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Performance of autumn planted maize (*Zea mays* L.) hybrids at various nitrogen levels under salt affected soils

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Abstract

Experiment was conducted to determine the response of two maize hybrids to nitrogen grown in salt affected soil. Both the maize hybrids differed significantly with respect to growth and yield performance. The response of hybrid Pioneer 32B33 was better with respect to growth and yield as compared to Dekalb 979. Maximum leaf area index and crop growth rate was found 60 days after sowing and after that it declined towards harvest. Nitrogen application increased leaf production and total leaf area for light interception for photosynthesis. Application of nitrogen at a level higher than recommended significantly improved the physiological parameters like leaf area index, crop growth rate, net assimilation rate and yield attributes compared to control but it was at par with the optimal level of nitrogen. The economical yield can be obtained by application of optimal level (225 kg ha^{-1}) of nitrogen.

Key word: Nitrogen, salt tolerance, growth, yield, yield components

Introduction

Salinity is one of the serious environmental problems that cause osmotic stress and reduction in plant growth and crop productivity in irrigated areas of arid and semiarid regions. Salinity limits the plant production in nearly 40% of agricultural lands worldwide (Gorham, 1992). Salinity is a major constraint to food production because it limits crop yield and restricts use of land previously uncultivated. Approximately 7% of the world's total land area is affected by salinity (Flowers *et al.,* 1997). Furthermore, there is also a dangerous trend of a 10% per year increase in the saline area throughout the world (Pannamieruma, 1984). In addition, salinity is a problem for agriculture because only few crop species and genotypes are adapted to saline conditions. Although irrigation covers only about 15% of the cultivated land of the world, irrigated land has at least twice the productivity of rain-fed land, and may therefore produce one-third of the world's food. The reduced productivity of irrigated lands due to salinity is, therefore, a serious issue. Salinity can inhibit plant growth by three major ways (Greenway and Munns, 1980): **a)** Water deficit arising from the more negative water potential (elevated osmotic pressure) of the soil solution; **b)** Specific ion toxicity usually associated with either excessive chloride or sodium uptake; and **c)** Nutrient ion imbalance when the excess of Na^+ or Cl^- leads to a diminished uptake of K^+, Ca^{2+}, NO_3^- or P, or to impaired internal distribution of one or another of these ions. Growth reduction differences in response to salinity among genotypes of a crop are evident during the second phase of inhibitions, as it was clearly found for wheat, barley and maize crops (Fortmeier and Schubert, 1995). Therefore, the failure of many short-term experiments to distinguish genotypic differences in salt tolerance is because the early response to salinity is to the osmotic effects of the salt and it is called as osmotic phase.

Salt tolerance of crops may vary with their growth stage (Mass and Grieve, 1994). In general, cereal plants are the most sensitive to salinity during the seedling, vegetative and early reproductive stages, and less sensitive during flowering and grain filling stages (Mass and Poss, 1989). However, a difference in the salt tolerance among genotypes may also occur at different growth stages. Therefore, the salt tolerance of different maize genotypes must be evaluated at different growth stages. Such evaluations may facilitate improvement. In salt tolerance of tested genotypes in breeding programs or it may prove feasible to irrigate with saline water during the more tolerant growth stages and with low salinity water only during the sensitive growth stages.

Nitrogen, in one form or another, accounts for about 80% of total mineral nutrients absorbed by plants

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(Marschner, 1995). Nitrogen deficiency is one of the major yield limiting factors for cereals (Shah *et al.,* 2003), hence nitrogen fertilizer application is an essential input for crop productivity in most areas of the world (Idris and Mohammad, 2001). Nitrate and ammonium ions are most abundent nitrogen sources for higher plants and their availability in the soil usually constitutes a limiting factor for plant growth (Causin and Barneix, 1993). Saline conditions can influence the different steps of nitrogen metabolisms such as uptake, reduction and protein synthesis that may be responsible for the reduction in the plant growth (Frechill *et al*., 2001). A significant negative correlation between concentration of nitrate (NO_3^-) and Cl^- was seen in the shoots or roots (Abdelgadir *et al.,* 2005). The reduction in NO_3^- uptake could be due to high Cl^- content in the saline soil. However, supplementing soil with nitrogen improved plant growth and yield due to antagonistic effect of N over Cl^- availability in the soil and thus their salt tolerance (Dubey and Pessarakli, 1995).

In Pakistan, maize is the third most important cereal after wheat and rice and is grown through out the country in a wide range of climatic conditions. Being an important "Kharif" crop, maize is grown on about 1118 thousand hectares with a total yield of about 4036 thousand tones and an average yield of 3610 kg ha^{-1} (Govt. of Pakistan, 2008-09). However, studies on salt tolerance are limited. The experiment was planned to determine the optimum level of nitrogen which could produce maximum growth and grain yield of maize under saline field conditions.

Materials and Methods

The crop was sown during the autumn season on August 4, 2007 at Post graduate Agricultural Research Station (PARS), University of Agriculture Faisalabad, Jhang Road Faisalabad. Representative composite soil samples were collected at five different places from 0-30 cm depth before planting and analyzed (Table 1) for EC_e (Rhoades, 1982), pH_s (Mclean, 1982), organic matter (Nelson and Sommers, 1982), total N (Tecator, 1981), particle size analysis (Gee and Bauder, 1986), P (Olson and Sommers, 1982), carbonate, bicarbonate and K as described by US Salinity Laboratory Staff (1954).

The experiment was laid out in a randomized complete block design with split plot arrangements. There were three replicates for each treatment. Net plot size was 5 m x 3 m. Maize hybrids and nitrogen levels were randomized in main and sub plots, respectively. The two maize hybrids (Pioneer32B33, Dekalb 979) were sown with single row hand drill in 75 cm apart rows, while plant to plant distance of 22.5 cm was maintained later on by hand thinning. There were four nitrogen levels which were applied as N_0 (Control), N_1 (175 kg N ha^{-1}), N_2 (225 kg N ha^{-1}), N_3 (275 kg N ha^{-1}). Nitrogen was applied to the plants in splits i.e. 1/3 at sowing, 1/3 at knee height and 1/3 at reproductive stage. The phosphorus and potassium were applied at recommended rate i.e.125 kg ha^{-1} of each. The whole phosphorus and potassium was applied at sowing time. The nitrogen, phosphorus and potassium were used in the form of ammonium nitrate (AN), single super phosphate (SSP) and sulphate of potash (SOP). Canal irrigation was applied as and when required. Hoeing was done at 25 days and 40 days after sowing to control weeds. Granules of carbofuran were applied @ 20 kg ha^{-1} on stem tops to control maize stem borer 35 days after sowing. The source of irrigation was canal water. All other agronomic practices were kept uniform for all the treatments. The following observations were recorded during the course of study.

Table 1. Physico-chemical properties of soil of the experimental field (0-30 cm depth)

Description	Value
Soil texture	Clay loam
Saturation percentage	33.7
Electrical conductivity (dS m^{-1})	5.71-8.91
Soil pH	7.72 - 7.90
Ca + Mg (mmol L^{-1})	4.61 - 7.19
Sodium (mmol L^{-1})	16.7 - 29.28
Total nitrogen (%)	0.030
Available potassium (mmol L^{-1})	1.55 - 2.01
Phosphorus (mmol $L^{-1)}$	0.18
Carbonate (mmol L^{-1})	Nil
Bicarbonate (mmol L^{-1})	1.67 - 1.83
Chloride (mmol L^{-1})	9.4
Sodium adsorption ratio (mmol $L^{-1})^{1/2}$	11.01 - 19.03

Plant height at maturity

Five plants were harvested at random from each plot from ground level. Their height was measured with the help of measuring tape at maturity and then average height was calculated.

Leaf area index

Leaf area of 10 g sub-sample of green leaf lamina was measured on a leaf area meter (ΔT Area meter MK2) and on the basis of fresh weight of leaves of four plants per plot converted into per square meter. Leaf area index (LAI) was calculated as the ratio of leaf area to land area as suggested by Watson (1952).

LAI = Leaf area / Land area

Crop growth rate

Dry matter (DM) accumulation was determined at fortnight intervals by selecting five plants randomly from each subplot. The sampling was started 30 days after sowing (DAS) and terminated at the harvest of crop. Soon after each harvest, samples were weighed to determine fresh weight. Each plant sample was chopped, thoroughly mixed and then sun dried. Afterwards samples were placed in oven at 70 $^oC \pm 5$ ^oC to dry the plant material to their constant dry weight. Then dry weight per m^2 was calculated and used to estimate crop growth rate as proposed by Hunt (1978).

$$CGR = W_2 - W_1 / t_2 - t_1$$

CGR = Crop growth rate, W_2 = dry weight per unit land area (g m^{-2}) at second harvest, W_1 = dry weight per unit land area (g m^{-2}) at first harvest, t_2 = time corresponding to second harvest and t_1 = time corresponding to first harvest

Net assimilation rate

The net assimilation rate (NAR) was estimated using the formula of Hunt (1978).

NAR = TDM / LAD
TDM = Total dry matter, LAD = Leaf area duration,
And $LAD = (LAI_1 + LAI_2) \times (t_2 – t_1)/2$
LAI_1 = leaf area index at t_1
LAI_2 = leaf area index at t_2
t_1 = time corresponding to first harvest
t_2 = time corresponding to second harvest

Cob length

Cob length of ten cobs was taken from each plot with the help of scale and then average was taken. It was expressed in centimeter (cm).

Number of grains per cob

Ten cobs were selected at random from each plot. Grains were shelled with hands and number of grains were counted. Then average of these ten cobs' grains was calculated.

Number of grain rows per cob

Ten cobs were selected randomly from each plot and number of grain rows in each cob was carefully counted and averaged.

100-grain weight

Hundred grains were taken at random from the grain lot of each sub-plot and weighed.

Biological yield

After harvesting the crop from each plot, whole material was sun dried. The total weight of cobs and stalk per plot was determined and converted on hectare basis.

Grain yield

All the cobs in each plot were shelled, sun dried and weighed. The weight of grains per plot was converted into kilograms per hectare.

Harvest index

The harvest index (HI) was calculated as the ratio of grain yield to biological yield and expressed in percentage. Harvest index was calculated by using the following formula:

HI = (Grain yield / Biological yield) x 100

Economic analysis

The experimental data were analysed by using methodology described in CIMMYT (1988). For economic point of view, cost of production of maize was calculated in the experiment during year 2007 by applying nitrogen under saline conditions. Net income and BCR (benefit cost ratio) was computed to examine the most profitable treatment.

Statistical analysis

Data regarding various growth and yield parameters were collected using standard procedures and were analyzed statistically by using Fisher's analysis of variance technique. Three replicates for each treatment were maintained in each experiment. The treatment means were compared using least significant difference test at 5% probability level (Steel *et al*., 1997).

Results

Leaf area index (LAI) is the main physiological determinant of crop yield. The results of field trial on saline soil indicated that leaf area index in both the hybrids (Figure 1A) continued to increase from 30 days after sowing (DAS) to 60 DAS and then gradually declined towards the final harvest. Maize hybrids differed significantly regarding LAI except at final harvest (90 DAS). Maximum LAI was recorded on 60 DAS harvest in both the hybrids which ranged from 3.11 for Pioneer 32B33 to 2.76 for Dekalb 979. Different nitrogen levels increased LAI significantly from 45 DAS towards final harvest (Figure 1B). Maximum LAI (3.06) was produced (60 DAS) in N_3 (275 kg N ha^{-1}) treatment, which was closely followed by N_2 (225 kg N ha^{-1}) and minimum LAI (2.73) was produced in control, where nitrogen was not applied. LAI significantly increased with the application of nitrogen but at 75 days after sowing there was non-significant difference among N_1 (175 kg N ha^{-1}), N_2 (225 kg N ha^{-1}) and N_3 (275 kg N ha^{-1}) treatments excluding control (no application). Interaction between maize hybrids and different nitrogen levels was found to be non-significant throughout the season (Table 2). Regression analysis between LAI and grain yield attributes indicate highly significant relationship (Figure 4B).

Figure 2A,B reveal that crop growth rate (CGR) continued to increase up to 60 days after sowing (DAS) thereafter, it declined in both the hybrids; however, Pioneer32B33 had significantly greater mean CGR (10.43 g m^{-2} d^{-1}) than Dekalb 979 (9.02 g m^{-2} d^{-1}) at final harvest. Application of nitrogen increased the CGR at all the harvests but effect was more pronounced under different levels of nitrogen on 60 days after sowing. At final harvest (90DAS), the average CGR for N_0 (control), N_1 (175 kg N ha^{-1}), N_2 (225 kg N ha^{-1}) and N_3 (275 kg N ha^{-1}) was 7.53, 10.15, and 10.70 g m^{-2} d^{-1}, respectively. Interaction between maize hybrids and different levels of nitrogen was non-significant through out the season including final harvest (Table 2). Regression analysis indicate that there was highly significant relationship between LAI and CGR (Figure 4A). The correlation between LAI and CGR was also significant.

Table 2. Interactive effect of maize hybrids and different nitrogen levels on leaf area index (LAI) and crop growth rate (CGR) under saline conditions

	LAI					CGR			
Treatments	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
H_1N_0	0.62	1.49	2.92	2.50	0.95	10.51	17.84	15.47	7.63
H_1N_1	0.65	1.66	3.10	2.78	1.13	11.76	21.54	18.12	12.07
H_1N_2	0.64	1.71	3.19	2.85	1.21	11.85	22.83	19.21	11.30
H_1N_3	0.65	1.74	3.21	2.99	1.17	11.76	23.56	19.11	10.72
H_2N_0	0.59	1.41	2.54	2.40	0.89	8.23	15.34	13.84	7.43
H_2N_1	0.62	1.53	2.75	2.48	1.04	9.18	17.47	15.64	8.23
H_2N_2	0.61	1.61	2.83	2.50	1.08	9.20	19.18	15.86	10.11
H_2N3	0.62	1.62	2.90	2.54	1.10	9.47	19.67	16.14	10.61
LSD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

H_1= Pioneer 32B33, H_2 = Dekalb = 979
N_0 = Control, N_1 = 175 kg ha^{-1}, N_2 = 225 kg ha^{-1}, N_3 = 275 kg ha^{-1}
Means sharing the same letters in a column do not differ significantly at p 0.05
* = Significant at P ≤ 0.05 levels respectively
NS = Non significant
DAS = Days after sowing

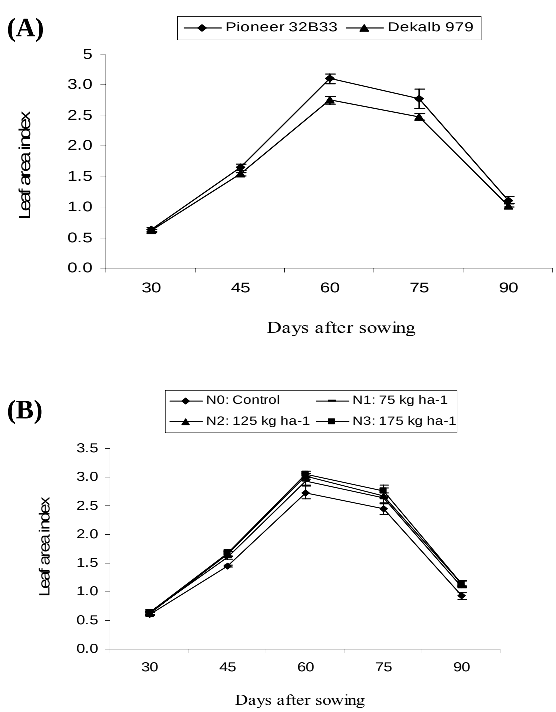


Figure 1(A, B). Leaf area index as affected by different nitrogen levels ± SE

Table 3 indicates that there were significant differences between maize hybrids for net assimilation rate (NAR). Nitrogen treatments showed significant role in improving the NAR compared with N_0 (no application) but there was non-significant differences among N_1 (175 kg N ha^{-1}), N_2 (225 kg N ha^{-1}) and N_3 (275 kg N ha^{-1}) treatments. Interaction between maize hybrids and different nitrogen treatments was non-significant.

Plant height at maturity is a function of combined effects of genetic make up of a plant, soil nutrient status, water availability, seed vigor and the environmental conditions under which it was grown. The analyzed data (Table 3) clearly indicates that plant height differed significantly in hybrids under saline conditions. Application of nitrogen significantly increased the plant height. Maximum plant height (150.80 cm) was attained in N_3 (275 kg N ha^{-1}) which was statistically at par when nitrogen was applied at the rate of 175 kg N ha^{-1} (N_2) and minimum was recorded in control (no application). The interaction between maize hybrids and nitrogen levels was non-significant (Table 4).

number of grains per cob (430) than Dekalb979 (367.58). Among nitrogen treatments; maximum number of grains per cob was found where nitrogen was applied @ 275 kg ha^{-1} which was statistically at par with that when nitrogen was applied @ 225 kg ha^{-1} and minimum was recorded for control (no application).

The data in Table 3 show non-significant difference between maize hybrids for the parameter under discussion.

Table 3. Effect of different nitrogen levels on net assimilation rate, plant height, and yield and yield components of maize hybrids under saline conditions

Treatment	**Net assimilation rate (g m^{-2} d^{-1})**	**Plant height (cm)**	**Cob length (cm)**	**Number of grains cob^{-1}**	**Number of grain rows cob^{-1}**	**100-grain weight (g)**	**Biological yield (Kg ha^{-1})**	**Grain yield (Kg ha^{-1})**	**Harvest index (%)**
	Mean								
Maize hybrids (H)									
(H_1^+)	7.89 a	145.83 a	14.52 a	430.00 a	14.66	14.03 a	12883 a	3012 a	23.33
(H_2^{++})	7.26 b	130.67 b	12.67 b	367.58 b	13.33	12.12 b	11587 b	2680 b	22.92
LSD at 5%	0.41	10.47	0.56	18.61	NS	0.85	436.82	114.92	NS
Nitrogen levels (N) (kg ha^{-1})									
N_0 : 0	7.14 b	123.50 c	12.06 c	342.80 c	12.00 c	10.99 c	9944 d	2136 c	21.54 b
N_1 : 175	7.70 a	133.70 b	13.13 b	394.30 b	14.00 b	12.43 b	12017 c	2560 b	21.32 b
N_2 : 225	7.78 a	145.00 a	14.47 a	428.80 a	14.67 ab	14.18 a	13224 b	3299 a	25.00 a
N_3 : 275	7.69 a	150.80 a	14.74 a	429.20 a	15.33 a	14.70 a	13756 a	3391 a	24.65 a
LSD at 5%	0.30	6.86	0.60	19.64	1.18	0.90	461	121	1.38
Interaction (H x N)	NS	NS	NS	NS	NS	NS	*	NS	NS

Means sharing the same letters in a column do not differ significantly at p 0.05
* = Significant at P ≤ 0.05 levels, respectively
NS = Non significant
[+] Pioneer 32B33
[+] Dekalb979

The cob length determines the productivity of maize crop which ultimately contributes to final grain yield. The data regarding cob length as influenced by different nitrogen levels under saline conditions are presented in Table 3. The hybrid Pioneer 32B33 significantly produced longer cob length (14.52 cm) than Dekalb979 (12.67 cm). Among nitrogen treatments, maximum cob length (14.74 cm) was recorded in treatment N_3 (275 kg N ha^{-1}) which was statistically at par with N_2 (225 kg N ha^{-1}) and minimum was noted in control where no nitrogen was applied. The interaction between maize hybrids and nitrogen levels was non-significant (Table 4).

The productive potential of hybrid is measured in term of number of grains per cob. It is important parameter which affects crop yield significantly. The analyzed data presented in Table 3 indicate that there was highly significant difference between maize hybrids and different nitrogen levels. The hybrid Pioneer 32B33 produced more

Among nitrogen treatments, maximum number of grain rows per cob (15.33) was recorded in treatment N_3 (275 kg N ha^{-1}) which was followed by N_2 (225 kg N ha^{-1}) and minimum was found in control (no application) treatment. The interaction between maize hybrids and nitrogen levels was non-significant (Table 4). Regression analysis clearly shows that there was highly significant relationship between number of grains per cob and grain yield attributes (Figure 5).

The weight of grain is an important yield component and makes a major contribution towards grain yield of maize. The analyzed data presented in Table 3 indicate that maize hybrid Pioneer 32B33 produced more 100-grain weight (14.03g) than Dekalb 979 (12.12 g). The effect of nitrogen application revealed that maximum grain weight was recorded in N_3 (275 kg ha^{-1}), whereas, minimum was noted in control. Treatment N_3 (275 kg N ha^{-1}) and N_2 (225 kg N ha^{-1}) were at par with each other. The interaction between maize hybrids and nitrogen levels was non-significant (Table 4). Regression analysis indicate that there was highly significant relationship between 100-grain weight and grain yield parameters (Figure 6). Correlation between 100-grain weight and grain yield was also significant.

recorded in N_3 (275 kg N ha^{-1}), which was similar to that of N_2 (125 kg N ha^{-1}), and minimum was recorded in control. The interaction between maize hybrids and nitrogen levels was non-significant (Figure 3A).

Table 4. Interactive effect of maize hybrids and different nitrogen levels on net assimilation rate, plant height, cob length, number of grains per cob, number of grain rows per cob, 100-grain weight, biological yield grain yield and harvest index under saline conditions

Treatment	Net assimilation rate ($g\ m^{-2}\ d^{-1}$)	Plant height (cm)	Cob length (cm)	Number of grains cob^{-1}	Number of grain rows cob^{-1}	100-grain weight (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})
H_1N_0	7.32	130	12.90	369	13	11.38	9906 d	2302
H_1N_1	8.15	136	13.96	437	15	13.50	12893 b	2700
H_1N_2	8.14	155	15.50	457	15	15.23	14160 a	3460
H_1N_3	7.99	161	15.73	458	16	16.00	14574 a	3586
H_2N_0	6.96	117	11.22	317	11	10.60	9982 d	1970
H_2N_1	7.27	130	12.29	352	13	11.35	11141 c	2419
H_2N_2	7.43	135	13.44	401	14	13.13	12289 b	3138
H_2N3	7.41	140	13.75	400	15	13.40	12938 b	3195
LSD at 5%	NS	NS	NS	NS	NS	NS	651	NS

H_1= Pioneer 32B33, H_2 = Dekalb 979
N_0 = Control, N_1 = 175 kg ha^{-1}, N_2 = 225 kg ha^{-1}, N_3 = 275 kg ha^{-1}
Means sharing the same letters in a column do not differ significantly at p 0.05
* = Significant at P ≤ 0.05 levels respectively
NS = Non significant
DAS = Days after sowing

The analyzed data (Table 3) show significant differences for biological yield in both maize hybrids and among different nitrogen levels. The hybrid Pioneer 32B33 produced higher biological yield (12883 kg ha^{-1}) than Dekalb979 (11587 kg ha^{-1}). All the nitrogen treatments differed significantly from each other for biological yield. Maximum biological yield was recorded in N_3 (275 kg N ha^{-1}), whereas, minimum was in control where no nitrogen was applied. Interaction between maize hybrids and different nitrogen levels shows that with the application of nitrogen the biological yield increased in both the hybrids (Figure 3A).

The efficacy and effectiveness of a package of technology is ultimately reflected by the level of grain yield per hectare, which is a function of cumulative behavior of yield components, such as number of grain rows per cob, number of grains per cob and 100-grain weight. The maize hybrids differed significantly from each other with respect to grain yield (Table 3). The comparison of nitrogen treatment means indicate that nitrogen application resulted in increased grain yield. Maximum grain yield was

The harvest index was non-significant between two maize hybrids. Different nitrogen treatments exhibited significant effect on harvest index and it ranged 21.32 to 24.65% among different nitrogen treatments (Table 3). Interaction between maize hybrids and different nitrogen levels (Figure 3B) indicates that nitrogen application enhanced the harvest indices of both hybrids and increase in harvest index was more pronounced in Dekalb979.

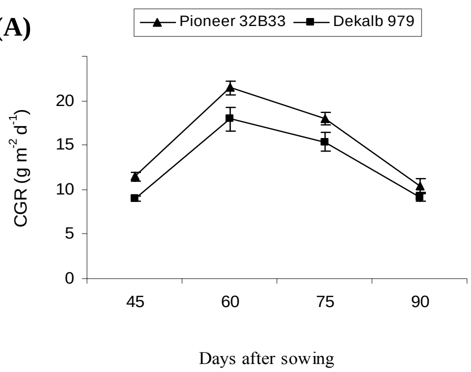
Economic analysis for the production of maize hybrid for 2007 indicate that different levels of applications of nitrogen resulted in different net income (Rs. ha^{-1}) as indicated in Table 5. Application of nitrogen @ 225 kg N ha^{-1} resulted in highest net income of Rs. 19182 during 2007. The highest benefit cost ratio (BCR) of 1.58 was recorded in N_2 (225 kg N ha^{-1}) treatment

Discussion

Salinity and low nitrogen availability are the main growth limiting factors in most of the plants. Application of nitrogen significantly increased the plant height in both the maize hybrids. Albassam (2001) and Flores *et al.* (2003)

reported that nitrogen availability increased with the addition of nitrogen fertilizers especially in saline soil and nitrogen may alleviate adverse effects of salinity on plant growth. Nitrate and ammonium are the most abundant nitrogen sources for plants and their availability usually constitutes a limiting factor for plant growth and productivity (Causin and Barneix, 1993). The individual physiological responses of plants to nitrogen sources are quite different, probably due to their genetic make up regarding varying ability to absorb and assimilate them (Botella *et al.,* 1994).

(A)



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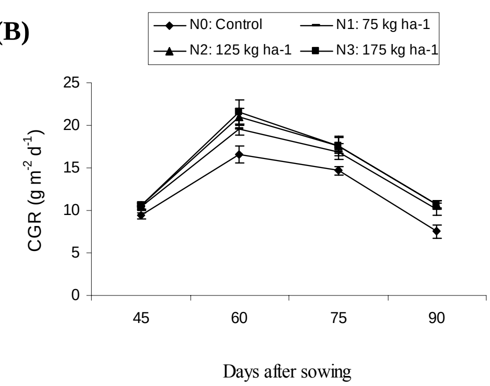
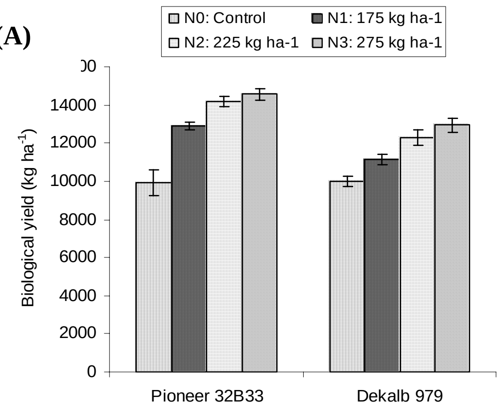


Figure 2(A, B). Crop growth rate (CGR) as affected by different nitrogen levels ± SE

Fall in leaf area index 60 days after sowing might be the result of leaf senescence because the sunlight does not reach the bottom leaves (Figure 1A and 1B). Salinity stress markedly reduced crop growth and net assimilation rate and altered root to shoot biomass allocation (Tattini *et al.*, 2002). Trapani *et al.* (1999) opined that the leaf size is responsible to nitrogen supply.

The present investigations have demonstrated that increasing the supply of nitrogen fertilizer increases growth and photosynthesis. Nitrogen deficiency reduces the leaf production and total leaf area for light interception for photosynthesis (Toth *et al*., 2002). Promotive effect of nitrogen on leaf area index (LAI) of maize has been reported by Bangarwa *et al*. (1988).

(A)



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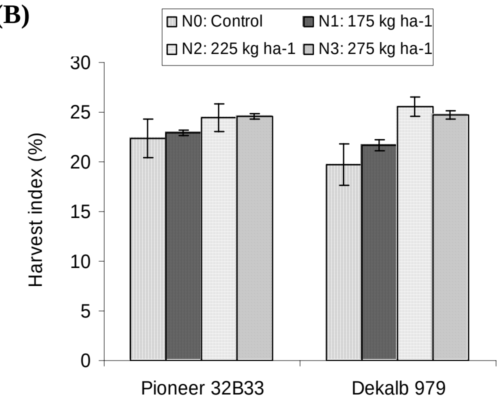

Figure 3(A, B). Interactive effect of maize hybrids and different nitrogen levels on biological yield (A) and harvest index (B) of maize hybrids under saline conditions ± SE

Salinity and nitrogen rate both affected total plant dry matter accumulation. The proper use of nitrogen fertilizer in all soils is important but particularly in saline soils, where nitrogen alleviates the adverse effects of salinity on plant growth and yield (Shen *et al*., 1994; Soliman *et al.,* 1994; Albassam, 2001; Flores *et al*., 2001) depending on plant species, intensity of salinity stress and other adverse environmental conditions (Grattan and Grieve, 1999).

In the present study, salt stress reduced the growth and yield of both maize hybrids. The higher biomass yield obtained in this study with ammonium nitrate source of nitrogen supports the findings that cereal crops supplied with both nitrate and ammonium produced higher yields because ammonium and sodium have antagonistic effect with each other (Camberato and Bock, 1989).

Table 5: Effect of nitrogen applications on net income and benefit-cost ratio (BCR)

Treatments	Total expenditure (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	BCR
Nitrogen				
Nitrogen applications				
N_0: Control	27110	34710	7600	1.28
N_1: 175 kg N ha^{-1}	32813	41600	8787	1.26
N_2: 225 kg N ha^{-1}	34426	53608	19182	1.58
N_3: 275 kg N ha^{-1}	36043	55103	19060	1.53

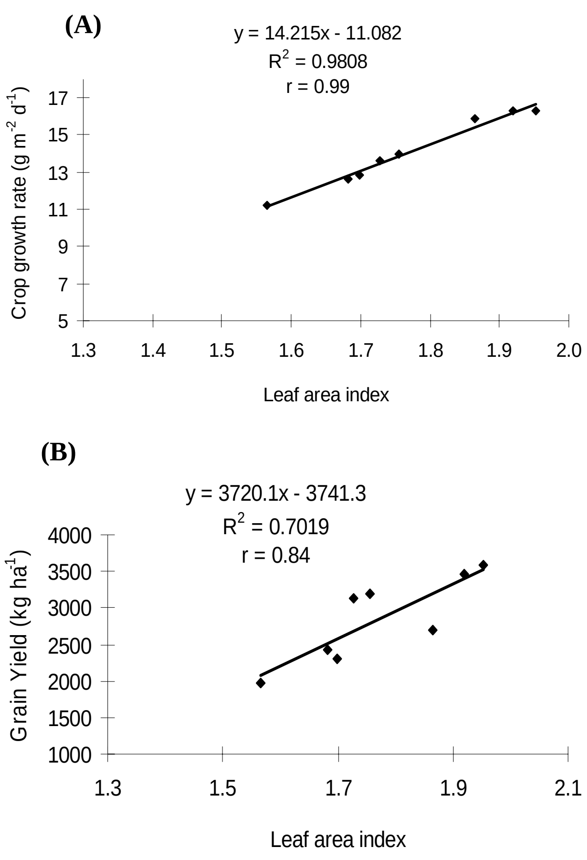

Figure 4(A, B). Regression between (A) leaf area index and crop growth rate (B) leaf area index and grain yield in maize hybrids

The fertilizer induced improvement in growth and development under salinity stress has been reported earlier in different crops (Ashraf, 1999). Nitrogen application improved the crop growth under saline conditions. This was due to the fact that nitrogen in the original soil was too low to meet the nitrogen requirements of the crop and addition

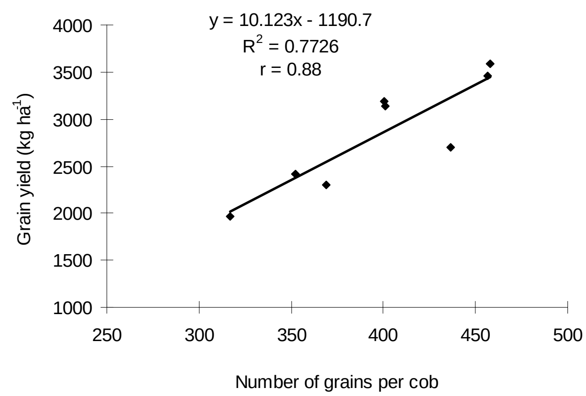

Figure 5. Regression between number of grains per cob and grain yield in maize hybrids

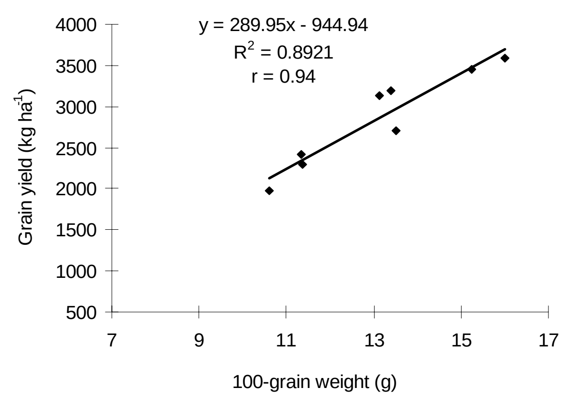

Figure 6. Regression between 100-grain weight and grain yield in maize hybrids

of nitrogen resulted in improvement in yield of maize (Ghafoor and Akhtar, 1991). Maize growth and nutrient content depend on nitrogen source and level of salinity. The salinity hazards on plants could possibly be reduced through appropriate use of nitrogen fertilizer. These short term effects of nitrogen need to be extended over a full cropping period in salt affected fields using different crops in order to validate these results.

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