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NITROGEN EFFECTS ON GROWTH AND DEVELOPMENT OF SUNFLOWER HYBRIDS UNDER AGRO-CLIMATIC CONDITIONS OF MULTAN

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Abstract

The effect of nitrogen (N) on growth, development, yield and yield components of different sunflower (*Helianthus annuus* L.) hybrids was evaluated under agro-climatic conditions of Multan during spring 2008 and 2009. The experiment was laid out in a randomized complete block design with split plot arrangement having three replications, keeping cultivars in the main plots and N levels in the subplots. The net plot size was 4.2 m x 5 m. The results showed that, with increasing N rates, there was increment in the biomass, yield and yield components while the oil contents were adversely affected. However, there was high seed yield in 2008 as compared to 2009. Among sunflower hybrids, Hysun-38 gave more yield as compared to other sunflower hybrids (Hysun-33, Pioneer 64A93), while in case of N levels, 180 kg ha^{-1} provided higher yield than other N rates (0, 60, 120, 240 kg ha^{-1}) in both years of study especially during 2008.

Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed crop in the world. Along with soybean, canola and cotton, sunflower also contributes significantly to the edible vegetable oil market (Zubillaga *et al.,* 2002). Among different nutrients, N is one of the major nutrient that enhances the metabolic processes that lead to increases in vegetative, reproductive growth and yield of the crop (Steer & Hocking, 1984) and are totally dependent upon the amount of N fertilization. An increment in the N fertilizer, there is also increment in the growth, photosynthesis rate and development of the crop (Fayyaz-Ul-Hassan *et al.,* 2005). The sensitivity of N fertilizer has great importance not only in all types of crop plants as well as in whole agriculture sector and by reducing the N fertilizer, there is also reduction in the photosynthesis, leaf production, development, individual leaf area and total leaf area. Furthermore, N fertilizer application affects all dry matter as well as N accumulation and partitioning into various parts of crop plants for the growth, development and other processes (Khaliq & Cheema, 2005). It is imperative to enhance the domestic production to meet the increasing demand of edible oils. In year 2008-09, 1.29 million tons edible oil which amounted to Rs. 84 billions, has been imported. The local production during 2008- 09 stood at 0.778 million tons. The total availability from all sources is estimated at 2.068 million tons during 2008-09, furthermore for the sunflower, the total area of production includes 1250, 000 acres, the yield from this area was 755, 000 tons (seed) and 287, 000 tones (oil) with the average yield of 1.6 tons ha^{-1} (Anon., 2009). In the similar way, the research and development constraints to increased production includes, non-availability of suitable local hybrids/cultivars, high cost of imported seed, losses due to bird damage near the crop maturity, defective and inefficient marketing/procurement system (Badar *et al.,* 2002), unavailability and high prices of inputs especially N fertilizers, and least but not last that the unawareness of the farmers for the latest sunflower production technology. The present study was, therefore, conducted with the objective to evaluate the effect of different N rates on achene oil quality, yield and yield components of different sunflower hybrids under agro-climatic conditions of Multan, Punjab, Pakistan.

Materials and Methods

Experimental location, climatic and soil data: The experiment was conducted at Central Cotton Research Institute (CCRI), Multan (30^{o}.18" N, 71^{o}.48" E) during spring 2008 and 2009 growing seasons. Multan is considered as a hottest location in the country. During both spring seasons, temperature (minimum and maximum) was recorded maximum and rainfall was recorded minimum especially during 2009. All climatic data such as minimum and maximum temperature, rainfall, solar radiation (Fig. 1) were obtained from measurements made at the meteorological observatory CCRI. Furthermore, the soil was shallow, fine, silty, mixed and hyperthermic soil (Anon., 1998). Its color is brown, well drained, with pH ranging from 8.6-8.8.

Experimental design and crop husbandry: After well-preparing experimental field, ridges (70 cm spaced) were prepared; the experiment was laid out in randomized complete block design with split plot arrangement having three replications. The crop was sown in second week of February 2008 and 2009, respectively. The crop was sown with hand mounted seed drill (dibbling) placing 3 seeds per hill, keeping plant to plant distance of 20 cm, using a recommended seed rate of 7 kg ha^{-1}. The net plot size was 4.2 x 5 m. Sunflower hybrids were kept in main plots while different N rates were kept in sub plots. After crop establishment, near 2-4 leaves stage, one plant per hill was maintained manually to keep the plant population optimum. There are fifteen treatments, including five N levels (0, 60, 120, 180 and 240 kg ha^{-1}) on and three sunflower hybrids (Hysun-33, Hysun-38 and Poineer-64A93). Phosphorus (P) and Potassium (K) were used @ 60 kg ha^{-1} each, in all plots. N, P and K, were applied in the form of urea, triple super phosphate and sulphate of potash (K_2SO_4). 1/3rd dose of N and all of the P and K fertilizer was applied at the time of sowing, while remaining 2/3rd of N was used in two splits; first doze at first irrigation and second doze of N at the flowering stage of crop during both years, crop was irrigated as the crop requires irrigations without any water stress. During both growing seasons, two hoeing were done to control weeds, the crop was then earthed up to protect it from lodging. All the cultural practices (hoeing, weed management, irrigation, plant protection measures etc.) were kept normal for the crop.

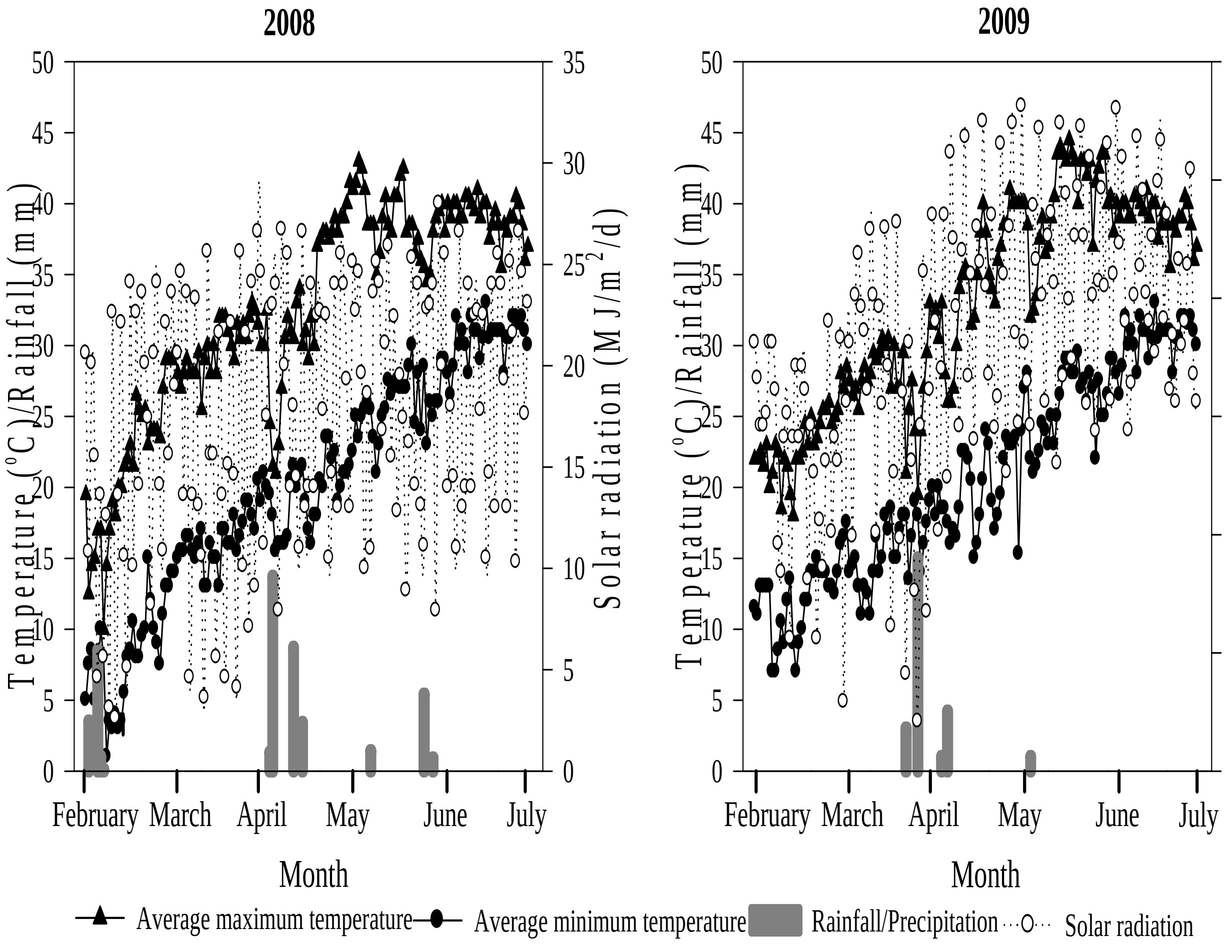

Fig. 1. Average climatic conditions (average maximum and minimum air temperature, daily total solar radiation and average precipitation) of agro-ecological zone of Multan.

Crop sampling: In both years, five plants were selected at random in each plot for studying the dates of anthesis and physiological maturity. Anthesis was defined as when 50% of the head of sunflower in the plot were flowered and physiological maturity defined as when almost all the heads in the plot showed complete loss of green colour. The final crop data such as head diameter, number of achenes (head^{-1}), 1000 achene weight, and average yield of the plots that were harvested after physiological maturity were determined. A sample of five heads was selected for the determination of thousand achenes weight and harvest index was calculated as the ratio of grain dry matter by total dry matter at harvest as described by Sinclair (1998), the oil contents were determined by soxhlet fat extraction method (Miner *et al.*, 1995).

The data collected at final harvest during both seasons, were statistically analyzed by using the computer statistical program MSTAT-C. Analysis of variance technique was employed to test the overall significance of the data, while the least significance difference (LSD) test at P = 0.05 was used to compare the differences among treatments, means for different yield and yield components (Steel *et al.*, 1997).

Results and Discussion

Crop growth rate: Fig. 2 demonstrates the effect of different nitrogen rates on seasonal crop growth rate (CGR). The year or seasonal effect was significant; mean CGR was higher 15.0 vs 14.3 gm^{-2}d^{-1} during 2008 and 2009, respectively. However, Hysun-38 gave mean maximum CGR (15.7 gm^{-2}d^{-1}) followed by Pioneer-64A9 with CGR value 14.4 gm^{-2}d^{-1} and statistically mean minimum CGR value (13.3 gm^{-2}d^{-1}) was observed in Hysun-33. The response of nitrogen fertilizer with different rates on CGR was higher and quadratic in nature with increasing application of nitrogen fertilizer. Over all, mean maximum CGR (16.2 gm^{-2}d^{-1}) was produced by N_4 treatment (180 kg N ha^{-1}) that was statistically at par with treatments N_5 (240 kg N ha^{-1}) that produced CGR 16.1 gm^{-2}d^{-1} and statistically mean minimum CGR (13.0 gm^{-2}d^{-1}) was recorded by 0 kg N ha^{-1} (N_1), respectively (Fig. 2). The improvement in the CGR may be attributed to more vegetative growth due to N fertilizer application. These results validate the findings of Miralles *et al.*, (1997) who also indicated the positive effects of nitrogen on CGR of sunflower crop, while the interactive effects of sunflower hybrids and nitrogen rates were found to be statistically non-significant.

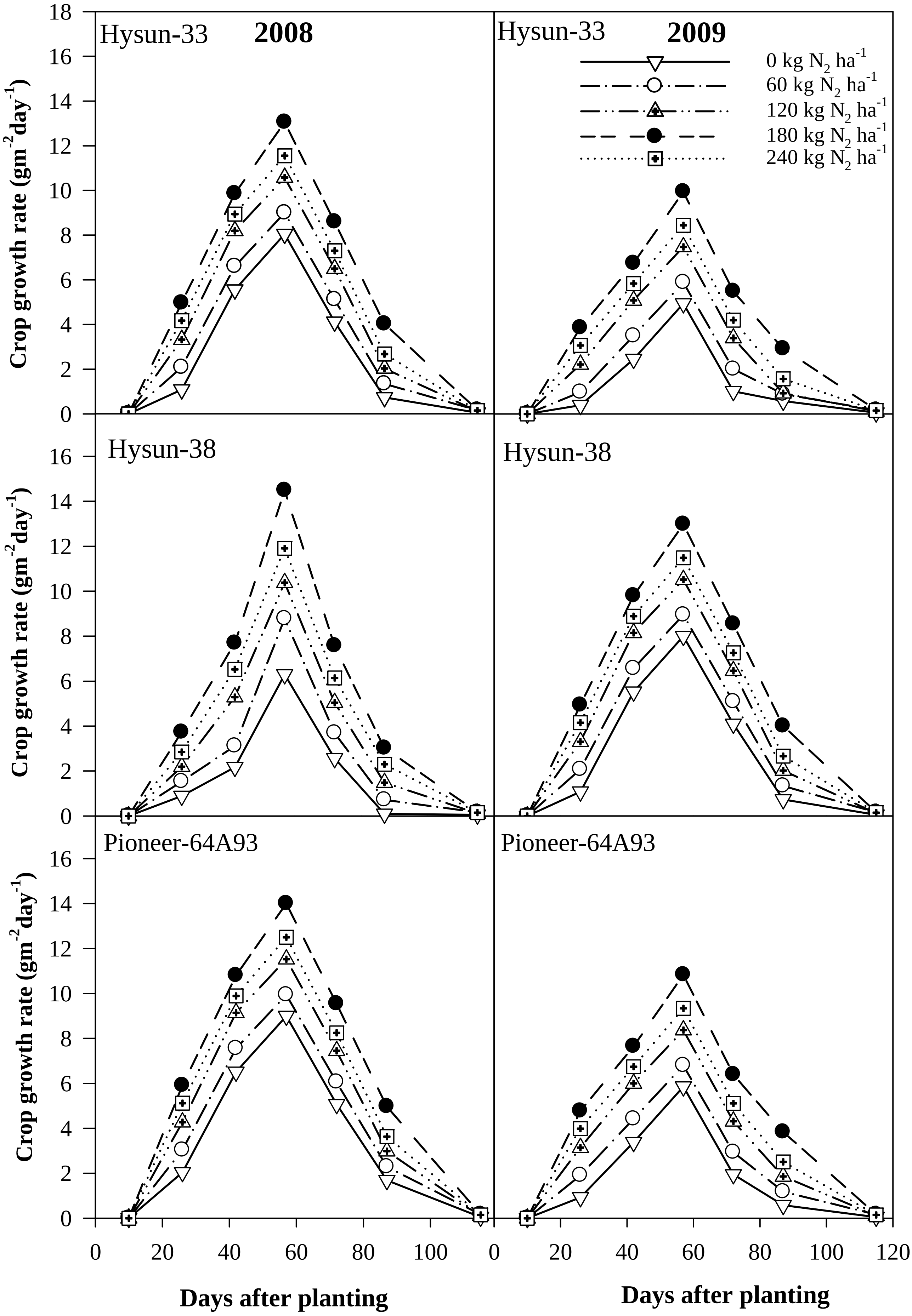

Fig. 2. Crop growth rate during the crop cycle as affected by different hybrids and N rates under agro-climatic conditions of Multan.

Net assimilation rate: The effect of different treatments on seasonal net assimilation rate (NAR) was significant (Fig. 3) as well as year or seasonal effect was significant; mean NAR was higher 5.98 $gm^{-2}d^{-1}$ and lower value of NAR 5.80 $gm^{-2}d^{-1}$ during 2008 and 2009, respectively. Additionally, Hysun-38 gave mean higher values of NAR (6.24 $gm^{-2}d^{-1}$) followed by Pioneer-64A9 in which the NAR was 6.06 $gm^{-2}d^{-1}$ and statistically mean minimum NAR (5.38 $gm^{-2}d^{-1}$) was observed in Hysun-33. Similarly, nitrogen fertilizer response with different rates on NAR was significant and cubic in nature with increasing rate of nitrogen fertilizer. Overall, mean maximum NAR (6.19 $gm^{-2}d^{-1}$) was produced by N_4 treatment (180 kg N ha^{-1}) that was statistically at par with treatments N_3 (120 kg N ha^{-1}) that produced NAR value of 6.05 $gm^{-2}d^{-1}$, statistically minimum NAR (5.52 $gm^{-2}d^{-1}$) was recorded by 0 kg N ha^{-1} (N_1). The improvement in the NAR may be attributed to more vegetative growth due to increasing rates of nitrogen fertilizer (Miralles *et al.,* 1997; Abelardo & Hall, 2002).

Leaf area index: Leaf area index (LAI) gradually increased and achieved its maximum value at 60 days after sowing (DAS); thereafter LAI decreased in all the treatments and reached its lowest values at less than 0.5 by 105 days after sowing (DAS) during both 2008 and 2009, respectively (Fig. 4). The growing conditions as well as season had significant effect on maximum LAI, throughout the growth; sunflower crop had greater LAI in 2008 (4.0) as compared to 2009 (3.8), respectively. The hybrid differences in maximum LAI were non-significant during both years; however, the mean maximum LAI (4.1) was observed by Hysun-38 that was statistically at par with hybrid Pioneer-64A93 (4.0) and the minimum LAI (3.4) was observed by Hysun-33 during both years. Furthermore, maximum LAI was significantly affected by nitrogen rates, and the response was linear and positive. The mean maximum LAI reached to a value (4.6) at 65 DAS in the N_4 (180 kg N ha^{-1}) treatments that was statistically at par with N_5 (240 kg N ha^{-1}) treatments that gain maximum LAI (4.5). Statistically minimum value for LAI (3.3) was recorded in N_1 (0 kg N ha). The greater leaf expansion in sunflower hybrids was attributed due to higher rate of cell division and cell enlargement as described by Bange *et al.,* (2000) and Cechin & Fumis (2000).

Total dry matter (kg ha^{-1}): Total dry matter (TDM) accumulation increased with time, after crop establishment and continued the whole crop cycle, until maturity in all the treatments. Year effect on TDM accumulation of sunflower hybrids was significant. The maximum TDM was observed in 2008 than in 2009 growing season (Fig. 5). The hybrid differences in maximum TDM were significant during both years; however, the mean maximum TDM (12800 kg ha^{-1}) was observed by Hysun-38 that was statistically at par with hybrid Pioneer-64A93 (12015 kg ha^{-1}) and the minimum TDM (11885 kg ha^{-1}) was observed by Hysun-33 during both years. Normally, the effect of nitrogen fertilizer was positive in case of TDM production. Overall, the mean maximum TDM accumulated to a value of 13480 kg ha^{-1} in the N_4 (180 kg N ha^{-1}) treatments that was statistically at par with N_5 (240 kg N ha^{-1}) with maximum TDM (12730 kg N ha^{-1}) while minimum TDM (10805 kg N ha^{-1}) was observed in N_1 (0 kg N ha^{-1}) as demonstrated from the Fig. 5. The enhancement in TDM with increasing rate of nitrogen was due to better crop growth rate, which gave maximum photosynthates, LAI and ultimately produced more biological yield. The study also corroborates with the work done by Steer & Hocking, (1984); Dordas & Siolas (2009).

Yield and yield components

Head diameter (cm): The data demonstrated in the Table 1 indicated significant differences in head diameter during both 2008 and 2009. The plants have more head diameter (17.4 cm) during 2008 and (16.4 cm) during 2009, respectively. The effect of sunflower hybrids on head diameter was significant; furthermore, Hysun-38 gave mean maximum head diameter (17.5 cm) followed by Hysun-33 (16.8 cm), while statistically mean minimum head diameter (16.5 cm) was observed in Pioneer-64A93. The response of nitrogen fertilizer with various N rates on head diameter was higher with increasing trend of nitrogen fertilizer. The maximum head diameter (19.1 cm) was produced by N_4 treatment (180 kg N ha^{-1}) that was statistically at par with treatments N_5 (240 kg N ha^{-1}) that produced 18.6 cm head diameter and statistically minimum head diameter (13.6 cm) was recorded in plots that were fertilized with 0 kg N ha^{-1} (N_1). The improvement in the head diameter may be accredited to more vegetative growth due to fertilizer etc. These results confirm the findings of Sadiq *et al.,* (2000) and Iqbal & Ashraf (2006) who have also the evidence regarding positive effects of nitrogen on head diameter of sunflower crop. The interactive effect was positive and linear between sunflower hybrids and nitrogen rates, while the cubic and quadric effects were non-significant (Table 1).

Number of achenes (head^{-1}): The achene numbers per head (A/H) is also important in response of contribution in achene yield (Miralles *et al.,* 1997; Arshad *et al.,* 2009). Hysun-38 showed significantly mean high values of A/H (803), followed by Hysun-33 (771) and statistically mean minimum values of A/H were observed by Pioneer-64A93 (751), respectively (Table 1). While in case of N treatments, 180 kg N ha^{-1} produced statistically mean higher A/H (887), followed by 240 kg N ha^{-1} (875), while statistically, 0 kg N ha^{-1} gave minimum A/H (573). Moreover, the interaction between hybrids and different nitrogen rates affecting A/H were significant. These results substantiates the studies carried by Rondanini *et al.,* (2007); Cantagallo *et al.,* (2009), who also reported that the shortage of N affects the development and growth of both source and sink, as well as it also affect on the A/H. The interactive effect was linear and positive between sunflower hybrids and nitrogen rates (Table 1).

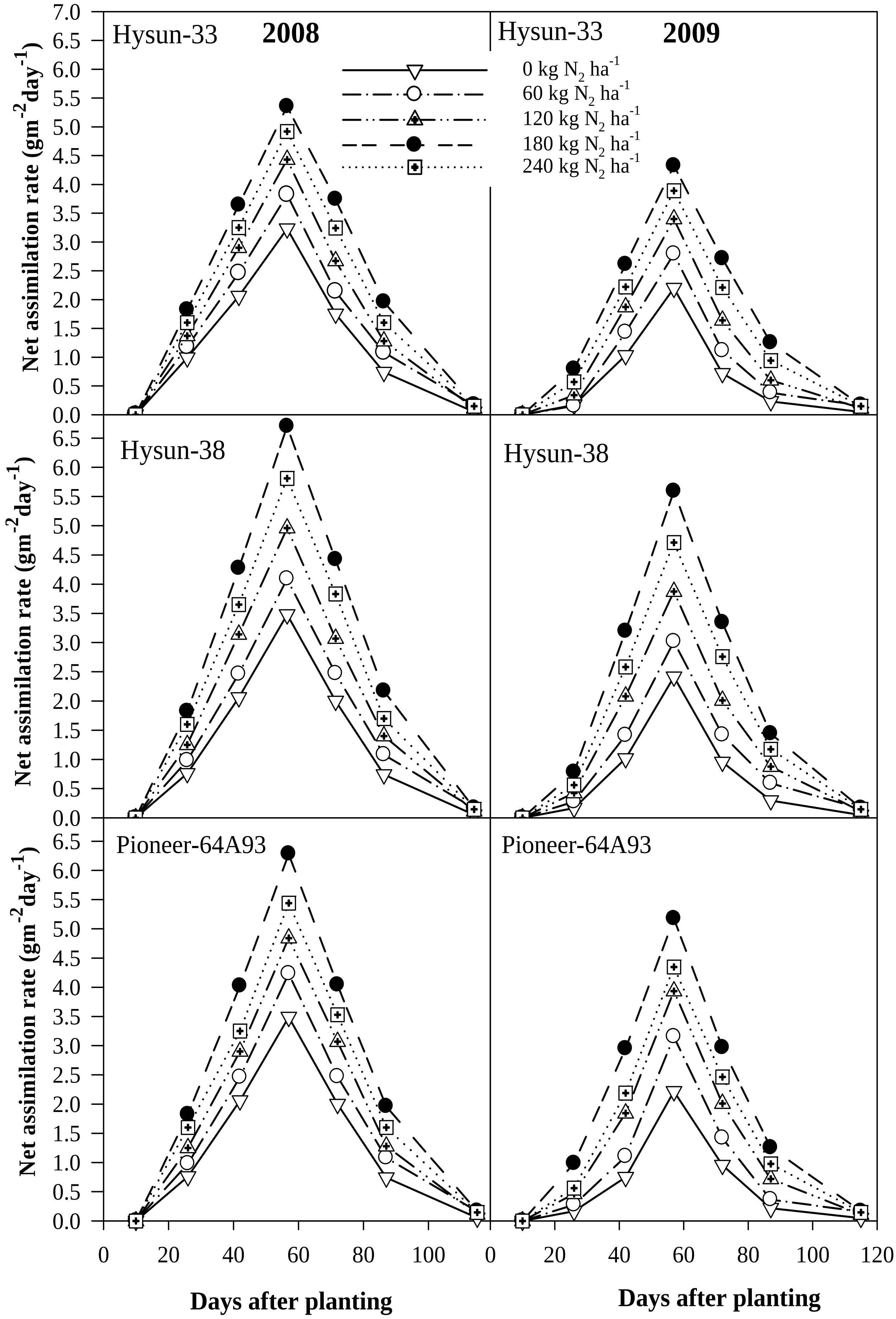

Fig. 3. Net assimilation rate during the crop cycle as affected by different sunflower hybrids and N rates under agro-climatic conditions of Multan.

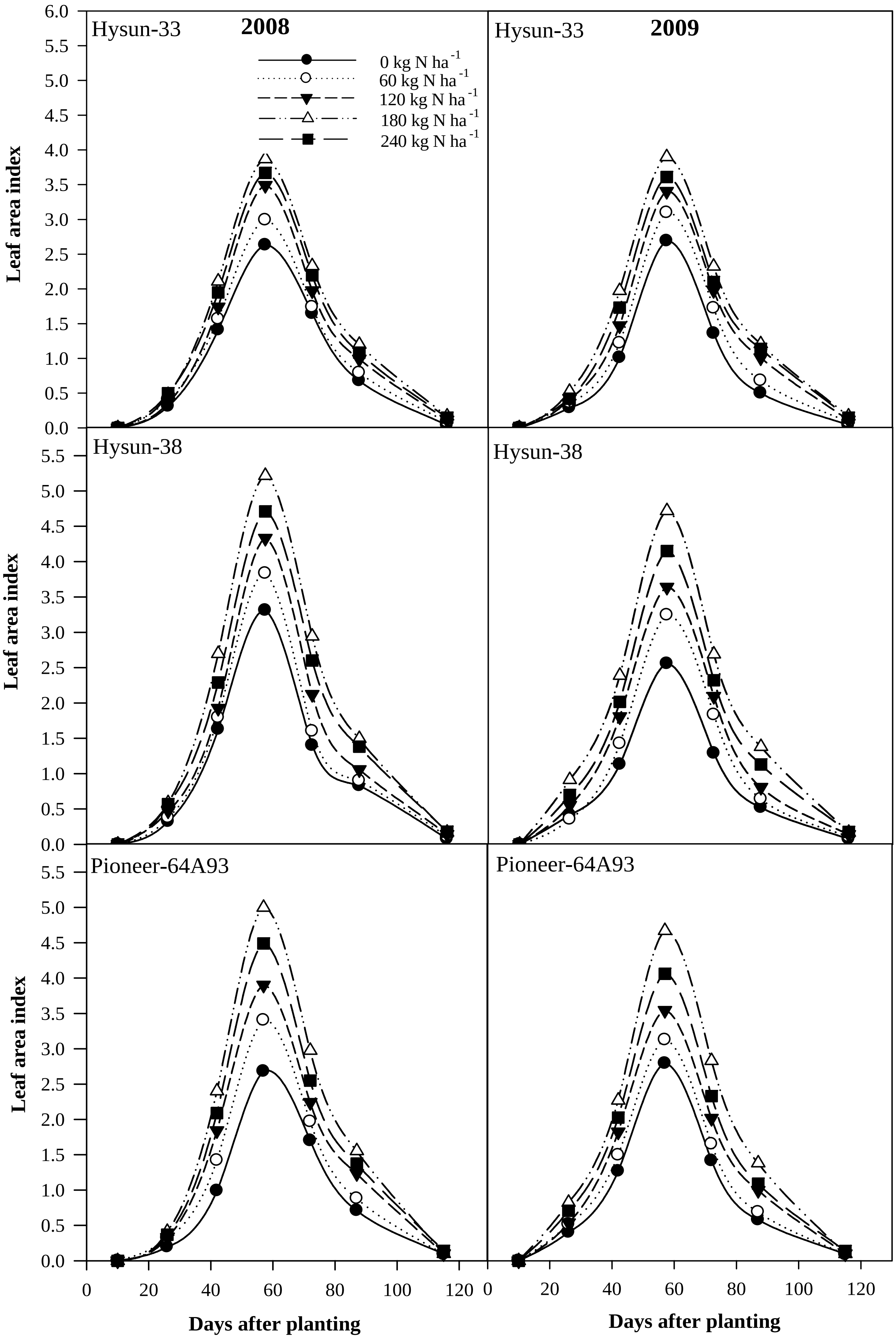

Fig. 4. Changes in leaf area index during the crop cycle as affected by different hybrids and N rates under agro-climatic conditions of Multan.

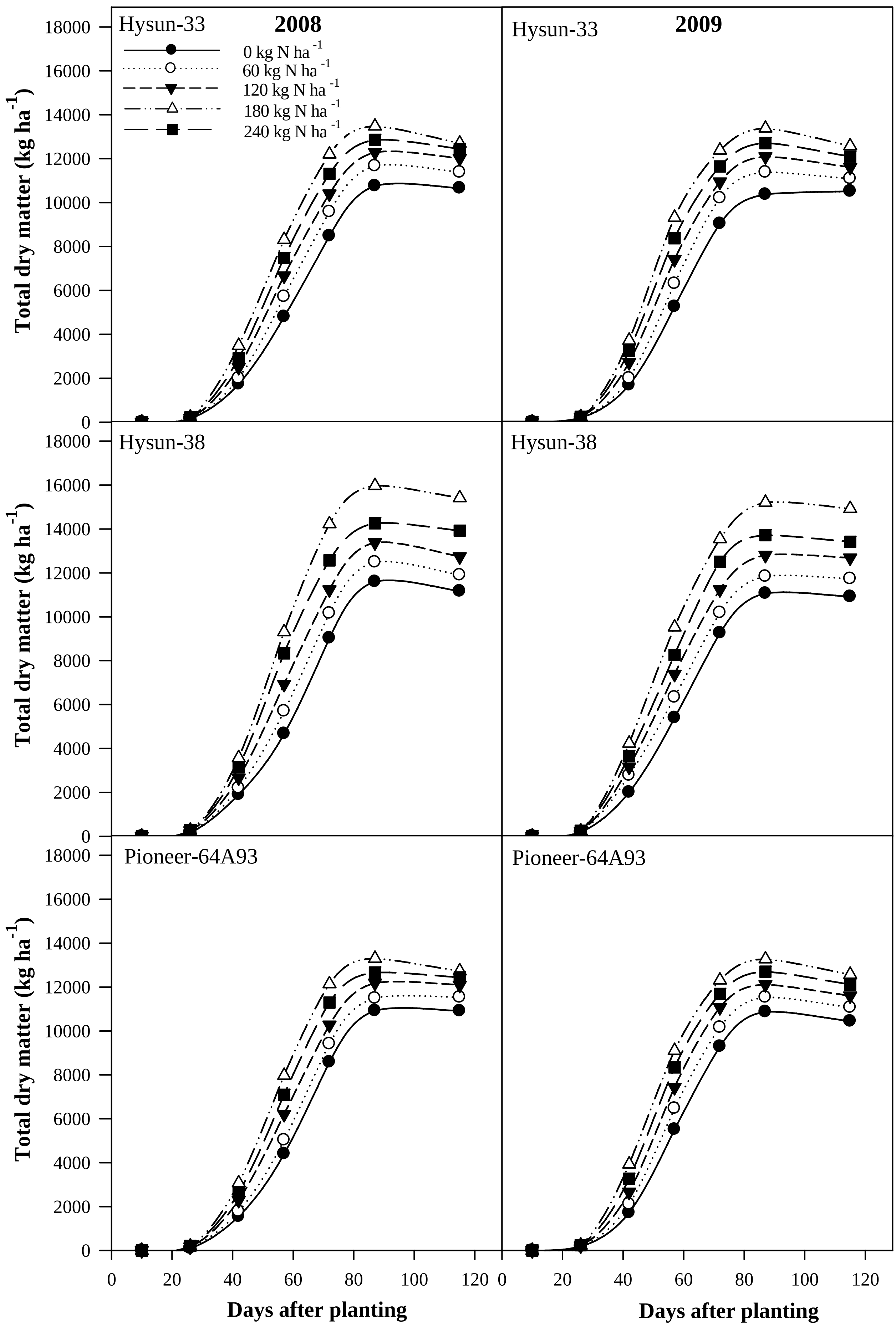

Fig. 5. Accumulation of total dry matter during the crop cycle as affected by different hybrids and N rates under agro-climatic conditions of Multan.

Table 1. The effect of various nitrogen rates on yield and yield components of sunflower hybrids under agro-climatic conditions Multan.

Treatments	Head diameter (cm)			Number of achene (head^{-1})			1000 achene weight (g)			Achene yield (kg ha^{-1})			Harvest Index (%)			Achene oil content (%)		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
Hysun-33	17.1b	16.4ab	16.8b	785b	758b	771b	35 b	31 b	33 b	2795b	2735c	2765c	23.3	24.6b	23.9ab	39.4c	38.3b	38.8c
Hysun-38	18.0a	16.9a	17.5a	820a	786a	803a	39 a	37 a	38 a	2897a	2862a	2880a	22.5	23.8b	23.1b	41.6a	40.1a	40.8a
Pioneer-64A93	17.2b	15.8b	16.5b	776c	726c	751c	38ab	35ab	37 ab	2886ab	2824b	2855b	23.8	26.5a	25.2a	40.2b	38.9ab	39.6b
LSD (0.05)	0.50	0.61	0.55	8.30	10.40	9.30	0.12	0.21	0.26	11.1	18.1	14.6	2.3	4.9	3.5	0.13	1.19	0.16
Nitrogen (kg ha^{-1})																		
0	14.3c	12.8d	13.6c	588e	559d	573d	30 e	27 d	29 e	2126e	2099e	2112e	19.4b	21.7b	20.6b	42.9a	41.6 a	42.2a
60	15.9b	15.1c	15.5b	753d	704c	729c	31 d	30 c	31 d	2742d	2664d	2703d	23.1a	25.3a	24.2a	41.7ab	40.6 b	41.2b
120	17.6b	16.8b	17.2b	832c	790b	811b	40 c	36 b	39 c	2926c	2866c	2896c	23.9a	26.4a	25.2a	40.5 b	39.2 c	39.8c
180	19.4a	18.8a	19.1a	907a	868a	887a	44 a	40 a	42 a	3325a	3284a	3305a	24.5a	25.4a	24.9a	38.8 c	37.5 d	38.2d
240	19.3a	17.8ab	18.6a	888b	862ab	875ab	42 b	40 a	41 b	3177b	3125b	3151b	24.9a	26.0a	25.5a	38.0 d	36.5 e	37.2e
LSD (0.05)	1.06	1.35	0.91	15.50	26.10	20.80	0.09	0.10	0.97	47.7	35.5	41.6	1.9	2.7	2.3	0.73	0.98	0.85
Significance	*	*	*	**	*	*	**	*	**	*	*	*	*	*	*	*	*	*
Linear	**	**	**	**	**	**	**	**	**	**	**	**	**	**	NS	**	**	**
Quadratic	NS	NS	NS	*	*	**	NS	NS	NS	**	**	**	NS	NS	NS	*	**	NS
Cubic	NS	NS	NS	NS	*	*	NS	NS	NS	NS	**	**	NS	**	NS	*	**	NS
Interaction (H x N)	NS	NS	NS	*	*	*	NS	NS	NS	*	*	*	NS	NS	NS	*	*	**
Mean	**17.4**	**16.4**	**17.1**	**794**	**757**	**775**	**37.0**	**35.0**	**36.0**	**2859**	**2807**	**2833**	**23.2**	**24.9**	**24.1**	**40.4**	**39.1**	**39.8**

Figures in the same column with different letters differ significantly at $p \leq 0.05$ by least significant difference test
* = Significant, ** = Highly significant, NS = Non-significant

Thousand achene weight (g): The average achene weight is critical yield contributing factor, which take up an important role in representing the potential yield of hybrid (Vega & Hall, 2002). On an average, heavier achenes were recorded from Hysun-38 (38.0 g) which is statistically followed by Pioneer-64A93 (37.0 g) and minimum achene weight (33.0 g) was observed from Hysun-33. As for as nitrogen treatments are concerned, mean maximum 1000 achene weight (42.0 g) was produced in N_4 treatment (180 kg N ha^{-1}) which was statistically at par with treatments N_5 (240 kg N ha^{-1}) in case of 1000 achene weight (41.0 g). The mean minimum 1000 achene weight (29.0 g) was obtained by the treatment that was without application of nitrogen fertilizer (Table 1). An increase in achene weight of sunflower hybrids in response to N fertilization has also been reported by Anwar-ul-Haq *et al.,* (2006).

Achene yield (kg ha^{-1}): Effect of different treatments on achene yield (AY) was predominant. The year effect was found to be highly significant (2859 vs. 2807 kg ha^{-1}) during 2008 and 2009, respectively. The positive climatic conditions during growing season especially at achene filling stage might be the reason of higher AY during 2008 than in 2009 (Table 1). As for as sunflower hybrids are concerned, mean higher AY was recorded from hybrid Hysun-38 (2880 kg ha^{-1}) followed by Pioneer-64A93 (2855 kg ha^{-1}) and mean minimum AY was observed (2765 kg ha^{-1}) in Hysun-33. It might be due to genetic prospective of sunflower hybrids (Ruiz & Maddonni, 2006). Furthermore, the response of nitrogen fertilizer rates on AY was linear and positive as well. Maximum AY (3305 kg ha^{-1}) was produced in N_4 treatment (180 kg N ha^{-1}) which was statistically at par with treatments N_5 (240 kg N ha^{-1}) that gave the AY of 3151 kg ha^{-1}. The minimum AY (2112 kg ha^{-1}) was observed by the treatment where there was no application of nitrogen fertilizer. Many scientists (Zubillaga *et al.,* 2002) also describe greater yield response for sunflower with N application under adequate soil water conditions.

Harvest index (%): Harvest index (HI) represents the physiological competence of plants to change the fraction of photoassimilates to achene yield. Seasonal effect on HI of sunflower hybrids was non significant. On the other hand, sunflower crop had an average HI (23.2 vs 24.9%) during the year 2008 and 2009, respectively (Table 1). The sunflower hybrid variations with respect to HI were significant, mean maximum HI (25.2%) was observed by Pioneer-64A93 followed by Hysun-33 (23.9%) as compared to Hysun-38 (23.1%) at final harvest (Table 1). Considerably high HI for Pioneer-64A93 might be achieved due to its genotypic dominance to utilize more photoassimilates for achene yield formation. Many workers (Sinclair, 1998) also reported similar type of approaches regarding harvest index in sunflower hybrids. Mean maximum HI (25.5 %) was produced in N_5 treatment (240 kg N ha^{-1}) which was statistically at par with treatments N_3 (120 kg N ha^{-1}) that gave less value of HI (25.2 %). The mean minimum HI (20.6 %) was observed by the treatment where there was no application of nitrogen fertilizer (Thavaprakash *et al.,* 2003).

Achene oil content (%): Treatment effects on achene oil content (AOC) of sunflower were highly significant during both years of experiment. The AOC were observed mean maximum (40.4%) in 2008 than AOC (39.1%) during 2009, respectively. However, Hysun-38 produces mean maximum AOC (40.8%) followed by Pioneer-64A93 (39.6%) and mean minimum AOC (38.8%) was observed in Hysun-33 sunflower hybrid. It might be due to genetic prospective of sunflower hybrid that also correlates with our findings. The response of nitrogen fertilizer rates was decreasing with increasing application of nitrogen fertilizer (Abelardo & Hall, 2002; Khaliq & Cheema, 2005). Mean maximum AOC (42.2%) were produced in N_1 treatment (0 kg N ha^{-1}) which was statistically at par with treatments N_2 (60 kg N ha^{-1}) that gained AOC of 41.2%. The standard treatment N_3 (120 kg N ha^{-1}) produced AOC at 39.8% that was significantly higher than N_4 (180 kg N ha^{-1}) with AOC value of 38.2%. The mean minimum AOC (37.2%) was observed by the treatment where there was maximum application of nitrogen fertilizer (240 kg N ha^{-1}) as demonstrated in the Table 1. This shows that with increasing nitrogen fertilizer, it increased the achene yield as well as protein contents but reduced AOC (Miner *et al.,* 1995). Furthermore, the interactive effect of hybrids and nitrogen levels was significant in both years of experiments (Table 1).

Conclusions

In this study, it can be concluded that, Hysun-38 should be planted to obtain higher achene yield and better quality oil contents, because it perform excellent characteristics under agro-climatic conditions of Multan, so it is recommended as best hybrids than other (Hysun-33 and Pioneer-64A93) hybrids. As for as among different nitrogen rates, 180 kg N ha^{-1} is better under well irrigated conditions to get maximum economic benefits than other N rates. Further research is required to get the proficiency for sunflower crop due to its high requirements of edible oil production, which is desire need not only in Pakistan but also in whole world because of higher budget of foreign exchange being invested on importing edible oil from different developed countries, so we can minimize this huge investment of budget, by adapting best hybrids and best agronomic management strategies under agro-climatic conditions of Multan.

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