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RESPONSE OF MAIZE VARIETIES TO NITROGEN APPLICATION FOR LEAF AREA PROFILE, CROP GROWTH, YIELD AND YIELD COMPONENTS

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Abstract

An experiment was conducted at NWFP Agricultural University, Peshawar, to study maize varieties and Nitrogen (N) rates for growth, yield and yield components. Three varieties (Azam, Jalal and Sarhad white) and three N rates (90, 120, 150, kg N ha^{-1}) were compared. Experiment was conducted in a Randomized Complete Block design; split plot arrangement with 4 replications. Uniform and recommended cultural practices were applied during the crop growth. The results revealed that maize variety 'Jalal' performed relatively better crop growth rate (CGR) and leaf area profile (LAP) at nodal position one to six as compared to the other two varieties (Sarhad white and Azam). This resulted higher radiation use efficiency by the crop canopy at vegetative stage of development and hence contributed higher assimilates towards biomass production. Heavier grains in number and weight were due to higher LAP and taller plants of Jalal which yielded higher in the climate. Nitrogen applications have shown that maize seed yield increase in quadratic fashion with increased N to a plateau level. Considering soil fertility status and cropping system, the 150 kg ha^{-1} N application to maize variety Jalal in Peshawar is required for maximum biological and seed production.

Introduction

Maize an important cereal of the world, ranked 1^{st} in seed yield production (Stephen *et al*., 2006) and can grow in areas where annual precipitation exceeds 600mm. Despite modern agriculture is concerned with yield and nutritional quality of crop but environment does play its role for production of the varieties (Derby *et al*., 2004). Horizontal improvement due to expansion of population is becoming limiting. Nonetheless, effort has to make for the vertical increase in the productivity. Moreover, cost of production has to economize while optimizing inputs through proper management. Additionally it would also control the environmental pollution (Derby *et al*., 2005). Nitrogen is highly volatile and its inappropriate application to field crops not only contributes towards pollution but also increases the cost of production. It is therefore worthwhile to study the N response on maize growth and development. Economic situation of the growers is major limiting factor affecting nutrients application to soil and to harvest yield potentiality of a crop in an area (Below, 2002). Economist categorized area status with respect to annual N application to the field crops (Sripada *et al*., 2005).

Crops yield improvements in past 50 years are due to breeding efforts or cultural improvement of which N played a significant role (Duvick, 1992; Sinclair, 1995). Optimum N has increased growth rate and delayed senescence (Muchow, 1988; Uhart & Andrade, 1995) with relatively higher leaf expansion rate and duration. Higher dry matter due to N was also observed in maize (Abbas *et al*., 2003). Radiation use efficiency (RUE) is important growth parameters and is relatively simple, stable and works well in situations with diversified climatic conditions (Boote *et al*., 1996). Optimum plants with sufficient inputs might play significant role in production due to efficient utilization of resources e.g. light, CO_2 and water etc. Assuming biotic and abiotic stresses constant, dry matter yield is equal to amount of radiation absorbed by the canopy (Kiniry *et al*., 1989; Sinclair & Muchow, 1999). Light interception by crop canopy is function of dry matter productivity where leaf contributes more than 80% (Bonhomme, 2000). Leaf area development at different nodal position is therefore important parameter to take in consideration of crop yield and yield components.

Materials and Methods

Experimental site and location: Field study on maize varieties in relation to N application were conducted at Agronomy Research Farm, NWFP Agricultural University, Peshawar during summer 2006. Sowing was done in Randomized Complete Block (RCB) design with split plot arrangement. Nitrogen was applied in main plots and varieties into subplots within blocks in four replications. Soil analysis was conducted before sowing which showed low (0.004%) nitrogen contents. Treatments details are shown below:

A. Main plot (N-rates)	**B. Subplots (Varieties)**
N_1 = 90 kg ha^{-1} (25% deficient)	V_1 = Azam
N_2 = 120 kg ha^{-1} (optimum)	V_2 = Jalal
N_3 = 150 kg ha^{-1} (25% sufficient)	V_3 = Sarhad white

Nitrogen was applied in three split applications: 1st at sowing, 2nd 35 days after sowing (DAS) and 3rd 50 DAS. Phosphorus and potassium were applied uniform at 110 and 60 kg ha^{-1} respectively during seedbed preparation. Size of the experimental unit was 5 m x 4.5 m having six rows. Planting was done on flat beds in rows spaced 0.75 m. Plant to plant distance was maintained 0.2 m in rows about 20 DAS. Extra plants were removed by thinning.

Sample size & methodology: Canopy leaf area index (LAI) was recorded using non-destructive leaf area meter (LI-2000, LI-COR, USA). Light measurements in the crop canopy during vegetative growth were recorded periodically using quantum point and line sensors (LI-190 & LI-191, LI-COR, USA) as per procedure adopted by Akmal & Janssens (2004). Briefly the quantum sensor was placed above, the line sensors below and at inverted positions in a treatment to record irradiance (I), reflectance (R), and transmittance (T). Ten readings for each treatment for I, R, and T were recorded and stored in data logger (LI-1400, LI-COR, USA) which were averaged for a mean reading of a treatment. Percent PAR absorption was calculated for each sampling observed during the crop growth. Daily solar radiation data was obtained from weather station located in 500 m distance from the experimental site. Cumulative Photosynthetically Active Radiations (PAR) for growth period was derived by multiplying solar radiation with 0.47. The cumulative PAR was multiplied with corresponding PAR percentage of a treatment to get cumulative PAR absorption. Radiation use efficiency was derived as ratio of DM and cumulative PAR absorption. For measurements of leaf area profile (LAP), leaf length, width and area of all leaves on different nodal position were measured on 10 selected plants. Plants were randomly harvested after completion of pollination (60 & 70 DAS). Leaves $plant^{-1}$ from nodal position 1 to n (bottom to top) were removed. Leaf area, length, average and maximum width were measured by passing all leaves from leaf area measuring machine (LI-3000A, LI-COR, USA). LAP was plotted as ratio between leaf area and corresponding nodal position. Periodic sample of one meter row length in each plot was harvested, dried in oven at 70^{O}C for dry matter growth comparison. Five samples during crop growth with 15-18 DAS were observed. Dry matter against time (DAS) was regressed using Richards's equation (Richards, 1959) to smooth the curves. For seed and dry matter yield (kg ha^{-1}), two central rows were reserved and harvested at maturity. Plant height, plants m^{-2} and cob number $plant^{-1}$ including 1000 grains weight were recorded and harvest index was determined as ratio of seed and total biomass.

Results and Discussion

Leaf area profile: The leaf area profile (LAP) i.e., leaf area (cm^{-2}) at different nodal positions of maize plant (bottom to top) is shown in Fig. 1. Both varieties (Fig. 1a) as well as N levels (Fig. 1b) showed differences in LAP. It was observed that as plant proceeds in growth, LAP increased till the 4^{th} node. Thereafter, at nodal positions 4^{th} and 6^{th} remained almost uniform and then decreased with further development of the crop canopy. LAP of maize $plant^{-1}$ showed a bell shape with marked differences among varieties and N levels at all nodes. Jalal clearly differed with relatively highest values for LAP from node 1 to 6. Azam showed visible differences in LAP at nodal position 4 to 6 when compared with Sarhad white. LAP of all varieties were relatively narrow at nodal position 7-11. The N levels showed significant difference from node 1 to 11. However, differences in LAP were relatively wider at position 4 to 6 compared to any other nodes (Fig. 1b). For N-levels, treatment 150 kg ha^{-1} was dominant over the other N application rates for almost all nodes. Treatment 120 kg ha^{-1} did not show similar leaf area at any nodal position when compared with 150 kg ha^{-1}. The 90 kg ha^{-1} was observed lowest to yield plant LAP as compared to 120 and 150 kg ha^{-1}. As expected, a bell-shaped LAP in maize plants was observed which differed for the varieties as well as N application rates to the crop (Ciganda *et al*., 2008) while corn yield has shown an increase in quadratic fashion when N to crop increased (Derby *et al*., 2005). In maize crop canopy, leaf area and vertical leaf area profile influence the interception and utilization of solar radiation which consequently drive dry matter accumulation and results the grain yield (Valentinuz & Tollenaar, 2006). Nitrogen is the primary chlorophyll constituents in plant body. Long- or medium-term changes in chlorophyll may relate to photosynthetic capacity (i.e. productivity) and influenced growth and developmental (Ustin *et al*., 1998) resulting both dry matter and seed yield (Dawson *et al*., 2003).

Crop growth rate: The relationship of dry matter with growing degree days ^{O}C (GDD) of maize varieties and N levels is shown in Fig. 2. The sigmoid dry matters were smoothed using Richards' non-linear growth equation. All the three maize varieties showed a sigmoid relationship against independent factor of production (GDD). Growth responses of three maize varieties were almost similar at initial establishment phase (Fig. 2a). Jalal showed a small difference over the others at 1000 GDD which increased with time (1500 GDD). Azam did not show any remarkable difference from Sarhad white at any stage of development. Differences in growth of varieties were mainly due to their leaf area expansion rate which was observed relatively higher for Jalal. The higher leaf area might have contributed higher in light capturing and hence has built higher assimilates under non limiting water and nutrients for leaf and stem development (Sumi & Katayama, 2000). The 150 kg ha^{-1} N did differ than treatments 120 and 90 kg ha^{-1} at 1000 GDD (Fig. 2b). Comparing 90 and 120 kg ha^{-1} N, the latter treatment showed a slight change in dry matter at 1200 GDD which expands with further growth (1500 GDD). Nitrogen is main nutrients for the plant vegetative growth and corn is an exhaustive crop have demanded higher N when planted in rotation with cereals e.g. wheat (Derby et al., 2005). We observed relatively a higher CGR when N was applied at 150 kg ha^{-1} which may be due to efficient N utilization by the crop (Uhart & Andrade, 1995). The highest LAP of Jalal and their similar effect with sufficient N has reflected higher CGR.

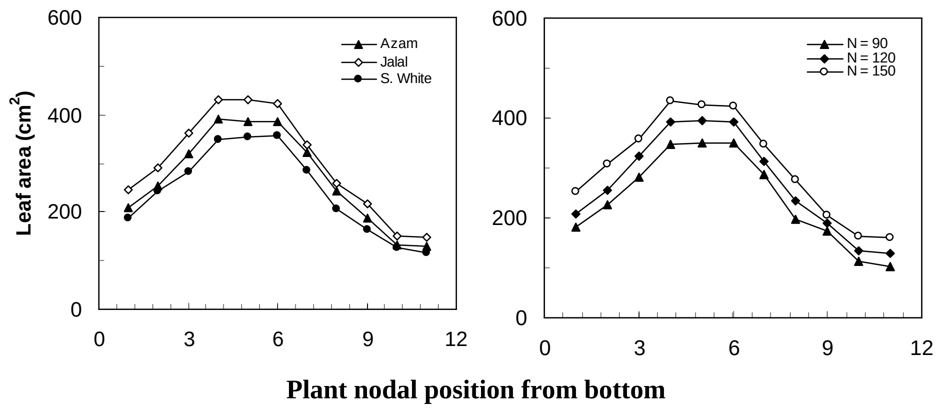

Fig. 1. Leaf area profile (LAP) in maize plant of different varieties and N levels.

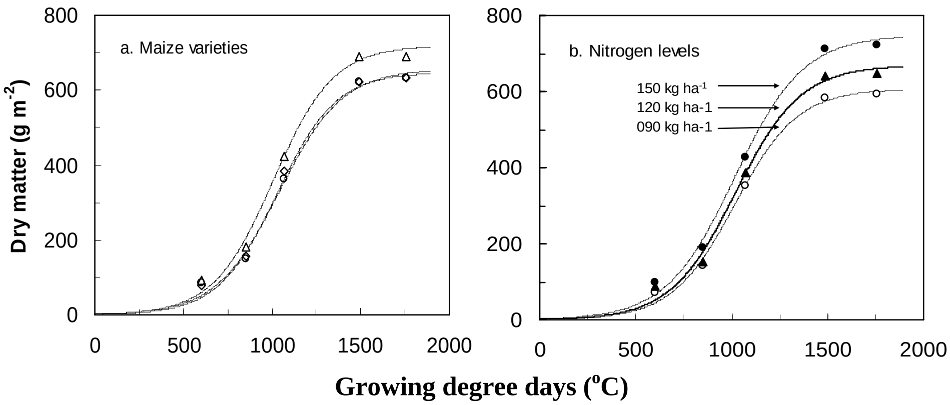

Fig. 2. Dry matter production in relation to growing degree days of (a) maize varieties and (b) N levels.

Yield & yield component: Statistical analysis of data showed difference ($p<0.05$) in height (cm) of varieties and N levels (Table 1). Maximum height (159 cm) was observed for Jalal and minimum (143 cm) for Azam. Likewise, 150 kg ha^{-1} N treatment showed tallest (160 cm) plants which differed significantly than 120 kg ha^{-1} N treatment. The minimum (140 cm) height was observed for 90 kg ha^{-1} N treatment. Interactive effect of treatments showed a uniform decreasing trend when N application reduced from 150 to 90 kg ha^{-1}. Different height of the varieties is genetic but N being primary yield constituent when increase resulted tallest plant (Abbas *et al.*, 2003). The maximum (3.5) leaf area index (LAI) was recorded for variety Sarhad white with no difference than Jalal (3.3) and Azam (3.1). Highest N rate (150 kg ha^{-1}) showed higher LAI (3.6) which did not differ than 120 kg ha^{-1} N treatment. Likewise, LAI reported for N 120 and 90 (kg ha^{-1}) also did not differ. However, LAI for 150 kg ha^{-1} and 90 kg ha^{-1} was significant ($p<0.05$). Difference in LAI of varieties was due to differences in leaf number and their arrangements on plant (Elings, 2000). High N has shown higher leaf area and slower the rate of senescence (Sumi & Katayama, 2000). Radiation use efficiency (RUE, g DM MJ^{-1} PAR absorbed) of varieties did not differ ($p<0.05$) but N levels showed a significant response. The lower N rate to crop resulted low RUE ($p<0.05$) when compared with high N rates (i.e. 120 and 150 kg ha^{-1}). RUE with N application of 120 and 150 kg ha^{-1} did not differ ($p<0.05$). The higher RUE with optimum N application is due to more green surface and lower senesce (Diker & Bausch, 2003).

Grain number ear^{-1} is significant parameter of seed yield and influenced with N application and varieties. High grains ear^{-1} (387.4) was recorded for Jalal. Sarhad white (320) and Azam (309.3) did not vary in grains ear^{-1}. N application of 150 (404) and 120 (349) did not show any difference in grains ear^{-1}. Treatment 90 kg ha^{-1} showed significantly lower grains ear^{-1} (262.9). Statistical analysis of data indicated that 1000 grains weight (g) differ ($p<0.05$) for varieties and N levels. The higher weight (184.7 g) was recorded for Jalal and lower (180.1 g) for Sarhad white. Azam did not differ from Sarhad white. Likewise, highest 1000 grain weight (192 g) was observed for 150 kg ha^{-1} N application and lowest (172 g) for 90 kg ha^{-1} N. Difference in grains ear^{-1} and weight is results of assimilate production and its partitioning. The higher leaf area exposed by the canopy has resulted higher grains and its weight and hence yielded higher seed yield.

Biological yield differed ($p<0.05$) for varieties and N levels. The maximum biological yield (9409 kg ha^{-1}) was recorded for Jalal and minimum (8490 kg ha^{-1}) for Azam. Treatment 150 kg N ha^{-1} yielded highest biological yield (9828 kg ha^{-1}) and 90 kg ha^{-1} the minimum (8055 kg ha^{-1}). Seed yield (kg ha^{-1}) was significantly affected by varieties and N levels. Highest seed yield (4535 kg ha^{-1}) was reported for Jalal. Sarhad white (3937 kg ha^{-1}) and Azam (3706 kg ha^{-1}) did not differ in seed yield. Treatment 150 kg N application yielded highest seed yield (4827 kg ha^{-1}), followed by 120 kg N application (3962 kg ha^{-1}) and 90 kg N (3327 kg ha^{-1}). Interactive effects of treatments (Varieties x N) were significant. Jalal remained dominated over Azam and Sarhad white for high N application. Maximum harvest index (47%) was recorded for Jalal and minimum (43%) for Azam. variety Sarhad white did not differ in harvest index than Azam. The highest ($p<0.05$) harvest index (48%) was derived for 150 kg N ha^{-1} and lowest (41.8%) for 90 kg N ha^{-1}. Treatment 120 kg N ha^{-1} did differ significantly than the 150 and 90 kg N rates. Rozas *et al*., (2008) reported similar results. Optimum utilization of solar light, higher assimilates production and its conversion to starches resulted higher grains number and weight that resulted more biomass and seed yield (Derby *et al*., 2004).

Conclusion

Nitrogen fertility of soil has a major role in maintaining maximum seed yield of maize; however, a number of other factors limit yields even when N fertility is optimal. In this study the higher LAP at nodal position 1 to 6 than 6 onwards showed higher CGR of Jalal. This might have resulted denser canopy which has shown higher light use efficiency by the canopy. The efficient utilization of solar light by variety Jalal resulted healthier grains and hence contributed towards high production. The difference in CGR at 1200-GDD onwards revealed that N demand of maize was higher and hence the treatments showed a remarkable difference thereafter in growth. Moreover, the N application e.g., 90, 120 and 150 kg ha^{-1} showed variation in LAP at node 1 to 8 that can associate to delay in senescence. Research of this nature should be used to modify existing fertilizer recommendation rates to maize variety in cultivation in the area and optimize productivity.

Table 1. Yield and yield components of maize affected by different varieties and N levels during growth in 2006.

Varieties		N-levels (kg ha^{-1})	Plant height (cm)	Leaf area index	Radiation use efficiency (g MJ^{-1})	Grain number ear^{-1}	1000 grains weight (g)	Biological Yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)
Azam		090	134.30	2.00	1.80	227.23	172.20	7280	2807	38.70
		120	141.60	3.10	1.60	334.00	181.20	8252	3415	41.40
		150	154.30	3.50	1.40	366.70	191.00	9936	4895	48.80
Jalal		090	147.30	3.00	1.90	307.50	173.00	8878	3975	44.70
		120	157.50	3.40	1.70	411.70	185.00	9399	4482	46.10
		150	172.80	3.60	1.50	443.00	196.20	9949	5147	49.30
S. White		090	137.80	3.20	1.70	254.00	171.00	8006	3380	42.10
		120	144.70	3.50	1.50	303.00	180.00	8909	3990	44.70
		150	153.70	3.70	1.30	402.00	188.70	9598	4440	46.20
Means	Azam		143.4 c	3.1 b	1.6 a	309.3 b	181.5 b	8489 b	3705 b	43.0 b
	Jalal		159.2 a	3.3 ab	1.7 a	387.4 a	184.7 a	9409 a	4535 a	46.0 a
	Sarhad white		145.4 b	3.5 b	1.3 a	319.8 b	180.1 b	8836 b	3936 b	44.0 b
Mean		090	139.8 c	3.0 b	1.5 a	262.0 b	172.0 c	8055 c	3387 c	41.7 c
		120	147.9 b	3.4 ab	1.8 a	349.0 a	182.3 b	8852 b	3962 b	44.1 b
		150	160.2 a	3.6 b	1.4 a	404.0 a	192.0 a	9828 a	4827 a	48.1 a
LSD ($p<0.05$) for Varieties (V)			0.885	0.270	NS	37.39	1.55	13.80	231.5	2.10
Nitrogen (N)			0.776	0.420	NS	55.88	1.85	08.12	213.6	1.66
V x N			1.533	NS	NS	NS	NS	NS	401.0	NS

Mean followed by different letters with in the category and with in the columns are not significantly different ($p<0.05$)

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