effect of irrigation schedules and nitrogen levels on the number of grains cob^{-1} was highly significant in both the seasons. The treatments I_2 (-4 bars) and I_3 (-8 bars) gave more number of kernels ear $^{-1}$ than I_1 (control) or I_4 (-12 bars). The average number of kernels ear^{-1} was 327.54, 378.55, 378.10 and 344.66 in I_1, I_2, I_3 and I_4 treatments, respectively. Increasing rates of nitrogen application also significantly enhanced the number of grains cob^{-1}; $N_3 > N_2 > N_1 > N_0$. This response was, however, cubic in nature. In 1997 the number of grains was 281.72, 321.75, 415.58 and 423.90 in N_0, N_1, N_2, and N_3, respectively. Equivalent values in 1998 were 266.41, 319.95, 409.28 and 419.10 respectively. Overall, mean number of grains cob^{-1} was 360.74 in 1997 and 353.69 in 1998, respectively (Table IV).

Greater number of grains cob^{-1} by adequate application of N is in accordance with the findings of others who also reported similar effects of N application on the number of grains cob^{-1} (Ahmad, 1998; Shah, 2001; Rasheed, 2002).

1000-grain weight. In both years the I_2 (-4 bars) and I_3 (-8 bars) treatments significantly enhanced 1000-grain weight as compared with ni1 (Control) or I_4 (-12 bars) treatments (Table IV). In 1997 mean grain weight was 204.85 g in I_1, 227.38 g in I_2, 225.02 g in I_3 and 215.25 g/1000 grains in I_4 treatments. Equivalent values in 1998 were 213.60g,

Table IV. Effect of irrigation schedules and nitrogen levels on yield components of maize

Treatment	No.Cobs plant^{-1}		No. of cob m^{-2}		No. of grains cob^{-1}		1000-grain weight (g)	
Sowing date	**1997**	**1998**	**1997**	**1998**	**1997**	**1998**	**1997**	**1998**
Irrigation schedule								
I_1 = Control	0.91 d	0.89 c	7.55 b	7.31 b	319.53c	235.54b	204.85c	213.60b
I_2 = - 4 bars	0.95 a	0.93 a	7.80 a	7.68 a	386.46a	370.64a	227.38a	222.26a
I_3 = - 8 bars	0.94 b	0.92 b	7.72ab	7.55 a	386.14a	370.06a	225.02a	220.60a
I_4 = -12 bars	0.93 c	0.90 c	7.62 b	7.37 b	350.81b	338.51b	215.25b	213.87b
LSD 5%	0.007	0.012	0.18	0.13	7.15	4.59	3.87	6.03
Nitroogen levels								
N_0 = Nil	0.85 c	0.82 d	6.95 d	6.77 d	281.72d	266.41d	197.09c	198.82b
N_1 = 100 kg ha^{-1}	0.92 b	0.89 c	7.55 c	7/.38c	321.75c	319.95c	216.16b	219.68a
N_2 = 200 kg ha^{-1}	0.98 a	0.95 b	7.93 b	7.68 b	415.58b	409.28b	230.19a	226.44a
N_3 = 300 kg ha^{-1}	0.99 a	0.97 a	8.27 a	8.08 a	423.90a	419.10a	229.08a	225.39a
LSD5%	0.012	0.014	0.17	0.18	6.63	6.77	5.98	7.54
Linear	**	**	**	**	**	**	**	**
Quadratic	**	**	NS	NS	**	**	**	**
Cubic	NS	NS	NS	NS	**	**	NS	NS
Mean	0.94	0.91	7.67	7.48	360.74	353.69	218.13	217.58

Means sharing different letters differ significantly at ($P \leq 0.05$)

222.26g, 220.60g and 213.87g/1000 grains, respectively.

Increasing rate of nitrogen application increased 1000-grain weight upto N_2 (200 kg ha^{-1}), and then it levelled off in both years. The response was quadratic in nature. The mean grain weight was 197.96g, 217.92g, 228.32g, and 227.79g/1000-grains in N_0, N_1, N_2 and N_3, respectively. Overall, mean grain weight varied at 218.13g (1997) and 217.58g (1998) per thousand grains (Table IV).

Increased nitrogen application recorded the higher mean grain weight. The higher grain weight in these treatments over control or lower rate of N application was because of adequate supply of nitrogen to the plants. These results substantiates the findings of Tiway *et al.* (1970) who also observed higher grain weight by nitrogen fertilizer in maize crop. Both, Ahmad (1998) and Rasheed (2002) also noted higher mean grain weight with adequate application of nitrogen in maize working under similar agro-ecological conditions.

In conclusion, results demonstrate that under Faisalabad conditions, application of 200 kg N ha^{-1} is appropriate for obtaining higher grain yield (> 7 t ha^{-1}) of hybrid maize, provided proper irrigation scheduling is followed.

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