水ストレスと窒素肥料がトウモロコシの生育と収量に及ぼす影響

Growth Parameters and Yield Response of Maize to Water Stress and Nitrogenous Fertilizer

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INTRODUCTION

In Bangladesh, maize is the third most important cereal crop and covers 2834 hectares of land with an annual production of 3000 tons (BBS,1997). Proper growth and development of maize needs favourable soil moisture in the root zone. The moisture content in the soil gradually decreases with the passing of time during dry season. Limited water supply during the growing season results in soil and plant water deficits and reduces maize yields (Gordon *et al.*, 1995). Proper time and supplemental irrigation should be realized in irrigation scheduling for the most effective use of available water in optimizing maize production. Water deficit has little effect on timing of emergence, number of leaves per plant but delayed tasseling initiation and silking, reduced plant height and vegetative growth of maize (Abrecht and Carberry, 1993). Heading to milking stage is the most sensitive period of water stress and has ultimate impact on grain yield (Shaozhong and Minggang, 1992). Improper scheduling of irrigation results not only in wastage of water but also decrease the crop growth and yield.

Nitrogen for maize cultivation is equally important to realize the yield potential (Talukder, 1985). Among different elements of Bangladesh soil, nitrogen is the key input for achieving higher yield of maize. But nitrogenous fertilizer may be increased to a certain level and thereafter it has got adverse effect (Gupta and Gautam; 1994, Singh *et al.*, 1996). Irrigation water dissolved the fertilizers and made available to the crop for proper growth and development. Therefore, an attempt has been made to evaluate the effect of irrigation and nitrogen on the performance of maize.

MATERIALS AND METHOD

The experiment was conducted in the Agronomy Research Field of Bangladesh Agricultural University, Mymensingh during November 1998 to April 1999 to evaluate the response of maize (cv. Bornali) to water stress and nitrogenous fertilizer. The experiment included two factors, namely i) five irrigation regimes with IW/CPE ratios of 0.0, 0.2, 0.5, 0.8, and 1.0 and was applied at 37, 58 and 75 days after sowing (DAS) and ii) four nitrogen doses i.e. 00, 70, 100 and 120 N kg/ha. The experiment was laid out in a split plot design with 3 replications assigning 5 irrigation treatments to main plots and 4 fertility treatments to sub-plots at random. Texturally, the soil was silt loam. The land was prepared by the power tiller. Seeds were sown on 19 November 1998 by dropping seeds by hand with 70 cm x 25 cm spacing. The unit plot size was 4 m x 1.5 m (5

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sq.m). Triple superphosphate (TSP) and muriate of potash (MP) were applied at the rate of 100 Kg P_2O_5 and 80 Kg K_2O/ha, respectively (BARC, 1997). One third of the nitrogen along with whole TSP and MP were applied at the time of final land preparation. The rest two-third urea was top dressed in equal two splits at 35 and 65 days after sowing. The maize was harvested on 6 April 1999. Intercultural operations were made as and when necessary to keep the crop free from weeds and to protect from diseases. Soil moisture was determined at 34, 39, 54, 60, 73 and 77 DAS from each main plot. Soil samples were also collected from unit plots during land preparation and at harvest to determine the physico-chemical properties of soil. Plant height, root length, ear length, ear breath, ear/plant, kernel/ear, 100 kernel weight, grain and straw yields were recorded. Data were analyzed following analysis of variance technique and mean difference were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984)

RESULTS AND DISCUSSION

Effect of irrigation regimes on the yield and yield contributing characters of maize are presented in Table 1. The yield and yield parameters were significantly affected due to application of irrigation water. The highest plant height (273.50 cm) was observed with IW/CPE ratio of 0.8 irrigation treatment and the lowest (249.80 cm) in control. Availability of well distributed soil moisture at different growth stages due to irrigation enhanced the growth of plant. Similar effect of irrigation on plant height was also reported by Gordon *et al.*, (1995) and Ne Smith and Ritchie (1992). Root lengths were significantly increased with the application of irrigation water. The highest root length (29.50 cm) was produced in IW/CPE ratio of 0.2 and 0.8 irrigation treatments and was statistically similar with other irrigation treatments except control (26.42 cm). Similar result was found by Dai *et al.*, (1990). Due to application of irrigation water ear length was significantly increased (Table 1). The highest ear length (19.72 cm) was produced by IW/CPE ratio of 0.2 irrigation treatment and was statistically similar with

Table 1. Effect of irrigation regimes on the yield and yield contributing characters of maize.

IW/CPE ratio	Plant height (cm)	Root length (cm)	Ear length (cm)	Ear breath (cm)	Ears/ plant (no.)	Kernels/ Ear (no.)	100 Kernel weight (g)	Grain yield (t/ha)	Stover yield (t/ha)
0	249.80c	26.42b	18.46b	4.04b	1.12	310.30d	24.40d	3.85d	6.84d
0.2	265.90ab	29.50a	19.72a	4.88a	1.35	372.50a	26.69c	5.77b	9.53b
0.5	271.50a	28.87a	20.21a	4.78a	1.38	351.00b	31.75a	6.77a	11.13a
0.8	273.50a	29.50a	18.34b	4.23b	1.38	333.10bc	31.05b	5.61b	8.35c
1.0	256.80bc	29.38a	18.25b	4.30b	1.20	327.10cd	27.03c	4.80c	7.87c
S_x	2.05	0.17	0.11	0.06	-	4.34	0.12	0.10	0.11
Level of significance	0.01	0.01	0.01	0.01	NS	0.01	0.01	0.01	0.01

Note : Figure in a column having common letter(s) do not differ significantly but dissimilar letter differ significantly; NS = Not significant.

the ratio of 0.5 irrigation treatment. The lowest ear length (18.25 cm) was obtained with IW/CPE ratio of 1.0 irrigation treatment and was statistically identical with 0.8 and control. Ear breath was significantly affected by irrigation water and followed similar trend as in ear length (Table 1). Number of kernels / ear were significantly affected due to application of irrigation water. IW/CPE ratio of 0.2 irrigation treatment produced the highest kernel number/ear (372.50) and the lowest (310.30) in control. A significant variation was recorded for 100 kernel weight owing to differences in irrigation treatments (Table1). Influence of irrigation on grain yield was statistically significant. The highest grain yield (6.77 t/ha) was obtained with IW/CPE ratio of 0.5 irrigation treatment and the lowest (4.80 t/ha) under no stress condition (IW/CPE = 1). The grain yields were strongly supported by the yield contributing characters. It can be seen that yield increased upto a certain level of irrigation and then decreased. The results are in conformity with the findings of Talukder (1985), Chowdhury and Islam (1993) and Zirkov *et al.*, (1995). Different irrigation regimes were found to have significant effect on straw yields (Table 1). Straw yields significantly increased and followed similar pattern as in grain yield. Chowdhury and Macksoud (1997) also found similar results.

The results on the yield and yield parameters of maize due to application of nitrogenous fertilizers are presented in Table 2. Significantly the highest plant height (269.40 cm) was found with 70 kg N/ha and was statistically identical (269.30 cm) with 100 kg N/ha. No significant differences were found between control and 120 kg N/ha treatments. Root length did not vary statistically due to application of nitrogenous fertilizers. Ear length and breath had marked variation due to changes in nitrogenous fertilizers (Table 2). Nitrogenous fertilizer significantly increased ears/plant while no variation was found in kernels/ear (Table 2). Highest number of ears/plant (1.33) was produced by 100 kg N/ha and no significant variation was found among 70 to 120 kg N/ha while the lowest (1.17) was in control. Different nitrogen treatments had significant influence on 100 kernel weight. The highest weight of 100-kernel (28.49 g) was found with 100 kg N/ha and the lowest (27.89 g) with 120 kg N/ha. The grain yields were significantly influenced by different doses of nitrogen (Table 2). The grain yield was the highest

Table 2. Effect of nitrogen regimes on the yield and yield contributing characters of maize.

Nitrogen (kg N/ha)	Plant height (cm)	Root length (cm)	Ear length (cm)	Ear breath (cm)	Ears/ plant (no.)	Kernels/ Ear (no.)	100 Kernel weight (g)	Grain yield (t/ha)	Stover yield (t/ha)
Control	254.20b	28.75	18.78c	4.27c	1.17b	332.72	28.44ab	4.93b	8.21b
70	269.40a	28.38	18.88bc	4.51ab	1.31ab	341.78	27.90b	5.61a	8.88a
100	269.30a	28.91	19.21a	4.32bc	1.33a	344.37	28.49a	5.46a	8.89a
120	258.70b	28.91	19.12ab	4.69a	1.33a	336.34	27.89b	5.44a	8.99a
S_x	2.20	-	0.08	0.05	0.04	-	0.19	0.07	0.10
Level of significance	0.01	NS	0.01	0.01	0.01	NS	0.05	0.01	0.01

Note : Figure in a column having common letter(s) do not differ significantly but dissimilar letter differ significantly; NS = Not significant.

Table 3. Interaction effect of irrigation and nitrogen on the yield and yield contributing parameters of maize.

Interaction (Irrigation x Nitrogen)	Plant height (cm)	Root length (cm)	Ear length (cm)	Ear breath (cm)	Ears/ plant (no.)	Kernel s/ear (no.)	100 Kernel weight (g)	Grain yield (t/ha)	Stover yield (t/ha)
I_0N_0	240.80j	25.87	18.22efg	4.03ef	1.13	307.17	24.67ij	3.18k	5.42j
I_0N_1	255.60ghij	25.30	18.42efg	3.85f	1.07	308.02	23.71ij	4.52ij	7.52ghi
I_0N_2	252.7hij	26.80	18.76def	4.07ef	1.20	318.26	24.28ij	4.22j	7.14i
I_0N_3	250.00ij	27.73	18.44efg	4.22cdef	1.07	307.85	24.93hij	3.50k	7.26hi
I_1N_0	247.50ij	29.00	19.29bcd	4.72abc	1.13	397.43	25.56ghi	5.28efgh	8.75ef
I_1N_1	269.50bcdefg	29.53	19.23cd	5.03ab	1.40	354.95	26.63fgh	5.80cdef	9.40de
I_1N_2	273.60bcde	30.40	20.00ab	4.67abcd	1.40	365.94	26.63fgh	5.61def	9.69cd
I_1N_3	273.00bcdef	29.07	20.37a	5.10a	1.47	371.70	27.96ef	6.41bc	10.27cd
I_2N_0	258.30efghi	29.27	19.89abc	4.62abcd	1.27	345.55	31.15bc	6.05cd	10.49bc
I_2N_1	274.80bcd	28.93	20.11a	4.93ab	1.47	367.25	31.05bc	7.26a	11.44a
I_2N_2	279.70ab	28.67	20.54a	4.63abcd	1.40	350.97	34.00a	6.79ab	11.16ab
I_2N_3	260.80defghi	28.60	20.31a	4.95ab	1.40	340.10	30.79bc	6.98ab	11.43a
I_3N_0	268.90bcdefgh	30.67	18.68def	3.97ef	1.27	306.59	31.94b	5.07fghi	8.46fg
I_3N_1	290.40a	29.47	18.30efg	4.13def	1.33	341.36	31.32bc	5.94cde	8.41fg
I_3N_2	277.90abc	29.87	17.97fg	4.33cdef	1.47	350.39	31.00bc	5.95cde	8.72ef
I_3N_3	257.00fghij	28.00	18.42efg	4.50bcde	1.47	334.22	29.94cd	5.47defg	7.82fghi
I_4N_0	255.20ghij	28.93	17.80g	4.03ef	1.07	306.87	28.90de	5.08fghi	7.91fghi
I_4N_1	256.40ghij	28.67	18.32efg	4.60abcd	1.27	337.34	26.80fg	4.55hij	7.62ghi
I_4N_2	262.80cdefghi	28.80	18.81de	3.90f	1.20	336.31	26.57fgh	4.71hij	7.74ghi
I_4N_3	252.70hij	31.13	18.07efg	4.67abcd	1.27	327.83	25.86ghi	4.86ghij	8.20fgh
S_x	4.91	-	0.18	0.12	-	-	0.42	0.17	0.22
Level of significance	0.05	NS	0.01	0.01	NS	NS	0.01	0.01	0.01

Note : Figure in a column having common letter(s) do not differ significantly but dissimilar letter differ significantly; NS = Not significant.
I_0 = Control, I_1 = IW/CPE ratio 0.2, I_2 = IW/CPE ratio 0.5, I_3 = IW/CPE ratio 0.8, I_4 =IW/CPE ratio 1.0
N_0 = Control, N_1 = 70 kg N/ha, N_2 = 100 kg N/ha, N_3 = 120 kg N/ha.

(5.61 t/ha) due to the application of 70 kg N/ha and was statistically similar up to 120 kg N/ha. The lowest grain yield (4.93 t/ha) was produced by control. The results are in agreement with the findings of Cox *et al.*, (1993) and Gupta and Gautam (1994). Straw yield followed the similar pattern as in grain yield (Table 2). This might be due to the exuberant vegetative growth noted in the case of higher doses of nitrogen application.

Interaction effect of irrigation and nitrogen on the performance of maize yield and yield contributing parameters are presented in Table 3. The highest grain yield (7.26 t/ha) was obtained by the combination of IW/CPE ratio of 0.5 and 70 kg N/ha while the lowest (3.81 t/ha) was in control. It is significantly supported by the yield contributing characters (Table 3). These results are in conformity with the findings of El-Noemami *et al.*, (1990) and Gab-Alla *et al.*, (1995). In combination, of irrigation and nitrogen had no significant effect on root length, ears/plant and kernels/ear, respectively (Table 3).

The moisture status of the experimental plots during growing period of maize is shown in Fig. 1 to 5. Percentage of soil moisture gradually decreased through the soil profile in control (Fig. 1). Moisture status at 20 and 40cm depths of soil decreased days after irrigation and then gradually increased at every time of irrigation applied (Fig. 2). It might be due to elapsed time of percolation through the soil profile. In Fig. 3, 4 and 5 soil moisture status at 40 and 60cm depths of soil followed similar trend as in Fig. 2. But

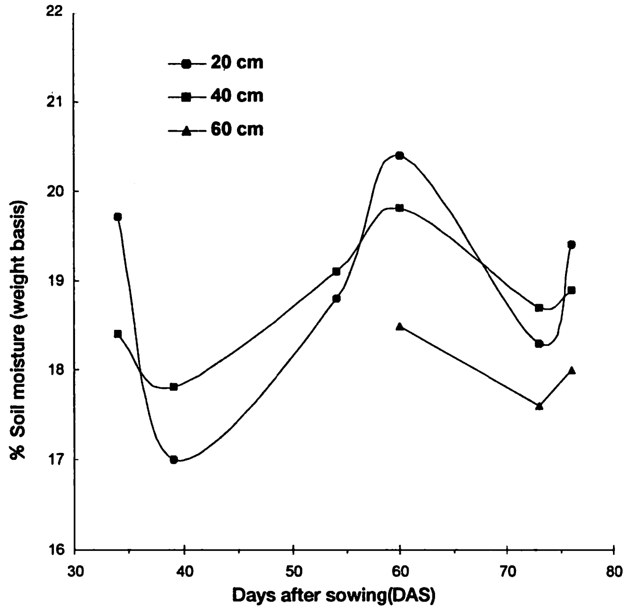

Fig. 2. Soil moisture status at I_1 (IW/CPE=0.2).

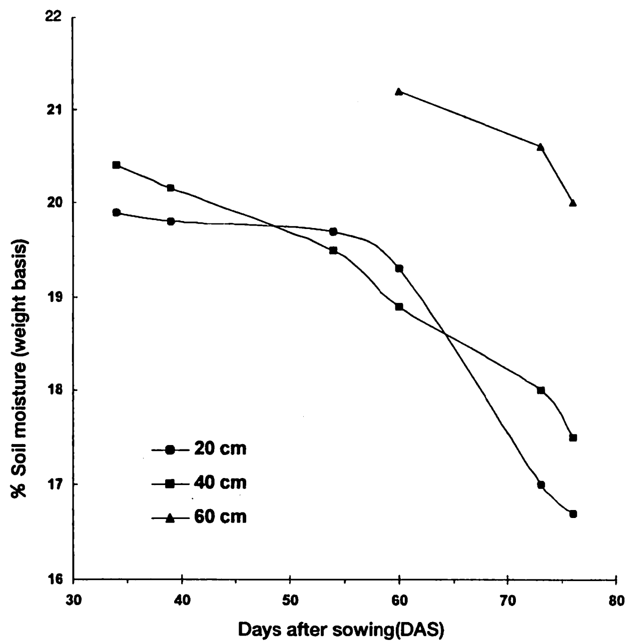

Fig. 1. Soil moisture status at I_0 (IW/CPE=0.0).

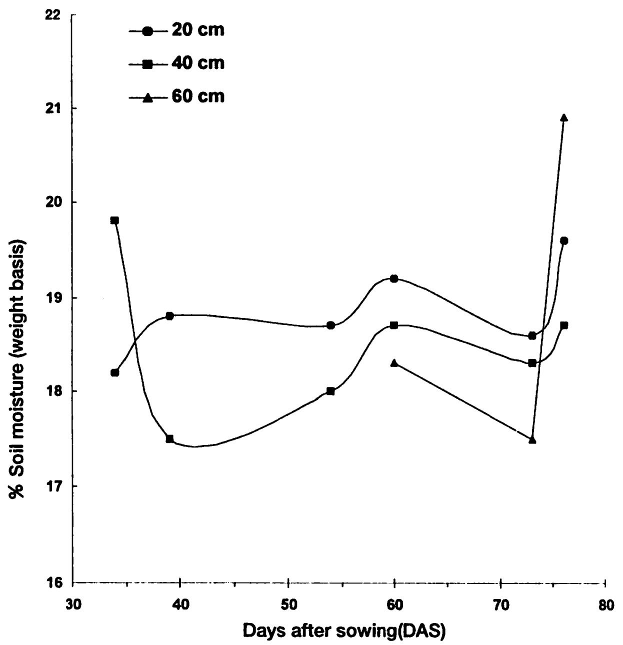

Fig. 3. Soil moisture status at I_2 (IW/CPE=0.5).

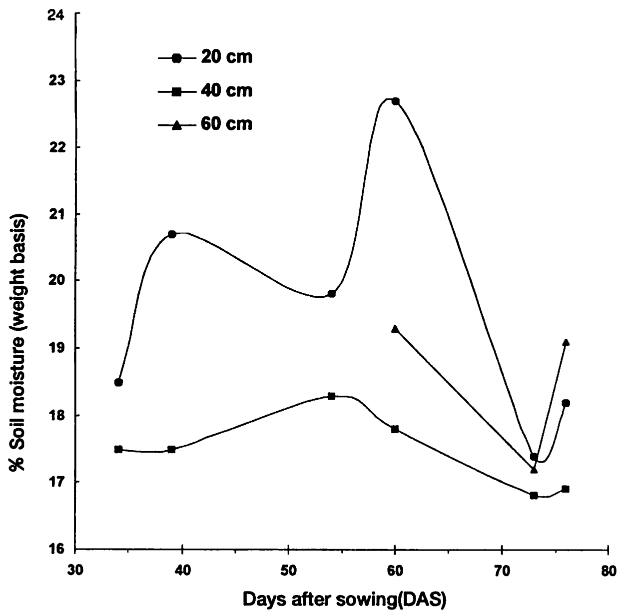

Fig. 4. Soil moisture status at I_3 (IW/CPE=0.8).

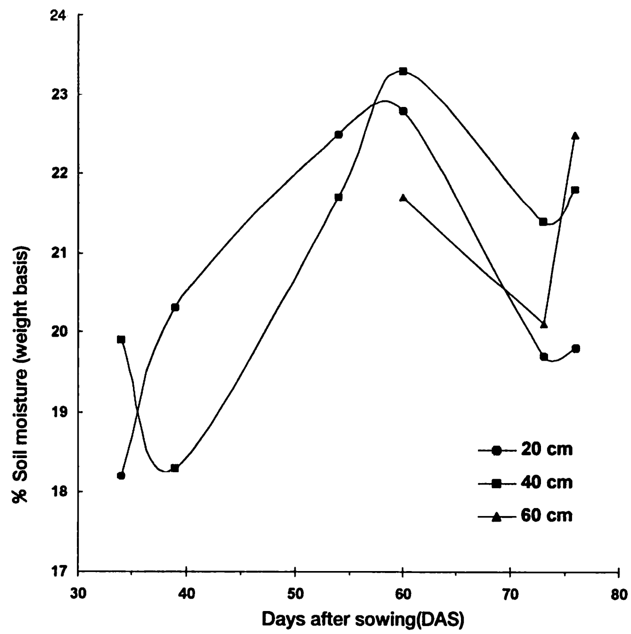

Fig. 5. Soil moisture status at I_4 (IW/CPE=1.0).

Table 4. Physico-chemical properties of soil during land preparation.

Treat-ment	pH	EC (µs/cm)	N (%)	NH_4-N (ppm)	NO_3-N (ppm)	P (ppm)	K (ppm)	S (ppm)	Organic carbon (%)	Soil texture
I_0N_0	6.48	420	0.162	4.20	11.20	57	42	20	0.95	Silt loam
I_0N_1	6.43	406	0.128	8.40	14.00	59	44	15	1.00	"
I_0N_2	7.42	440	0.055	7.00	12.60	57	40	15	1.00	"
I_0N_3	6.60	464	0.026	7.00	9.80	59	40	34	0.48	"
I_1N_0	7.72	478	0.124	5.60	4.20	50	50	20	1.48	"
I_1N_1	6.76	430	0.059	3.80	7.00	58	64	25	0.84	"
I_1N_2	6.78	340	0.028	4.20	4.80	56	62	15	1.48	"
I_1N_3	7.80	368	0.008	5.80	4.80	59	66	20	1.26	"
I_2N_0	6.74	488	0.052	4.20	7.00	60	48	20	0.79	"
I_2N_1	6.86	354	0.124	4.20	4.20	69	40	28	1.44	"
I_2N_2	6.87	468	0.139	4.20	8.40	59	44	28	0.61	"
I_2N_3	7.60	401	0.152	3.80	8.40	64	40	18	0.79	"
I_3N_0	6.67	440	0.131	5.60	8.40	56	39	20	0.53	"
I_3N_1	7.48	356	0.047	5.60	12.60	59	62	30	0.70	"
I_3N_2	6.76	483	0.039	4.20	8.40	60	39	30	1.61	"
I_3N_3	7.23	340	0.068	8.00	8.67	58	50	28	0.88	"
I_4N_0	7.80	402	0.990	7.68	10.11	50	55	28	0.79	"
I_4N_1	7.68	411	0.101	8.10	6.67	60	60	30	0.90	"
I_4N_2	7.70	414.35	0.800	9.20	10.45	62	48	35	0.69	"
I_4N_3	7.52	378	0.850	8.88	8.85	55	56	27	1.00	"
Mean	7.14	414.35	0.168	5.98	8.68	58.35	49.45	24.30	0.96	
Range	6.42-7.80	340-488	0.068-0.162	3.80-8.88	4.80 14.00	50-69	39-66	15-34	0.48-1.61	

Table 5. Physico-chemical properties of soil at harvest.

Treat-ment	pH	EC (μs/cm)	N (%)	NH_4-N (ppm)	NO_3-N (ppm)	P (ppm)	K (ppm)	S (ppm)	Organic carbon (%)
I_0N_0	6.52	411	0.131	8.40	10.00	49	27	17	0.88
I_0N_1	6.88	434	0.096	8.40	12.60	55	28	13	1.02
I_0N_2	6.90	419	0.086	8.40	19.60	58	29	14	0.93
I_0N_3	7.03	439	0.075	9.80	4.20	53	60	32	0.83
I_1N_0	7.12	448	0.077	7.00	8.40	52	67	13	0.85
I_1N_1	7.04	402	0.085	11.20	4.80	55	68	14	0.95
I_1N_2	7.16	376	0.087	8.40	7.00	51	47	19	0.95
I_1N_3	6.99	407	0.064	7.00	8.40	54	39	15	0.74
I_2N_0	6.73	337	0.121	5.60	4.80	56	36	16	1.14
I_2N_1	7.12	381	0.141	7.00	5.60	59	43	30	1.28
I_2N_2	6.57	382	0.064	7.00	19.00	55	39	27	0.72
I_2N_3	6.58	479	0.072	7.00	14.00	59	39	17	0.79
I_3N_0	6.98	394	0.062	7.00	7.00	56	40	15	0.67
I_3N_1	6.61	327	0.078	5.60	11.20	50	48	24	0.85
I_3N_2	6.89	470	0.082	11.20	5.60	49	64	22	0.93
I_3N_3	7.30	312	0.088	8.30	10.50	38	30	22	0.78
I_4N_0	7.22	372	0.120	8.88	11.60	42	37	28	0.89
I_4N_1	7.60	410	0.131	7.60	8.67	49	48	27	0.67
I_4N_2	7.13	375	0.088	7.89	7.89	37	51	33	0.88
I_4N_3	7.33	340	0.990	7.00	6.78	51	55	22	0.85
Mean	6.99	395.75	0.137	7.93	9.38	51.40	44.75	13-32	0.88
Range	6.52-7.60	312-479	0.064-0.141	5.60-11.20	4.20-19.60	37-59	27-74	9-40	0.67-1.28

moisture status at 20 cm depth of soil fluctuated at prior to and post irrigation, respectively. It might be due to low infiltration, evaporation and water holding capacity of soil.

The physico-chemical properties of soil during land preparation are presented in Table 4. Texturally, the soil of the study area was silt loam. pH, electrical conductivity (EC), nitrogen (N), NH_4-N, NH_3-N, phosphorous (P), potassium (K), sulphur (S) and organic carbon varied from 6.42 to 7.80, 340 to 488 μs/cm, 0.068 to 0.162%, 3.80 to 8.88 ppm, 4.80 to 14.00 ppm, 50 to 69 ppm, 39 to 66 ppm, 15 to 34 ppm and 0.48 to 1.16%, respectively. The physico-chemical properties of soil at harvest are presented in Table 5. It was found that pH, electrical conductivity (EC), nitrogen (N), NH_4-N, NH_3-N, phosphorous (P), potassium (K), sulphur (S) and organic carbon varied from 6.52 to 7.60, 312 to 479 μs/cm, 0.064 to 0.141%, 5.60 to 11.20 ppm, 4.20 to 19.60 ppm, 37 to 59 ppm, 27 to 74 ppm, 13 to 32 ppm and 0.67 to 1.28%, respectively. Table 4 and 5 indicate that the plant nutrients N, P, K, S and percentage of organic carbon decreased slightly at harvest in comparison with land preparation. This might be due to the uptake of plant nutrients during the growing period of the crop.

ABSTRACT

An experiment was carried out during November 1998 to April 1999 to find out the response of yield and yield contributing parameters of maize (cv. Bornali) to water stress and nitrogenous fertilizer. The experiment included two factors such as five irrigation regimes and four nitrogen levels. Texturally, the soil was silty loam. Yield and yield contributing characters were

significantly affected due to the application of irrigation and nitrogen. The highest grain yield of 6.77 t/ha was obtained with IW/CPE ratio of 0.5 and 5.61 t/ha by the application of 70 kg N/ha. Interactions between IW/CPE ratio of 0.5 and 70 kg N/ha were the best combination for yield of maize.

水ストレスと窒素肥料がトウモロコシの生育と収量に及ぼす影響

要　旨

トウモロコシの水分ストレスと窒素肥料に対する反応を調べるために、1998年11月から1999年4月にかけて実験を行なった。実験は、潅漑水量5水準と4水準の窒素レベルについて行なった。実験にはシルト質ロームを用いた。潅漑水量と窒素レベルにより収量は明らかな影響を受けた。潅漑水量に関して、最大収量の6.77t/haはIW/CPEが0.5で得られた。また、窒素レベルに関しては、最大収量の5.61t/haは70kgN/haの窒素施肥で得られた。従って、IW/CPE=0.5の潅漑水量と70kgN/haの窒素施肥量は、トウモロコシ栽培において高収量を得るのに良い組み合わせであるといえる。

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