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RATE OF NITROGEN APPLICATION INFLUENCES YIELD OF MAIZE AT LOW AND HIGH POPULATION IN KHYBER PAKHTUNKHWA, PAKISTAN

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Abstract

Getting maximum production from maize (*Zea mays* L.) lies not only to economize the N application to crop but also to maintain a desired plants density. Field experiments were conducted as spring and summer season (S) crops for two years at Cereal Crops Research Institute, Nowshera. Three plant populations (PP = 43, 53 and 67) thousands ha^{-1} and three nitrogen rates (N = 90, 120 and 150 kg ha^{-1}) were studied for grain yield of maize. The experiments were conducted in completely randomized block (RCB) design with split plot arrangements. Treatment PP was assigned to main and N rates to the subplots in three replications. Sowing of spring experiments were done in March and harvested in July while sowing of the summer experiments were done in July and harvested in November. Experimental results revealed that emergence, silking, tesseling and maturity took more days in spring than summer. Plant height (PH) and ear height (EH) were observed higher for the summer. Low PP (43,000) sowed lower PH and EH over the higher PP. Increasing N augmented both PH and EH of maize. High N applied 150 kg ha^{-1} delayed maturity. Summer over spring season crop showed higher leaf area index (LAI) which did increase by increasing the treatment PP and/or N rates. Interaction of the treatments S x PP, S x N, PP x N and S x PP x N were found significant for the LAI. Grain yield (GY) in summer was higher than spring sown crop. This increase in the GY was observed in coordination with increasing the treatments PP and N. The finding suggests that GY of summer crop was relatively stable. Moreover, growing maize at higher population (67,000 ha^{-1}) treated with nitrogen 150 kg ha^{-1} is economical for 'Jalal' variety in the area as summer crop.

Introduction

A considerable portion of the plant dry matter (80-90%) is carbonaceous and is derived from light dependent reduction of CO_2 during photosynthesis. It is related to the crop radiation use efficiency (Gramig *et al*., 2006). From a barren field solar energy can be gathered and converted by the available crop canopy into biomass that could be consumed as food or feed. The availability of the optimum plant population over an area of a variety plays a significant role in fraction of the intercepted radiation by crop canopy. The relationship of plant dry matter with intercepted radiation is always linear. Light interception by the crop canopy mainly depends on leaf area index (LAI) exposed by the crop (Bonhomme, 2000).

Maize is important cereal with 1st ranking order for grain yield in world among the cereals crops (Long *et al*., 2006). It is widely cultivated in all regions of the world with multiple utilizations. It is planted on about 43% cropped area in Pakistan and 37% in Khyber Pakhtunkhwa. It is hence the 2nd most important crop after wheat in Khyber Pakhtunkhwa and Pakistan. Maize is either cultivated as spring or summer crop for both grain and fodder. The current national average yield of maize is about 2984 kg ha^{-1} with a further 45% lower in Khyber Pakhtunkhwa sector. Possibility does exist to improve crop yield though management to overcome this existing yield gap without further expansion in the area under maize cultivation. Acute fodder shortage of summer led growers to use higher population and remove green plants for fodder during growth and development.

Effort has been focused on soil improvement and nutrients application to the crop to improve existing production (Amanullah *et al*., 2010; Rafiq *et al*., 2010). The radiations absorbed by the crop canopy depend on many characters and therefore variations in its calculation occur (Sinclair & Muchow, 1999). Bonhomme (2000) assumed 85% of intercepted photosyntheticaly active radiation (IPAR) by the maize crop canopy. The maize crop productivity depends on average daily IPAR around silking (Lizaso *et al*., 2003). Thus, the accurate calculation of daily IPAR is often a useful in its biomass production. The radiation interception is primarily determined by the LAI (Bonhomme, 2000). It also based on the index of the efficiency of radiation intercepted (Lizaso *et al*., 2003). However, little is known about the required plant population on an area and its relationship with N rate to sustain production of the crop in the area. Farmers usually plant maize with relatively high densities and during vegetative growth they remove green plants as feed which not only affect yield but also results lower biomass. Research with ideas about planting geometry and population and techniques for inputs rate and applications are therefore essential to increase production. This will also manage inputs application to the crops to protect not only the environment but also ensure sustainable production for future growing population. Optimum population and required nitrogen is therefore the essential factors of the study for spring and summer season sown crop for the area.

Materials and Methods

Experimental location: The experiments were conducted at Cereals Crop Research Institute (CCRI) Nowshera. The site is located at latitude 34°N, longitude 72°E and an altitude of about 288 m from sea level to exhibit a continental climate (Jan *et al*., 2010). The soil of the experimental site is sandy loam, moderately calcareous, pH 7.7, low in N (0.016%), poor in organic matter (0.33%) and sulpher (8.3 mg kg^{-1}). Two experiments, one in spring and one in summer, were conducted during 2006 and repeated in 2007.

Layout, treatments and management: The experimental design was a randomized complete block in split plot arrangement. Each experimental unit was replicated thrice. The main plot factor was plant population i.e. 43,000 (low), 53,000 (medium) and 67,000 (high) ha^{-1}. The intended population was maintained for the experiments after emergence by manual thinning. Maize variety (cv. Jalal) was planted with high seed rate in 0.75 m rows. Planting was done on ridges made with tractor drawn-ridger and subsequently refined with shaper. A day before sowing, seeds were treated with fungicide (Confidor). Sowing of the spring experiments was done on March 14, 2006 and March 03, 2007 and subsequently in summer on July 23, 2006 and July 28, 2007. At emergence (20 days after sowing) plants were thinned by maintaining distance within rows for low, medium and high densities. The split-split factor was Nitrogen (N) fertilizer (90, 120 and 150 kg ha^{-1}) allotted to the sub plots. Each experimental unit was measuring 5.0 m in length and 6.0 m in width accommodating eight rows in north south directions. Before sizing plots for treatments, land was prepared at proper field capacity with field cultivator. Field was plowed three times followed by disk harrow and subsequently planked. Fertilizers were applied at 110 and 80 (kg ha^{-1}) as P and K, respectively from SSP and K_2SO_4 sources at seedbed preparation. Nitrogen was applied in split applications; 1^{st} at sowing and 2^{nd} half application about 32 days after sowing (DAS). Cultural practices i.e. weeding, granule applications (Furadon) and irrigations were applied uniformly to all the treatments. Data were recorded on, emergence, silking, tasseling and maturity by counting plants in four central rows when more than 50% of the respective observation met in an experimental unit. For plant and ear heights, 20 random plants within a treatment were observed. Leaf area index (LAI) was recorded using non-destructive samplings optic sensors (LI-2000, LI-COR, USA) adjusted as to record one above and three below the canopy readings to calculate single mean LAI for a treatment. Harvesting of spring experiments were made on July 10, 2006 and July 08, 2007 and subsequently of the summer experiments on November 13, 2006 and November 13, 2007, respectively. Grain yield was calculated for the treatments using following relationship (Carangal *et al*., 1971).

$$\text{Grain yield ha}^{-1}\text{ (15\% GMC)} = \frac{\text{Fresh Weight (kg plot}^{-1}\text{) x (100 – GMC) x (0.8) x 10,000 m}^{-2}}{\text{(100-15) x Area harvested (m}^{2}\text{)}}$$

where:
FW = Fresh weight of ears at harvest
GMC = Grain moisture content (%)
0.8 = Shelling coefficient for maize
(100-15) = 15% moisture in grain at dry state
10000 m^{-2} = Harvested area conversion in to standard unit (ha)

Statistical analysis: All data were statistically analyzed using Gen-stat (Discovery Edition 3) computer software. Statistical analysis were made combine over the years and seasons using appropriate analysis technique (Steel & Torrie, 1980) for randomized complete block design with split plot arrangements. Main effects and interactions were compared using the LSD test ($p<0.05$) where means were found significant.

Results and Discussion

Days to emergence, tasseling, silking and maturity: Two years average data for days to emergence, silking, tasseling and maturity are shown in Table 1. Analysis of the data indicated that days to emergence (DTE) differed significantly for seasons (S). Spring season crop took more DTE than summer season crop. In early March, temperature and photoperiod were relatively low hence the crop took more days to complete emergence. Contrary to that, July temperature was high and thus summer crop took few days to complete emergence. Advantage of summer on spring season was that field was too wet and cold. Seed took more time to stay for completing germination process in spring as compared to summer. Because number of the required growing degree days (GDD) available are the basis to complete germination (Goesch & Archer, 2005). During spring seasons, the required GDD was met in more days than summer. Germination of maize was found curvilinear with the temperatures change from cool to warm and completed emergence from 16 to 3 days, respectively (Kim *et al*., 2007). Emergence was not affected by both the treatments population (PP) and nitrogen (N) because sowing was initially done with higher densities and thinned out after emergence. Moreover, N at the early stage may not be essential to affect germination as seed germination depends on reserved food in seed. Days to tasseling (DTT) and silking (DTS) also showed differences ($p<0.05$) by seasons. Spring crop took long time (66 days) to tassel compared to the summer crop (51) and similarly was observed for DTS with about 3 to 4 days difference in tassling-silking intervals. Higher days taken to flower by spring crop might be climate of the growing season. Photoperiods, solar light and temperatures had played a role in crop growth and development with maximum in spring than summer (Kim *et al*., 2007). Maize flowering showed coordination with diurnal temperature changes (Pardo, *et al*., 2006). It is known that delay flowering in maize is due to increased photoperiods (Wang *et al*., 2008). Spring versus summer crop showed increasing trend for photoperiod from sowing to anthesis. Treatments (PP and N) found non-significant for DTT and DTS and support findings of the literature e.g., Tokatlidis & Koutrubas (2004). Rajcan & Tollenaar (1999) reported that high N to maize delayed tasseling but did not agree with our findings due to either differences in the N rates intervals or the variety performance in the prevailing soil fertility status and/or the climate response for variety in the area. Days to maturity (DTM) found significant for S and N. It is quite obvious that crop emerged late has to be flowered late and also matured late (Tollenaar, 1999). Major factor of the delay maturity in spring than summer is climate which was relatively cooler from March to June. The treatment PP did not show any effect ($P<0.05$) on maturity presuming that the tested densities did not over crowded the canopy for the variety under the soil and climate of the area (Boomsma *et al*., 2009). However, the treatment low nitrogen (90 kg ha^{-1}) than higher rates (120 and 150 kg ha^{-1}) showed early maturity which might be due to deficient N to the crop (Hamid & Nasab, 2001). Vos & Biemond (1992) stated that higher N application has prolonged the vegetative life of plant's organs (leaf and stem) rather than retarding growth which extend crop to stay green longer.

Table 1. Days to emergence, silking, tasseling and maturity of spring and summer planted maize affected by plant populations and nitrogen levels.

Treatments	Days to			
Season (S)	**Emergence**	**Tasseling**	**Silking**	**Maturity**
Spring	11.33 a	66.13 a	69.41 a	117.76 a
Summer	05.39 b	50.56 b	54.85 b	105.02 b
LSD	0.30	0.79	0.95	1.13
Population (PP ha^{-1})				
43,000	8.44	58.17	62.03	110.97
53,000	8.25	58.19	62.11	111.50
67,000	8.39	58.67	62.25	111.69
LSD	NS	NS	NS	NS
Nitrogen (N kg ha^{-1})				
090	8.42	58.25	62.11	110.92 b
120	8.36	58.25	62.19	111.47 ab
150	8.31	58.53	62.08	111.78 a
LSD	NS	NS	NS	0.69
Year	Ns	(0.79)	(0.95)	NS
Interactions				
S x PP	NS	NS	NS	NS
S x N	NS	NS	NS	NS
PP x N	NS	NS	NS	NS
S x PP x N	NS	NS	NS	NS

Ns = Non-signifiant; * = Signifiant (p<0.05); ** = Signifiant (p<0.01)
Means with common letter within a category are non-significant (p<0.05)

Plant height, ear height, leaf area index (LAI) and grain yield: Two years mean data regarding plant height (PH in cm), ear height (EH in cm), leaf area index (LAI) and grain yield (GY in t ha^{-1}) are shown in Table 2. The data showed that PH and EH did differ (p<0.05) by S, PP and N treatments. Plant height increment was due to growth between inter-nodes expansion. Plant growth relates to the climatic conditions of the area. We observed that both temperatures and photoperiods expanded during spring (Mar.-Jun.) as compared to summer (Aug.-Oct.) during the crop growth and development. Maize showed excellent growth and development at higher temperature, resulting taller canopy (Pagano & Maddonni, 2007). It is most probably due to increase in the internodes length which results relatively higher ear appearance within the maize crop canopy. The treatment low plant population (43,000 ha^{-1}) than high (53,000 ha^{-1}) showed dwarf canopy. It might be due to rapid canopy closure at higher densities. It is known that denser canopy augmented inter-plant competition of light which resulted taller plants due to over-shedding effect on lower leaves within the crop canopy (Modarres, 1998). Literature shows that denser canopies forced plants to compete for resources (water, nutrients and light) and resulted long inter-node of maize (Modarres et al., 1998; Turgut, 2002). High than low N might have resulted rapid cell production and enlargement which resulted taller plants (Boomsma *et al*., 2009). No differences (P<0.05) between the treatment 120 and 150 kg N ha^{-1} might be probably due to limiting their effect by other nutrients and/or variety potential performance to exhaust the available nutrients from soil. The only interactive response of the treatment S x N showed a significant difference on PH (Fig. 1). Summer crop showed taller plants with consistently increased in plant height when N application to crop increased. Contrary to which spring crop showed increase in PH when N enhanced from 90 to 120 kg ha^{-1} but thereafter remains unchanged with further increase in N application to the crop. It showed that higher light during summer than spring resulted faster growth of plants which enabled them to get more height with increase application of N from 90 to 150 kg (Shapiro & Wortmann, 2006). Nonetheless, light for maize canopy during spring was enough to enhance growth from 90 to 120 kg ha^{-1}. Further increase from 120 kg ha^{-1} onwards was not advantageous for the crop under the prevailing circumstances. Interactive response of S x PP showed that increasing PP augmented EH in summer. It might be due to faster growth rate which resulting relatively long inter-nodes (Fig. 2). Moreover, increased population per unit area augmented EH for all N levels (Fig. 3). The EH at high N (120 and 150 kg ha^{-1}) than low (90 kg ha^{-1}) was maximum for all the three PP but with a consistently positive increase from 43,000 to 67,000 ha^{-1}. This might be due to retarded growth by limited nutrients availability and hence resulted a static EH under the increasing population from 43,000 to 67,0000 ha^{-1}.

Table 2. Plant height (PH), ear height (cm), leaf area index (LAI) and grain yield (GY) of spring and summer planted maize affected by plant populations and nitrogen levels.

Treatments Season (S)	PH (cm)	Ear height (cm)	LAI	GY ($t\ ha^{-1}$)
Spring	139.03 b	63.20 b	3.18 b	5.34 b
Summer	170.07 a	66.02 a	4.00 a	5.93 a
LSD	2.46	1.30	0.03	0.15
Population (PP ha^{-1})				
43,000	151.28 b	63.66 b	3.58 b	5.15 b
53,000	156.97 a	64.44 ab	3.57 b	5.92 a
67,000	155.40 a	65.74 a	3.63 a	5.83 a
LSD	2.24	1.52	0.02	0.33
Nitrogen (N kg ha^{-1})				
090	150.47 b	61.04 c	3.49 c	4.97 c
120	155.41 a	65.64 b	3.61 b	5.87 b
150	157.78 a	67.15 a	3.68 a	6.06 a
LSD	2.78	0.87	0.03	0.17
Year	2.46	1.30	0.03	0.15
Interactions				
S x PP	NS	**	**	NS
S x N	**	NS	**	**
PP x N	NS	**	**	NS
S x P x N	NS	NS	**	**

Ns = Non-signifiant; * = Signifiant ($p<0.05$); ** = Signifiant ($p<0.01$)
Means with common letter within a category are non-significant ($p<0.05$)

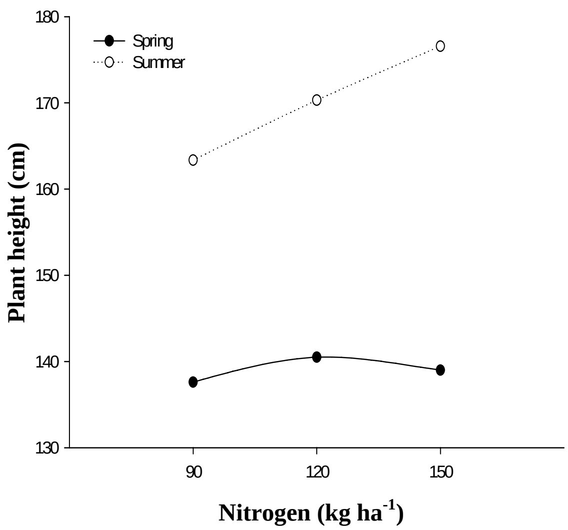

Fig. 1. Seasons and nitrogen supply interactive effect on plant height (cm) of maize planted at CCRI, Nowshera.

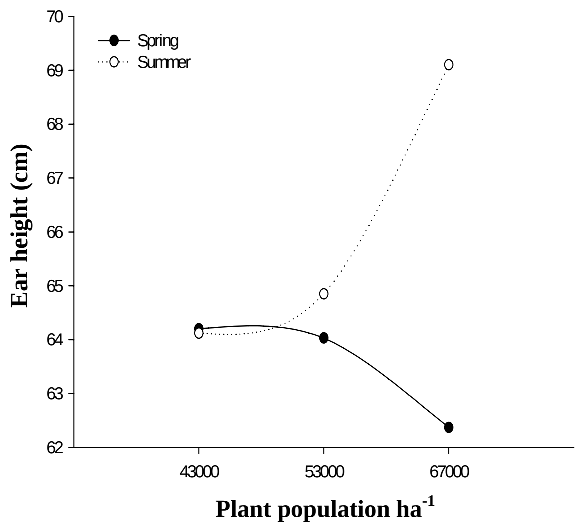

Fig. 2. Seasons and plant population interaction effect on ear height (cm) of maize planted at CCRI, Nowshera.

Non-destructive green leaf area index (LAI) showed variations ($p<0.05$) for S, PP, N and interactions. LAI differed by S and was observed lower in spring than summer. Spring season is relatively cool and crops grow slowly to develop canopy volume with less surface area expansion rate. The smaller leaf size results lower LAI which accounts lower light interception by canopy, water transpiration and carbon fixation etc. and hence resulted less biomass and grain yield in spring than summer (Wilson & Meyer, 2007). Significant difference in LAI with increased populations was observed from 53,000 to 67,000 but not between 43,000 to 53,000. This showed that unit area was fully exploiting the light interception at 67,000 populations in the prevailing climate for the variety to intercept light and resulted high biomass (Akmal & Janssens, 2004). No change in LAI was observed between 43,000 and 53,000 ha^{-1} population which showed that both the densities were insufficient for maximum light interception to gather dry matter (Westgate *et al*., 1997). An increase in N from 90 to 150 kg ha^{-1} also increased LAI. Nitrogen improves greenness of the vegetation and hence results higher LAI by increasing N to the crop. Other results also showed that LAI was increased with increasing N (Gimenez *et al*., 1994). Among the treatment interactions S x PP, S x N, PP x N and S x PP x N were found significant for the crop LAI. Increasing PP increased LAI but remained stable with further increased in spring. Summer crop showed a slight reduction to increase with the increasing PP (Fig. 4). However, LAI of the summer crop was higher and incomparable with spring at any PP. As expected, increased N application increased LAI (Fig. 5). Increase N from 90 to 150 kg ha^{-1} to maize crop increased LAI with a relatively stable rates in both spring and summer seasons. Nitrogen, being major nutrients of the crop growth, has shown an expansion in the crop leaf surface area (Coulter & Nafziger, 2008). The PP with N interaction showed that LAI was steadily increased with increasing PP from 43,000 to 67,000 at low N (90 kg ha^{-1}) rate but this trend of increase was not regular for the higher N rates (Fig. 6). Increasing PP from 43,000 to 53,000 and further increased to 67,000 showed a moderate to slight reduction with a reverse increase for both N i.e. 120 and 150 kg ha^{-1}, respectively. This showed that maize was highly sensitive for leaf development at low N (90 kg ha^{-1}) compared to high N rates (120 and 150 kg ha^{-1}). Among three factor interactions (S x PP x N), spring crop showed almost a similar increase in LAI with increasing PP and N (Fig. 7). However, this fashion of increase in LAI during summer by increasing PP and N was observed different. It might be due to climate which was observed relatively cooler in spring. Contrary to that summer was hot and 53,000 PP has exposed higher fraction of lower leaves that might have started early senescence. Differences in plant heights within rows may also be a reason that showed the strange reverse response of LAI at 53,000 population of summer.

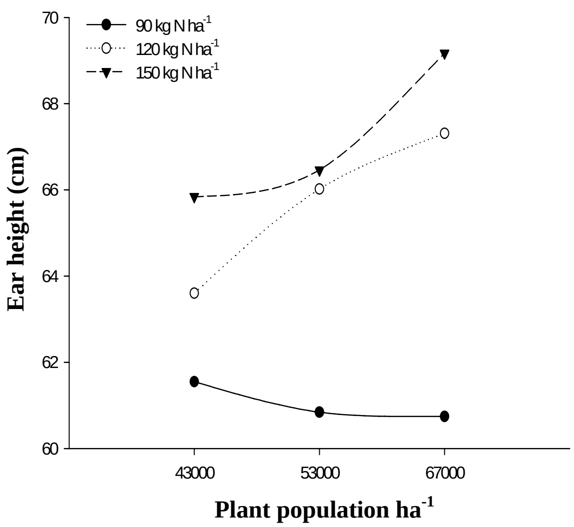

Fig. 3. Plant population and nitrogen interactive effect on ear height (cm) of maize planted at CCRI, Nowshera.

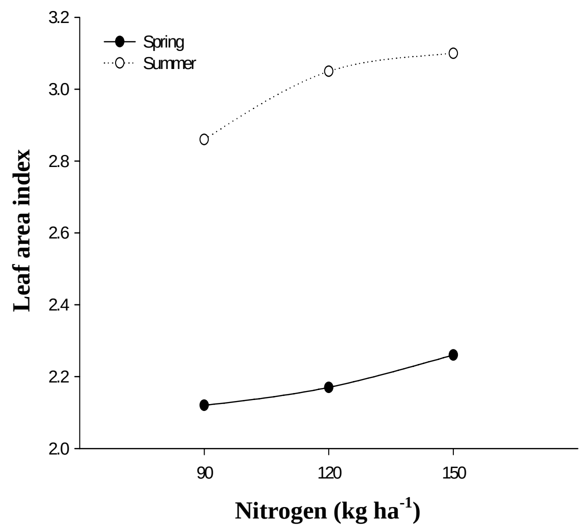

Fig. 5. Season and nitrogen interactive effect on leaf area indices of maize planted at CCRI, Nowshera.

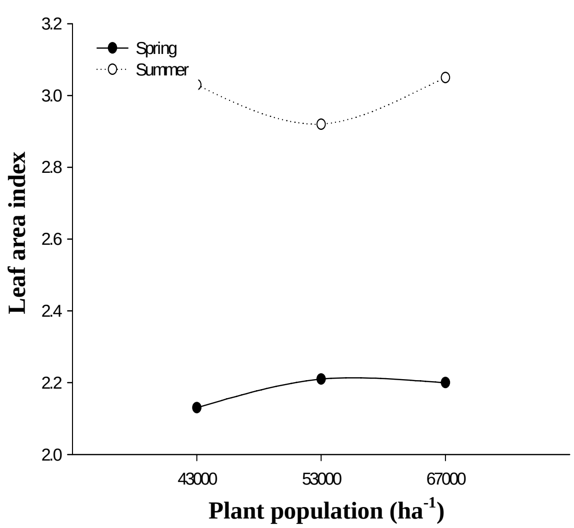

Fig. 4. Season and plant population interactive effect on leaf area indices of maize planted at CCRI, Nowshera.

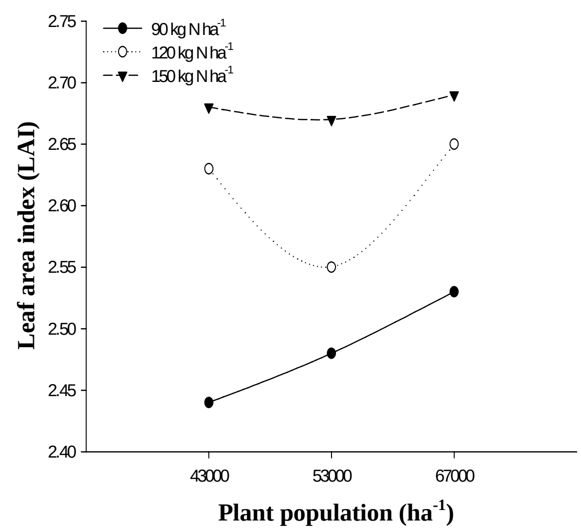

Fig. 6. Plant population and nitrogen supply interactive effect on leaf area indices of maize planted at CCRI, Nowshera.

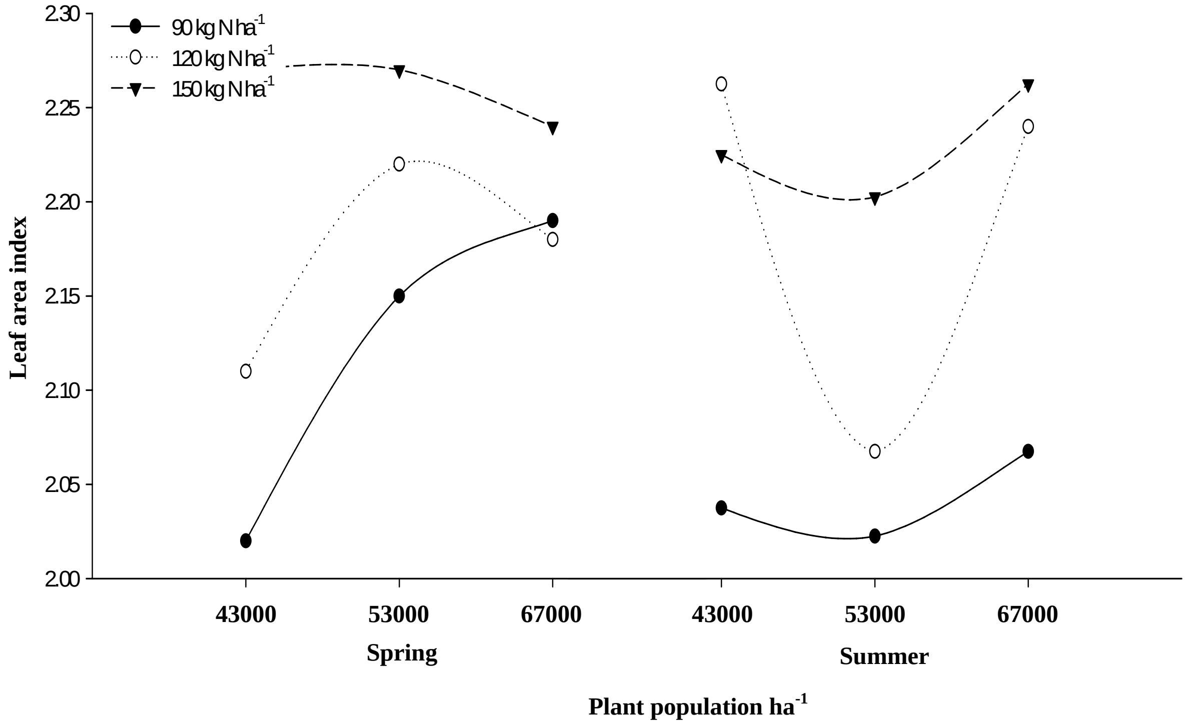

Fig. 7. Seasons, plant population and nitrogen interactive effect on leaf area indices of maize planted at CCRI, Nowshera.

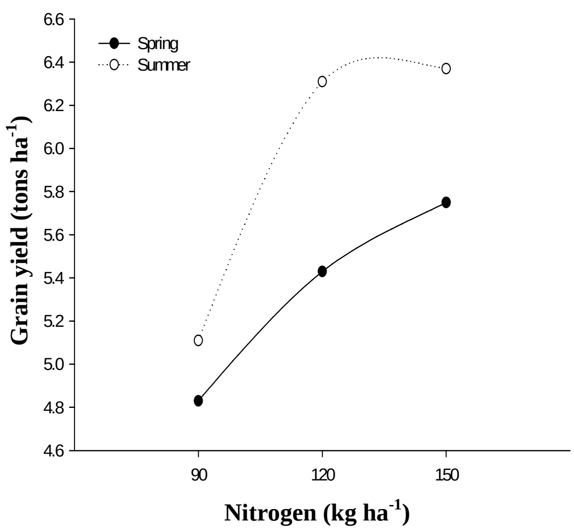

Fig. 8. Seasons and nitrogen supply interactive effect on grain yield (t ha^{-1}) of maize planted at CCRI, Nowshera.

Grain yield (GY t ha^{-1}) showed a significant difference between seasons, the treatments PP and N rates. Summer GY out yielded the spring it might be due to prolonged sunshine hours of summer and/or higher growth rates per unit area per unit time (Iqbal *et al*., 2010). This higher GY in summer was due to availability of more cumulative GDD during growth and/or relatively mild humid environment at anthesis stage of crop. Contrary to that, spring crop mature in hot seasons which also has to expose plants at higher temperature during pollination. Additionally mild drought stress at the spring crop at anthesis stage may also adversely contribute to grain setting and development (Earl & Davis, 2003). Previous results revealed that increasing PP increase yield and plateau with further increased in PP also support our findings (Turut, 2002). As expected and observed, increased N positively contributed in yield (Khan *et al*., 2009; Amanuallah *et al*., 2010). Nitrogen from 90 to 150 kg ha^{-1} showed a significant GY increase (Tokatlidis & Koutroubas, 2004; Ammanullah *et al*., 2010). Many other investigators have found that increased N application enhanced grain yield if not limiting by any other factor of production (El-Sheikh, 1998; Zidane, 2006). Interaction of S with N showed significant for GY (Fig. 8). Increasing N from 90 to 120 kg ha^{-1} showed relatively a greater increase in GY for spring and summer season crop. A further increase of N to 150 kg ha^{-1} did not show any change in GY of spring but a slight increase in summer. Increasing population from 43,000 to 67,000 showed different trends for GY during spring and summer seasons under the given N (Fig. 9). For a given level of N, GY was higher at PP 53,000 ha^{-1} for all N rates in spring. The minimum values of GY were observed at PP 43,000 ha^{-1} at each N level. At higher PP (67,000) ha^{-1}, GY decreased as compared to 53,000 ha^{-1} for all levels of N in spring. In case of summer, there was no decline in GY at 67,000 PP ha^{-1} for any N rates. However, for 120 and 150 kg N, after a sharp increase with increasing PP from 43,000 to 53,000 ha^{-1}, GY either remains static for further increase in PP from 53,000 to 67,000 ha^{-1} or showed a little increase Virtually both levels of N (120 and 150 kg ha^{-1}) behaved similar with increasing PP in summer.

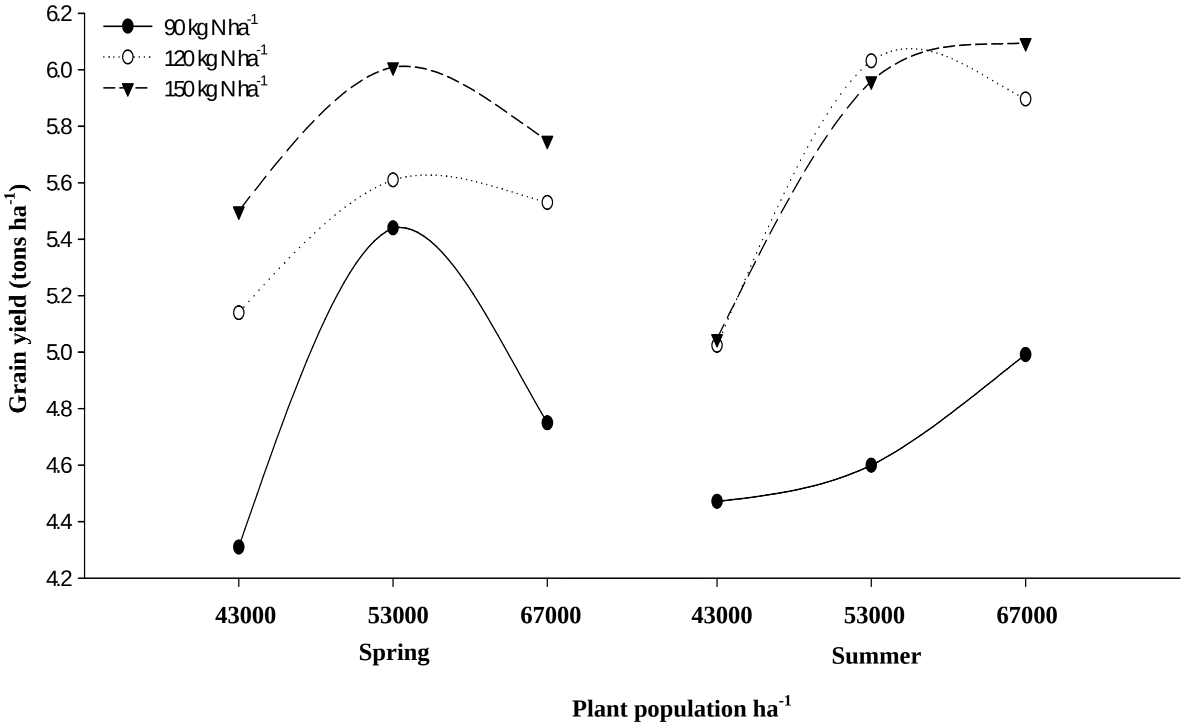

Fig. 9. Season, plant population and nitrogen supply interactive effect on grain yield (t ha^{-1}) of maize planted at CCRI, Nowshera.

Conclusion

Spring crop delayed emergence, silking, tasseling and maturity compared to the summer crop and utilized the available inputs efficiently with taller plants, healthy LAI and hence resulted higher yield. We conclude that plant population had no significant effect on maize phenology except increasing LAI and plant height. The treatment 67,000 and 53,000 ha^{-1} population range is sufficient for the Jalal variety. Despite the N applications had no effects on phenology but high N (150 kg ha^{-1}) not only delayed maturity but resulted healthier grains with higher GY. The currently practiced 120 kg N ha^{-1} in Khyber Pakhtunkhwa needs to be enhanced to 150 kg ha^{-1} for summer sown maize regardless of the increase in plant populations.

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