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OPTIMIZING WATER AND NITROGEN REQUIREMENT IN MAIZE (*ZEA MAYS* L.) UNDER SEMI ARID CONDITIONS OF PAKISTAN

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Abstract

Water and nitrogen are the most important factors, play their role in better growth and yield of maize. To find out effective use of resources a field experiment was conducted to study the effect of irrigation regimes and nitrogen rates on growth and yield of maize hybrid at Agronomic Research Area, University of Agriculture, Faisalabad, during 2009. The experiment was laid out in Randomized Complete Block Design with split plot arrangement having three replications. Three irrigation regime i.e., I_1 (eight irrigation), I_2 (six irrigation, two missed at vegetative stage) and I_3 (seven one missed at grain filling stage) were kept in main plots and four rates of nitrogen; N_1 (150 kg ha^{-1}), N_2 (200 kg ha^{-1}), N_3 (250 kg ha^{-1}) and N_4 (300 kg ha^{-1}) were randomized in sub plots. Results showed that maximum leaf area index (4.92), number of grains per cob (490), grain yield (8.49 t ha^{-1}) and harvest index (47.73%) were achieved in N_3 treatment with I_1 irrigation regime while the highest biological yield (17.97 t ha^{-1}) was recorded in N_4 treatment with the I_1 irrigation regimes . The minimum1000-grains weight (314 g), biological yield (12.48 t ha^{-1}) and grain yield (4.67 t ha^{-1}) were recorded in the combination of I_2 and N_1 treatments. Water stress at six and twelve leaves stage simultaneously decreased grain yield 30% while water stress at grain filling stage decreased 20% yield.

Introduction

Maize requires 600-700 mm water for optimum growth and yield depending upon climatic conditions (Reddy, 2006). Water deficiency at any growth stage of maize reduces growth and productivity of the crop (Paudyal *et al*., 2001). Water stress affects crop productivity as much as all other environmental factors combined. It reduces leaf area (Pandey *et al*., 2000) and plant height (Soler *et al*., 2007) by decreasing cell division and leaf expansion (Reymond *et al*., 2003). However, optimum irrigation is a solution but it is becoming short day by day. The knowledge of maize crop performance at various stages of water deficit in a semi arid environment is becoming important to manage water more efficiently. Several studies have been conducted on maize water requirement and effect of water stress in temperate and semi-arid zones (Eck, 1985). Similarly, lower yield was found in maize when the crop was subjected to drought with high dose of nitrogen (Moser *et al*., 2006; Grant *et al*., 2002). Nitrogen deficiency is evident in the reduction of light interception by decreasing leaf area index which results in lower grain yield (Uhart & Andrade, 1995).

The supply of water is also important for crop production as much as nitrogen. (Mansouri-Far *et al*., 2010;). Nitrogen availability or uptake may also be modified by water supply. More residual nitrate remains in the soil at the end of the cropping season when soil water is insufficient as compared to when it is adequate (Fapohunda & Hussain, 1990). Variable water supply either due to water shortage or failure of the irrigation system to supply water at critical crop growth stages in many irrigated areas of the world (Igbadun *et al.,* 2007), especially in Pakistan is becoming a problem in realizing good yield. Keeping in view the above facts, the present study was conducted to evaluate the effects of different irrigation regimes and nitrogen levels on yield and yield components of maize hybrid under semi arid conditions of Pakistan.

Materials and Methods

Site: A field study was conducted at the Agronomic Research Farm, University of Agriculture, Faisalabad (31° 25´ N, 73° 04´ E) during the year 2009.

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Soil analysis: Composite soil samples were taken to a depth of 30 cm from the experimental site with the help of Auger before sowing of crop. Soil analysis of the samples showed that experimental site had pH 7.54 and N, P_2O_5 and K_2O amount was found 0.064%, 6.93% and 194 ppm, respectively and it was suitable for maize production. A soil was sandy clay loam in texture with organic matter and total soluble salt 1.14 and 12.29%, respectively.

Design and treatments: The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement having three replications and a net plot size of 3 m × 5 m. Three irrigation regime i.e., I_1: (eight irrigation), $I_{2:}$ (six irrigation, one missed at six leaves and other at twelve leaves stage) and $I_{3:}$ (seven irrigations, one missed at grain filling stage) were kept in main plots (three inch depth of water was applied in each irrigation) and four N levels N_1 (150 kg ha^{-1}), N_2 (200 kg ha^{-1}), N_3 (250 kg ha^{-1}) and N_4 (300 kg ha^{-1}) were randomized in sub plots of the experiment.

Crop husbandry: The crop was planted on August 1, 2009 with P × P distance of 20 cm and in 75 cm apart rows. Maize hybrid, Pioneer 31-R-88 was sown using seed rate 25 kg ha^{-1}. Recommended dose of P and K each at the rate of 125 kg ha^{-1} with 1/3rd of N was applied at the time of sowing while the remaining dose of N was applied in two splits according to the treatments. Irrigation was also applied according to the treatments by following cut throat flume method to calculate the depth of applied water by using following formula;

$$t = (A \times d) \div Q$$

where; t = time to irrigation (s), Q = discharge (m^3 s^{-1}), A = area (m^2) and d = depth of water (mm). All other agronomic practices such as thinning, hoeing and plant protection measures were kept uniform for all the treatments.

Sampling strategy: Half of the plot area was used for growth and developmental studies and remaining half for the final harvest data. After 20 days of planting, plant sampling was started. One meter long row was harvested from each plot at ground level after 14 days interval leaving appropriate borders. Fresh and dry weight of component fractions of plant was determined separately. A sub-sample from each fraction was taken to dry in oven at 70^{o}C till constant weight. Total dry matter (TDM) production was calculated by adding dry weights of leaves, stems, tassels and cobs. Sub sample (10 g) of leaf was used to record leaf area by using leaf area meter (CI-202) and leaf area index (LAI) was calculated by using standard procedures at each harvest.

Final harvest: Twenty plants from 3 m^2 were harvested for measuring grain yield and components of yield: number of grains per cob, 1000-grain weight (g), grain yield (t ha^{-1}), TDM (t ha^{-1}) and harvest index (%). All the data obtained were analyzed by employing “M-Stat C” statistical package. Differences among treatments means were compared by the least significant difference (LSD) test at 5% probability level (Steel *et al.,* 1997).

Results and Discussion

Components of yield: Maize yield depends on number of grains per cob and grain weight. The data (Table.1) showed significant effect of irrigation regimes on number of grains. Maximum numbers of grains (474) per cob were produced by I_1 treatment while minimum (441) were obtained from I_2 treatment. This could be due to stress that affected grain formation as reported by Ahmad *et al*., (2002). With nitrogen at the rate of 250 kg ha^{-1} maximum (471) numbers of grains per cob was observed while further increase in nitrogen supply (300 kg N ha^{-1}) decreased (2.88%) number of grains per cob and minimum (439) grains per cob was obtained by N_1(150 kg N ha^{-1}) treatment. Significant interaction between irrigation regimes and nitrogen level was recorded it illustrated that more grains per cob (490) was obtained by I_1 treatment with 250 kg N ha^{-1} while minimum number of grains per cob (427) was found in N_1 (150 kg ha^{-1}) under vegetative stress (I_2). Similar results were reported by Khan *et al*., (1999) and Sharar *et al*., (2003).

Table 1. Effect of irrigation regimes and nitrogen levels on yield and yield components.

Treatments	Number of grains cob^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Total dry matter (g m^{-2})	Harvest index (%)	Maximum leaf area index
I_1	474 a	361 a	7.29 a	1703 a	42.26	4.68
I_2	441 c	330 c	5.13 b	1319 c	38.51	4.52
I_3	449 b	336 b	5.84 b	1496 b	38.72	4.31
Significance	**	**	*	**	NS	NS
LSD 5%	4.09	2.63	0.81	4.824	5.51	0.59
N_1	439 d	327 c	5.22 d	1403 d	36.88 d	4.19 b
N_2	451 c	352 a	6.70 c	1485 c	40.44 b	4.35 ab
N_3	471 a	346 b	6.71 a	1542 b	42.72 a	4.8 a
N_4	458 b	345 b	6.34 b	1595 a	39.28 c	4.62 ab
Significance	**	*	**	**	**	*
LSD 5%	3.16	1.49	0.12	8.602	0.86	0.50
I_1N_1	458 d	333 fg	5.80 f	1570 e	36.64 e	4.48
I_1N_2	471 c	376 a	7.033 c	1682 c	41.50 c	4.61
I_1N_3	490 a	371 b	8.49 a	1765 b	47.73 a	4.92
I_1N_4	477 b	366 c	7.82 b	1797 a	43.18 b	4.72
I_2N_1	427 h	314 h	4.67 h	1248 k	37.02 e	4.31
I_2N_2	437 g	339 e	5.163 g	1291 j	39.59 d	4.46
I_2N_3	455 de	333 fg	5.36 g	1336 i	39.71d	4.80
I_2N_4	446 f	335 f	5.33 g	1400 h	37.73 e	4.50
I_3N_1	432 g	334 fg	5.19 g	1391 h	36.98 e	4.28
I_3N_2	446 f	342 d	6.027 e	1483 g	40.24 cd	3.50
I_3N_3	469 c	332 g	6.27 d	1526 f	40.72 cd	4.81
I_3N_4	450 ef	334 fg	5.86 ef	1586 d	36.94 e	4.66
Significance	*	**	**	**	*	NS
LSD 5%	5.48	2.59	0.21	14.9	1.49	0.86

Mean sharing the same letter in the table do not differ statistically at $p \leq 0.05$

N_1 = 150 kg ha^{-1}, N_2 = 200 kg ha^{-1}, N_3 = 250 kg ha^{-1}, N_4 = 300 kg ha^{-1}, I_1 : 8 Irrigations, I_2 : 6 Irrigations (2 missing at vegetative stage), I_3 : 7 Irrigations (1 missing at reproductive stage), LSD = Least significant difference, NS = Non significant, * = Significant at 5% level, ** = Highly significant at 5% level

The effect of irrigation regimes on 1000-grain weight was highly significant (Table 1). Maximum 1000-grain weight (361g) was attained by treatment I_1 and it was followed by I_3 (stress of one irrigation at reproductive stage) and minimum (330 g) 1000-grain weight was recorded in I_2 (stress at vegetative stress). These results are in line with the findings of Moser *et al*., (2006); Salah *et al*., (2010). Nitrogen rates also showed significant effect on 1000-grain weight. Increase in nitrogen rate increased the 1000-grain weight. Maximum 1000-grain weight (352 g) attained in N_2 (200 kg N ha^{-1}) which was reduced by further increase or decrease of nitrogen rate. The lowest 1000-grain weight (327 g) was produced in N_1 (150 kg N ha^{-1}). In this parameter interaction was also found to be statistically significant. Maximum number of 1000-grain weight (376 g) was obtained in I_1 with N_2 (200 kg N ha^{-1}) while minimum 1000-grain weight (314 g) was observed at lowest nitrogen rates (150 kg ha^{-1}) and under vegetative stress (I_2). Many researchers also found similar effects of irrigation and N on 1000-grain weight (Akbar *et al*., 2002; Khaliq *et al*., 2009).

Grain yield: Grain yield was increased with increase in nitrogen rate up to 250 kg ha^{-1} after that it decreased by increasing nitrogen rate at 300 kg N ha^{-1} (N_4) but at this level total dry matter increased (Table 1). Minimum grain yield (5.22 t ha^{-1}) was shown by N_1 (150 kg ha^{-1}) these results were similar to that reported by Khaliq *et al*., (2009), working under similar ecological conditions. The combined effect of nitrogen levels and irrigation regimes was also significant. When crop was normally irrigated (I_1) with nitrogen dose at the rate of 250 kg ha^{-1} (N_3) the highest grain yield (8.49 t ha^{-1}) was achieved in this treatment (I_1N_3) crop was fully irrigated with optimum dose of nitrogen which lead to maximum number of grain per cob and LAI as a result grain yield boost up while minimum grain yield (4.67 t ha^{-1}) was observed with nitrogen dose of 150 kg ha^{-1} and stress at vegetative stage (I_2). Positive correlation was observed between grain yield and 1000-grain weight, the regression accounted for 0.75% of variation in data (Fig. 1). Similar results were reported by Akbar *et al*., (2002); Inman *et al*., (2005). The grain yield also showed highly significant corelation (R^2 = 0.87, r = 0.97; Fig. 2) with biological yield of the crop. These results are supported by the findings of Khaliq *et al*., (2009).

Harvest index: Harvest index is the ratio of economic yield to biological yield and is the productive efficiency of crop. Data regarding harvest index (Table 1) showed that irrigation effect was non significant while nitrogen rates showed statistically significant effects recorded on harvest index. The maximum harvest index (42.72%) was found with nitrogen dose @ 250 kg ha^{-1} (N_3). However when nitrogen supply was increased up to 300 kg ha^{-1} then harvest index was reduced (39.28 %) since at this level biological yield increased as a result harvest index decreased. Minimum harvest index (36.88%) was produced by lower level of nitrogen (150 kg ha^{-1}). Interactive effect of irrigation regimes and nitrogen rates was also significant (Table 1). The maximum harvest index (47.73%) was achieved with the combination of I_1 and N_3 (250 kg N ha^{-1}). While minimum (36.64%) interactive response was found in I_1 with N_1 treatments combination Sharar *et al*., (2003) reported similar results.

Total dry matter accumulation: The potential of a crop is depended upon its biomass production, which is related to the total dry matter (TDM) production. The effect of irrigation regimes to TDM accumulation was significant throughout the growing period except at 20 DAS and 62 DAS (Fig. 3). Differences among treatments for TDM accumulation were due to shortage of water because I_1 gave the maximum TDM which was followed by I_3 and least values were observed in I_2 in this treatment stress was given during vegetative period so plant was unable to utilize inputs properly. At final harvest, TDM for I_1, I_2 and I_3 was 1703 g m^{-2}, 1319 g m^{-2} and 1496 g m^{-2} respectively. The effect of N levels on the accumulation of TDM showed a sharp increased in TDM by increasing N levels (Fig. 4). However TDM accumulation was slower upto 34 DAS, but thereafter it increased rapidly up to 76 DAS. The maximum TDM (1595 g m^{-2}) at final harvest was accumulated by N_4 (300 kg N ha^{-1}), followed by N_3 (250 kg N ha^{-1}) which gave 1542 g m^{-2}. The minimum value (1403 g m^{-2}) of TDM was founded by N_1 (150 kg N ha^{-1}).

Leaf area index: In interception of radiation and ultimately yield of a crop, leaf area index (LAI) had the primary importance which was affected by irrigation regime. The periodic data illustrated that maximum and minimum value of LAI was 4.68 and 4.31 for I_1 and I_3, respectively. These values were observed on 62 DAS when crop achieved maximum canopy cover, thereafter it started to decrease till 104 DAS (Fig. 5) due to start of leaf senescing as a result LAI fell down gradually as noted by Bu-Chong *et al*., (2007). By increasing N levels significant enhancement occurred in LAI and this increased steadily from 20 DAS to 62 DAS for the entire N levels (Fig. 6). Maximum values (4.80) of LAI at 62 DAS was in N_3 (250 kg N ha^{-1}) while minimum 4.19 was observed in N_1 (150 kg N ha^{-1}) it was cleared from Fig. 5. The values of LAI were decreased continuously 62 DAS up to final harvest (104 DAS) in all treatments. The decline in LAI was much prominent in lower doses of nitrogen (Valero *et al*., 2005). Leaf expansion was improved in plants by giving more nitrogenous fertilizers and leaf expansion was illustrated in terms of leaf length and leaf breadth (Ma *et al*., 1996). More leaf expansion means more radiation absorption and high biomass production which ultimately increased the yield of the crop. These results collaborated the finding of Lindquist *et al*., (2005).

Conclusions

Based on the experimental results optimum dose of nitrogen was found 250 kg N ha^{-1} with 560 mm water ha^{-1} in maize crop during whole growing season with hybrid Pioneer 31-R-88. This combination gave high yield by improving all other yield relating components such as number of grains per cob, 1000 grain weight and LAI. Water stress at six and twelve leaves stage concurrently decreased yield 30 % while water stress only at grain filling stage decreased 20 % yield. In autumn maize optimum dose of N is 250 kg ha^{-1} with eight irrigations under semi arid condition of Pakistan. It is further suggested that future research should be focused with other plant nutrient (P_2O_5 & K_2O) at different irrigation regimes.

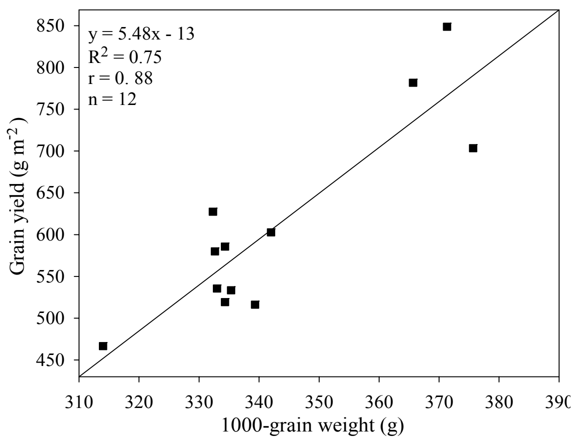

Fig. 1. Relationship between 1000-grain weight (g) and grain yield (g m^{-2}).

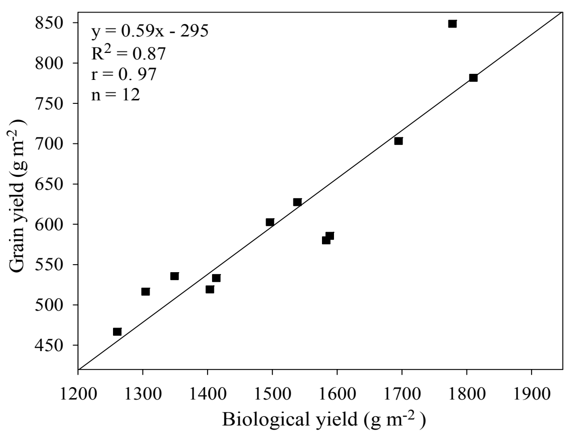

Fig. 2. Relationship between biological yield (g m^{-2}) and grain yield (g m^{-2}).

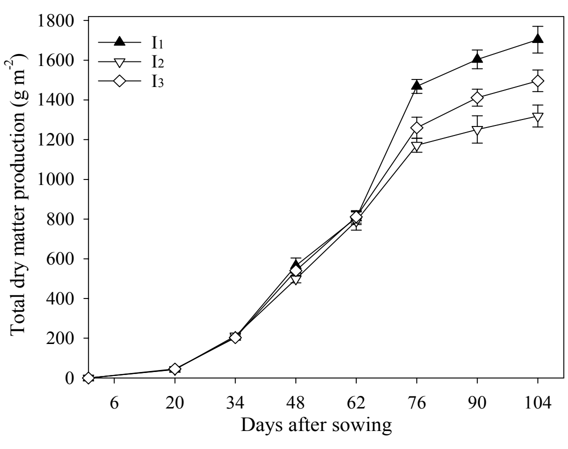

Fig. 3. Change in total dry matter production with time as affected by irrigation regimes.

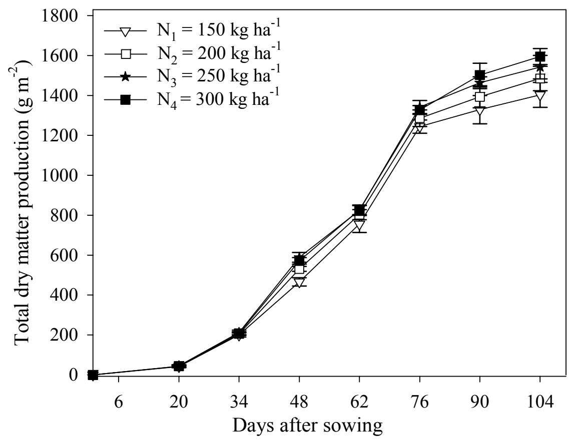

Fig. 4. Change in total dry matter production with time as affected by nitrogen levels.

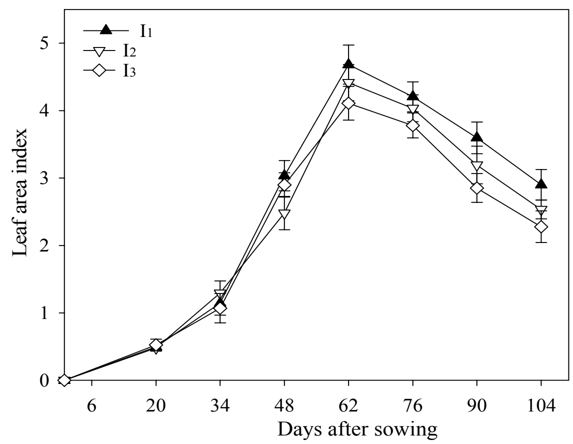

Fig. 5. Changes in LAI with time as affected by irrigation regimes.

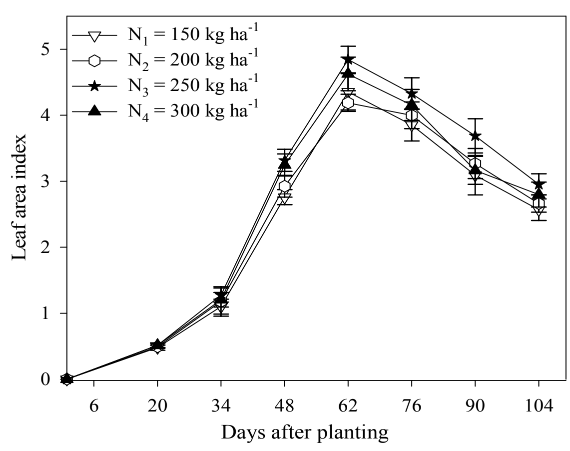

Fig. 6. Changes in LAI with time as affected by nitrogen levels.

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