

Effect of Nitrogen on Yield and Oil Quality of Sunflower (*Helianthus annuus* L.) Hybrids under Sub Humid Conditions of Pakistan

Wajid Nasim^{1,2,3,4*}, Ashfaq Ahmad², Asghari Bano¹, Rabiou Olatinwo³, Muhammad Usman⁵,
Tasneem Khaliq², Aftab Wajid², Hafiz Mohkum Hammad^{2,6}, Muhammad Mubeen², Muzzammil Hussain⁷

¹Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan; ²Agro-Climatology Laboratory, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan; ³Department of Biological & Agricultural Engineering, University of Georgia, Griffin, USA; ⁴Department of Environmental Sciences, COMSATS Institute of Information Technology (CIIT-Vehari Campus), Vehari, Pakistan; ⁵Department of Irrigation & Drainage, University of Agriculture, Faisalabad, Pakistan; ⁶AgWeatherNet, Washington State University, Prosser, USA; ⁷Adaptive Research Farm Gujranwala, Government of Punjab, Lahore, Pakistan.
Email: wajidnaseem2001@gmail.com, wajidnasim@ciitvehari.edu.pk

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ABSTRACT

Sunflower (*Helianthus annuus* L.) has emerged as an economically important crop in Pakistan due to its significant share in vegetable oil production. The plant metabolic processes require protein to increase the vegetative, reproductive growth and yield of the crop. The protein is wholly dependent upon the amount of nitrogen fertilization available for plant use. A two-year field study was conducted in 2008 and 2009. The objective was to determine the effect of different nitrogen (N) levels ($N_1 = 0 \text{ kg}\cdot\text{ha}^{-1}$, $N_2 = 60 \text{ kg}\cdot\text{ha}^{-1}$, $N_3 = 120 \text{ kg}\cdot\text{ha}^{-1}$, $N_4 = 180 \text{ kg}\cdot\text{ha}^{-1}$ and $N_5 = 240 \text{ kg}\cdot\text{ha}^{-1}$) on three sunflower hybrids (Hysun-33, Hysun-38 and Poiner-64A93) in agro-climatic conditions of Gujranwala, a sub-humid region in the centre of the Punjab province of Pakistan. A randomized complete block design split plot experiment was set-up with cultivars in the main plots and N levels in the subplots. Results showed that Hysun-38 gave maximum TDM ($15815 \text{ kg}\cdot\text{ha}^{-1}$) and maximum grain yield ($3389 \text{ kg}\cdot\text{ha}^{-1}$), while minimum TDM ($14640 \text{ kg}\cdot\text{ha}^{-1}$) and grain yield ($3125 \text{ kg}\cdot\text{ha}^{-1}$) was observed in Hysun-33. Among different N rates evaluated, N_4 gave maximum TDM ($17890 \text{ kg}\cdot\text{ha}^{-1}$) and grain yield ($3809 \text{ kg}\cdot\text{ha}^{-1}$) compared to the other N rates. The maximum oil content (46.2%) was observed in Hysun-38 without application of N fertilizer (N_1), while the minimum oil content (40.6%) was observed from N_5 treatment. In conclusion, the application of $180 \text{ kg}\cdot\text{ha}^{-1}$ N to Hysun-38 provided the best combination for good yield in sunflower crop under the prevailing sub-humid conditions of Pakistan.

Keywords: *Helianthus annuus* L.; Nitrogen Rates; Yield; Subhumid Conditions; Pakistan

1. Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oilseed that originally belonged to subtropical and temperate zones [1,2] crop and it is widely adaptable and more drought tolerant than most other grain crops [3]. It is well adjusted to soil that has high water-holding capacity but is easily adapted to a range of soil conditions [4]. Nutrients play an important role in crop growth and development. Among the nutrients, N is one of the major nutrients that enhance the metabolic processes that based on protein, leads to increases in vegetative, reproductive growth and yield of the crop [5,6]. As the history indicates that there is a severe shortage of edible oilseeds in Pakistan that can hardly accumulate the requirements. To

meet the needs of population and never-ending rise in urbanization has led to broaden the gap between local availability and requirement to increase in number of mouths as well as rise in per capita consumption. So, total domestic fling of edible oil stood at about 3.07 million tons, of which 27.20% (0.83 million tons) came from local production (GOP, 2009). Thus, the country is constrained to import edible oil in large quantities. The import of edible oil accounts largest drain on national exchequer that is second to only mineral oil. The import bill is imposing a severe drain on foreign exchange reserves. During 2008-2009 (July-March), Pakistan spent Rs. 84000 million for 1290 thousand tons of edible oil and Rs.13756.83 million for 723.96 thousand tons of oilseeds during 2008-2009. A developing country like ours cannot afford such a mounting export bill indeed. The situation

*Corresponding author.

thus warrants enhancing the indigenous oilseed production to set aside the country from a foremost disaster in not too far a future. The local production of edible oil in Pakistan stood at 6.84 million tons during 2008-2009, which is almost 24% of the total local demand, while the remaining 76% is imported with estimated cost of Rs. 80 billion annually [7]. In Pakistan, sunflower was sown on approximately 3.53 M ha with total production of 5.54 M tons for seed and 2.11 M tons for oil, respectively [7]. The research and development constraints limiting increased production include non-availability of suitable local hybrids/cultivars, high cost of imported seed and losses due to bird damage near the crop maturity. Others include defective and inefficient marketing system, unavailability and high prices of inputs, reliance on old traditional methods of sowing and harvesting, post harvest problems and the lack of awareness of the farmers about latest sunflower production technology [8]. The present study, therefore, was conducted with the objective to evaluate the effect of different N rates on achene's oil quality, yield and yield components of different sunflower hybrids under Gujranwala's agro-climatic conditions of Punjab, Pakistan.

2. Materials and Methods

The experiment was conducted on the Adaptive Research Farm, Gujranwala (32°19'N, 74°17'E), which represents the sub-humid agro-ecological region in Pakistan (Figures 1 and 2). Gujranwala has a shallow, fine, silty, mixed and hyperthermic soil. Its color is medium brown,

moderately well drained, with field capacity (FC) of $0.57 \text{ m}^3 \text{ m}^{-3}$ and permanent wilting point of $0.23 \text{ m}^3 \text{ m}^{-3}$ having the pH ranges from 8.1 - 8.6, while the organic matter percentage was 0.87% in the whole profile [4]. In this study, there were fifteen treatments, including five N levels ($N_1 = 0 \text{ kg} \cdot \text{ha}^{-1}$, $N_2 = 60 \text{ kg} \cdot \text{ha}^{-1}$, $N_3 = 120 \text{ kg} \cdot \text{ha}^{-1}$, $N_4 = 180 \text{ kg} \cdot \text{ha}^{-1}$ and $N_5 = 240 \text{ kg} \cdot \text{ha}^{-1}$) and three sunflower hybrids (Hysun-33, Hysun-38 and Poiner-64A93). Phosphorus (P) and Potassium (K) were used at the rate of $60 \text{ kg} \cdot \text{ha}^{-1}$ 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), respectively. A 1/3rd dose of N and all of the P and K fertilizer were applied at the time of sowing, while remaining 2/3rd of N was used in two splits; first dose at first irrigation and second dose of N at the flowering stage of crop during both years. Crop was irrigated as the crop required irrigations without any water stress. The experimental field was well-prepared to form ridges (70 cm spaced), the experiment was laid out in randomized complete block design with split plot arrangement having three replications. The crop was sown in February 2008 and 2009 with hand-mounted seed drill (dibbling) placing three seeds per hill, keeping in between plant distance at 20 cm, using a recommended seed rate of $7 \text{ kg} \cdot \text{ha}^{-1}$. The net plot size was $4.2 \text{ m} \times 5 \text{ m}$. Sunflower hybrids were kept in main plots while different N levels were applied to the sub-plots. After crop establishment, near 2 - 4 leaf stage, seedlings were thinned down to one per hill manually, to keep optimum plant population. During the 2008 and 2009 growing seasons,

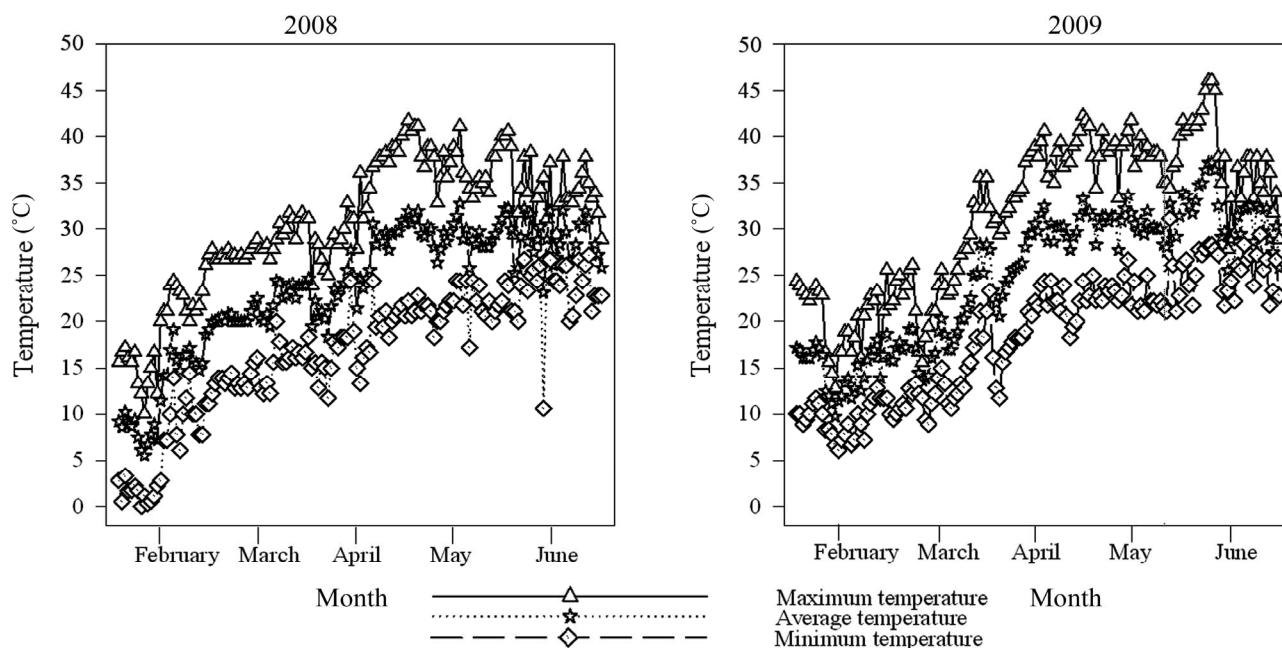


Figure 1. The daily temperature (maximum, minimum and average) during the 2008-2009 sunflower growing seasons in the sub-humid area of Pakistan.

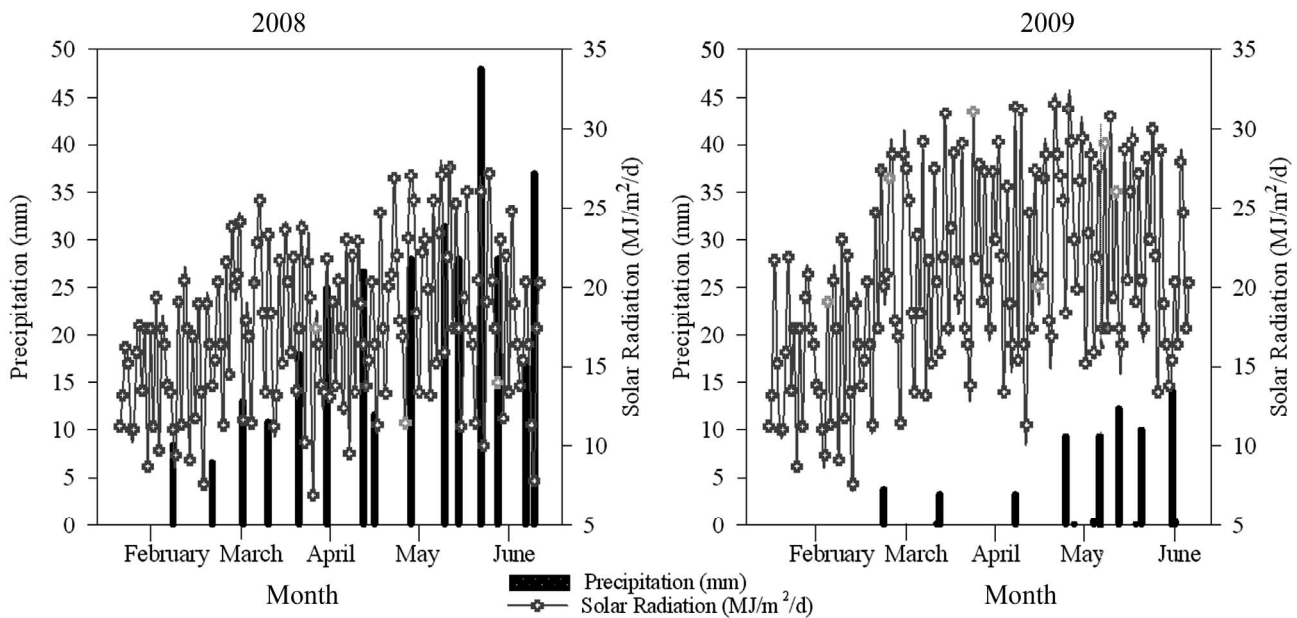


Figure 2. Precipitation and solar radiation during the 2008-2009 sunflower growing seasons in the sub-humid area of Pakistan.

two manual weeding by hoe 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. The cropping husbandry and oil determination method were determined [9]. The data on leaf area index, total dry matter, head diameter, number of grains, 1000-grain weight, grain yield, and harvest index and achene oil content were taken. Data collected from the experiments were statistically analyzed using the computer statistical program MSTAT-C [10]. Mean comparison among treatments were evaluated using the least significance difference (LSD) test at $P = 0.05$ for yield and yield components of the sunflower crop.

3. Results and Discussion

3.1. Weather Conditions

There were differences in environmental conditions during both years; spring season 2008 was cooler while spring season 2009 was hotter. All the weather data (minimum and maximum temperature, relative humidity, rainfall, solar radiation) were obtained from the nearest meteorological observatory around the experimental site. **Figures 1 and 2** indicate the means of weather elements during 2008 and 2009. Gujranwala was considered as cooler with minimum temperature and maximum rainfall especially during experimental year 2008. Rainfall was experienced more during spring 2008 than spring 2009 growing seasons. Gujranwala had precipitation of 263 mm in 2008 and 106.7 mm in 2009. Solar radiation was

observed $22.3 \text{ MJ}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ during 2008 and almost similar trend was observed in year 2009 (**Figure 2**).

3.2. Leaf Area Index

Leaf area index (LAI) progressively increased and achieved its maximum value at 60 days after sowing (DAS); thereafter, LAI decreased in all the treatments and reached its lowest value at less than 0.5 by 105 DAS during 2008 and 2009 seasons, respectively (**Figure 3**). Such reduction in LAI was more pronounced in lower N levels (0 and $60 \text{ kg}\cdot\text{N}\cdot\text{ha}^{-1}$) than high N levels due to early senescence of leaves, earlier than the latter stages of growth of sunflower crop. Maximum LAI value was observed in hybrids Hysun-38 followed by Pioneer-64A93 and the minimum LAI was observed in Hysun-33 during 2008 and almost similar trend of treatments was observed in year 2009 but on an average basis year 2008 produced more LAI compared to 2009 (**Figure 3**). Furthermore, maximum LAI reached to a value at 65 DAS in N_4 and minimum value for LAI was recorded in N_1 (**Figure 4**). The greater leaf expansion shown in sunflower hybrids could be attributed to higher rate of cell division and cell enlargement [11-13].

3.3. Total Dry Matter

The total dry matter (TDM) production increased progressively, after crop establishment and continued until maturity in all the treatments. Maximum TDM was observed to be higher in 2008 than in 2009 growing season for the three hybrids, which could be due to more favorable

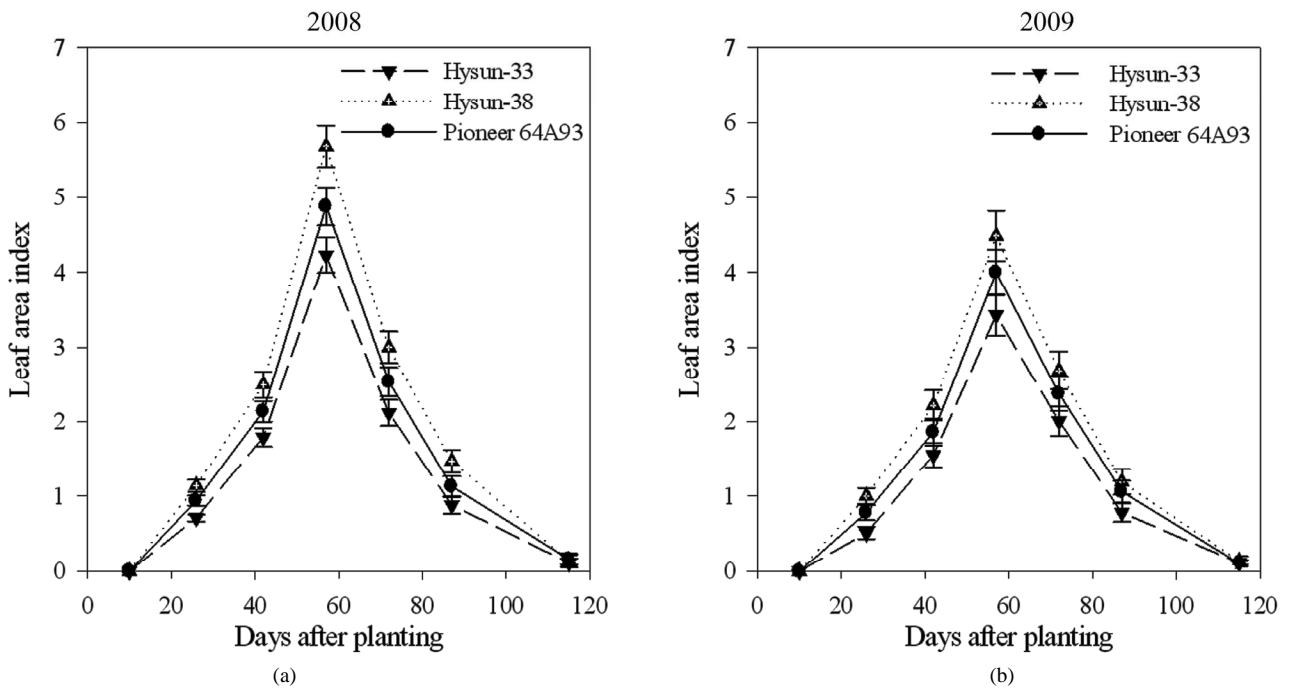


Figure 3. The Leaf Area Index (LAI) and the standard error of the mean for three hybrids during the 2008 (a) and 2009 (b) crop cycle under subhumid conditions of Pakistan.

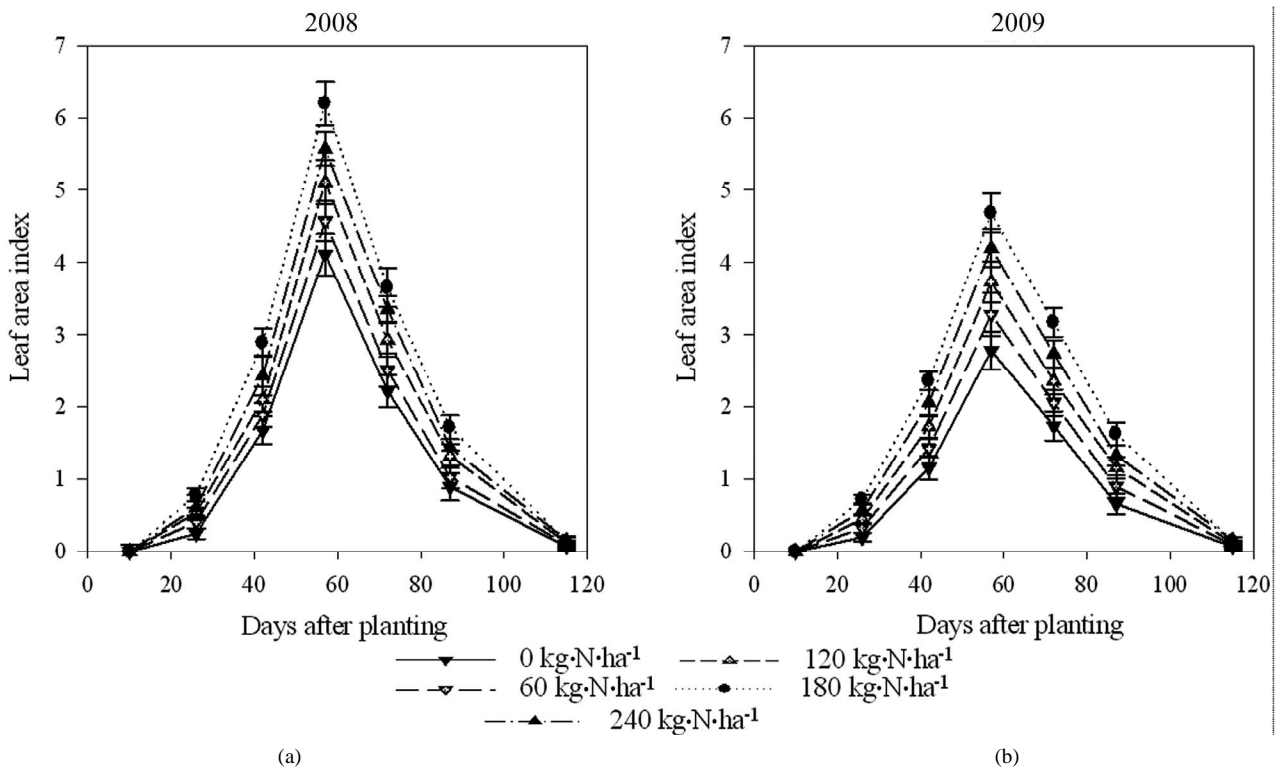


Figure 4. The Leaf Area Index (LAI) and the standard error of the mean for different nitrogen levels during the 2008 (a) and 2009 (b) crop cycle under subhumid conditions of Pakistan.

conditions (more rainfall with low temperature in spring 2008) during 2008 than in 2009 (Figure 2). A maximum

TDM was observed in hybrids Hysun-38 followed by Pioneer-64A93, and the minimum TDM was observed in

Hysun-33, both during 2008 and 2009 seasons (**Figure 5**). Maximum TDM was reported in N₄ treatments followed by N₅ while minimum value of final TDM was observed in N₁ (**Figure 6**). The enhancement in TDM with increasing rate of nitrogen was due to better crop growth rate, which gave maximum photosynthates ultimately producing higher biological yield. The study also corroborates previous work done [14-16] on the use of different N levels.

3.4. Head Diameter

The results in **Table 1** showed significant differences in head diameter during 2008 and 2009. The pooled mean from 2008 and 2009 indicate that, Hysun-38 had the higher head diameter (19.4 cm) followed by Pioneer-64A93 (18.7 cm), while statistically lower head diameter (17.7 cm) was observed in Hysun-33. The response of N fertilizer with various rates on head diameter was higher with increasing trend of N fertilizer. The maximum head diameter (21.2 cm) was produced by N₄ treatment followed by N₅ that produced 20.4 cm head diameter and statistically minimum head diameter (15.3 cm) was recorded in plot that was not fertilized with N (N₁). These results validate the findings [17,18] that have also the evidence regarding to positive effects of nitrogen on head diameter.

3.5. Number of Grains

Hysun-38 showed significantly high values of grains per head (1051), followed by Pioneer-64A93 (1041) and

statistically minimum values of grains per head were observed by Hysun-33 (1008), respectively (**Table 1**). While in case of N treatments, N₄ produced statistically higher grains per head (1215), followed by N₅ (1163), while statistically, N₁ gave minimum grains per head (807). These results corroborate the studies [19,20] who also reported that the shortage of N affects the development and growth of source and sink, as well as the number of achene per head and also some scientists also explain the similar characteristics of the sunflower hybrids used in this study [20].

3.6. Thousand Grain Weight

The average grain weight is critical yield contributing factor, which take up an important role in representing the potential of respective hybrid. Maximum grain weight were observed in Hysun-38 (48.3 g) followed by Pioneer-64A93 (47.3 g) and minimum grain weight was observed (46.6 g) in Hysun-33. In the similar way, among different N levels, Maximum 1000 grain weight (56.9 g) was produced in N₄ treatment, followed by N₅ (53.7 g) treatment. The minimum 1000 grain weight (35.5 g) was obtained by the treatment without application of nitrogen fertilizer (**Table 1**). An increase in grain weight of sunflower hybrids in response to N fertilization has also been reported [21,22].

3.7. Grain Yield

The constructive climatic conditions (lower temperature and higher relative humidity) during growing season

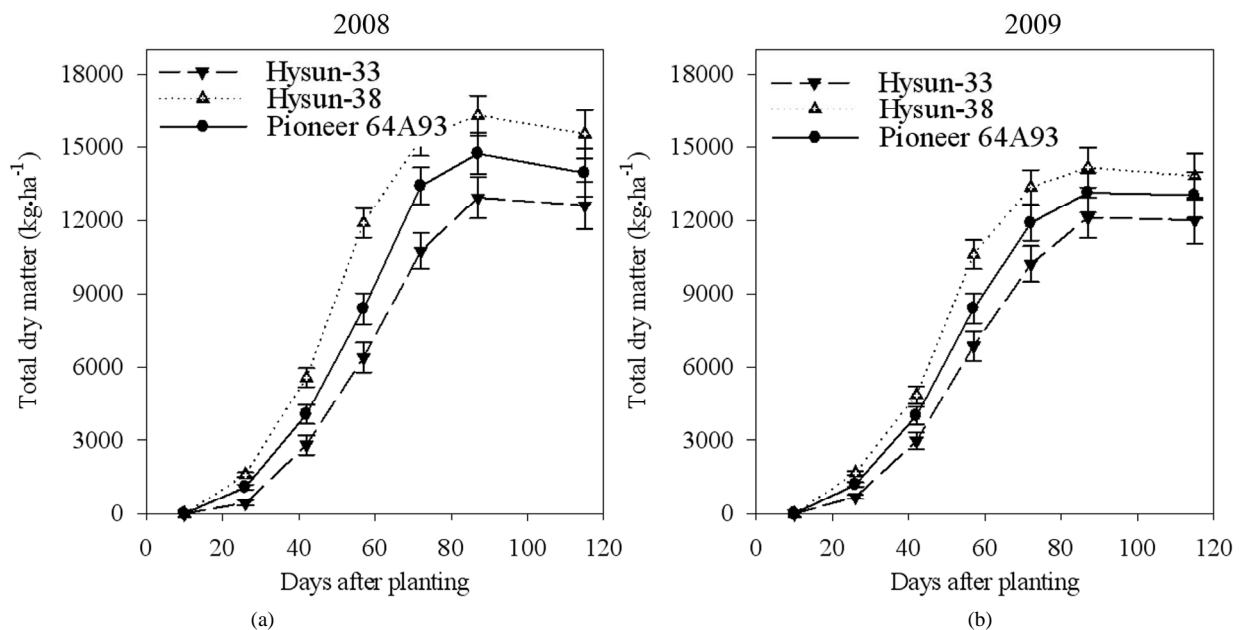


Figure 5. The Total Dry Matter (TDM) and the standard error of the mean for three hybrids during the 2008 (a) and 2009 (b) crop cycle under subhumid conditions of Pakistan.

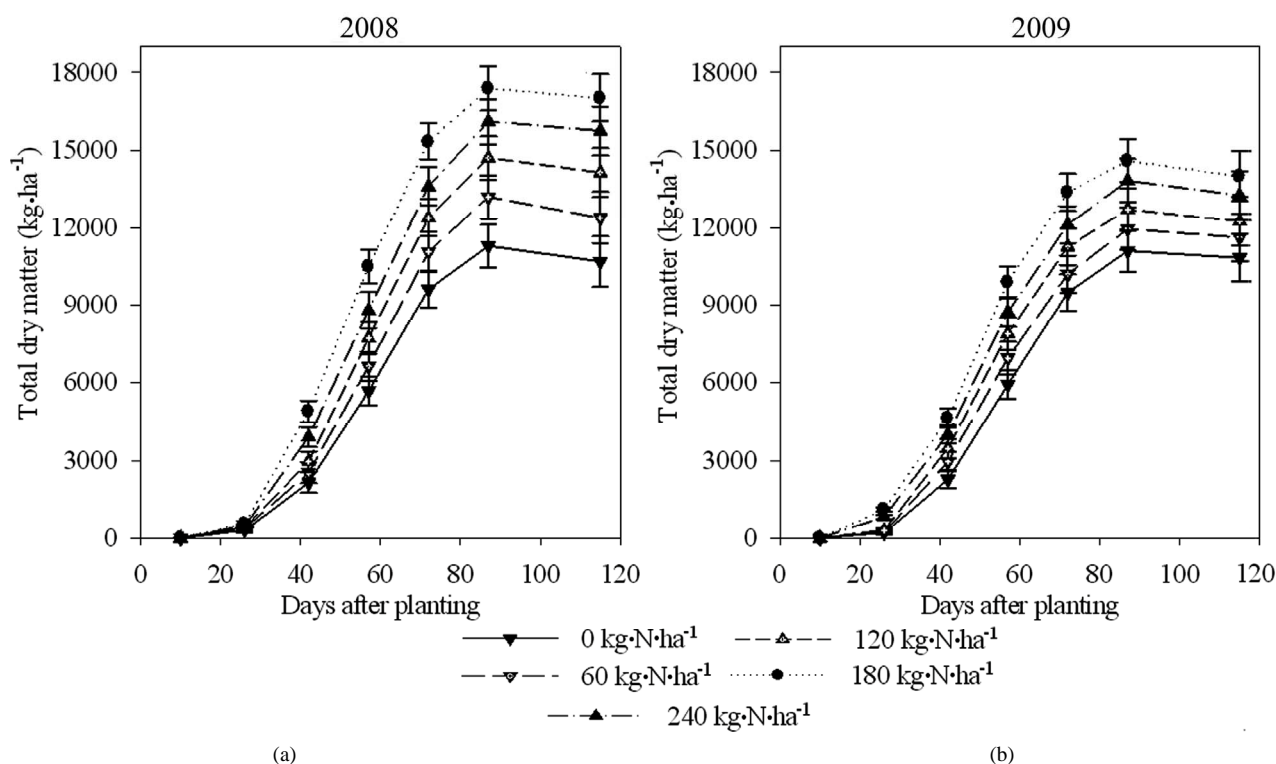


Figure 6. The Total Dry Matter (TDM) and the standard error of the mean for different nitrogen levels during the 2008 (a) and 2009 (b) crop cycle under subhumid conditions of Pakistan.

Table 1. Effect of different nitrogen rates on the yield components of sunflower hybrids under agro-climatic conditions Gujranwala-Pakistan.

Treatments	Head diameter (cm)			Number of grains (head ⁻¹)			1000 grain weight (g)		
	2008	2009	Pooled mean	2008	2009	Pooled mean	2008	2009	Pooled mean
Hysun-33	18.4b	17.1b	17.7c	1079b	938c	1008b	48.1b	45.2c	46.6c
Hysun-38	19.6a	19.3a	19.4a	1136a	1023a	1051a	49.2a	47.4a	48.3a
Pioneer-64A93	18.9b	18.5a	18.7b	1084c	998b	1041a	48.2b	46.4b	47.3b
LSD (0.05)	0.67	0.87	0.66	12.41	14.10	12.60	0.15	0.36	0.23
Nitrogen (kg·ha ⁻¹)									
0	15.4e	15.2c	15.3d	867e	746e	807e	37.4e	33.6e	35.5e
60	17.8d	16.6c	17.2c	1001d	904d	952d	41.3d	39.9d	40.6d
120	19.3c	18.2b	18.8b	1151c	1012c	1081c	51.5c	49.2c	50.3c
180	22.2a	20.3a	21.2a	1261a	1169a	1215a	57.4a	56.5a	56.9a
240	20.8b	19.9a	20.4a	1218b	1109b	1163b	55.3b	52.2b	53.7b
LSD (0.05)	1.18	1.44	1.29	14.30	13.10	12.20	0.99	0.92	0.94
Significance	**	*	**	**	**	**	**	**	**
Interaction(H × N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Figures in the same column with different letters differ significantly at probability level of *P = 5 %, **P = 1 %, NS—non-significant.

especially at grain filling stage might be the reason of higher grain yield especially, during 2008 than 2009. Higher grain yield was recorded from hybrid Hysun-38 (3389 kg·ha⁻¹) followed by Pioneer-64A93 (3218 kg·ha⁻¹) and minimum grain yield was observed (3125 kg·ha⁻¹) in Hysun-33. The response of N fertilizer rates on grain yield was significant, increasing with application of more

N fertilizer. Maximum grain yield (3800 kg·ha⁻¹) was produced in N₄ treatment followed by N₅ treatment that gave the grain yield of 3775 kg·ha⁻¹. The minimum grain yield (2290 kg·ha⁻¹) was observed by the treatment where there was no application of nitrogen fertilizer (Table 2). These results were also in conformity with other findings [21,23]. The yield was high due to low temperature during

Table 2. Effect of nitrogen levels on different yield parameters of sunflower hybrids under agro-climatic conditions Gujranwala-Pakistan.

Treatments	Grain yield (kg·ha ⁻¹)			Harvest index (%)			Grain oil content (%)		
	2008	2009	Pooled mean	2008	2009	Pooled mean	2008	2009	Pooled mean
Hysun-33	3170c	3081c	3125c	26.7	24.9	25.8	41.0c	40.3c	40.7c
Hysun-38	3340a	3338a	3389a	24.0	25.0	24.5	43.2b	42.5b	42.9b
Pioneer-64A93	3262b	3174b	3218b	27.4	25.6	26.5	43.6a	43.9a	43.7a
LSD (0.05)	19.3	17.3	16.4	NS	NS	NS	0.05	0.12	0.08
Nitrogen (kg·ha ⁻¹)									
0	2339d	2241e	2290e	20.6d	19.9c	20.3d	46.6a	45.9a	46.2a
60	2961c	2912d	2936d	23.3c	23.0b	23.1c	46.5a	45.7a	46.1a
120	3172b	3102c	3137c	25.4b	23.8b	24.6b	44.1b	43.5b	43.8b
180	3809a	3791a	3800a	27.6a	26.4a	27.0a	41.3c	40.8c	41.0c
240	3806a	3743b	3775b	27.9a	27.1a	27.5a	40.4d	40.8c	40.6d
LSD (0.05)	44.0	33.3	22.6	1.5	1.4	1.5	0.81	0.45	0.44
Significance	*	*	*	*	**	*	*	*	*
Interaction(H × N)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Figures in the same column with different letters differ significantly at probability level of *P = 5 %, **P = 1 %, NS—non-significant.

the grain filling stage and the crop grown under the minimum temperature with high moisture content in not only atmosphere but also under the crop root zone as well in the form of precipitation and these environmental conditions leads to better crop yield.

3.8. Harvest Index

The harvest index represents the physiological competence of plants to change the fraction of photoassimilates to grain yield. The data in **Table 2**, demonstrated that seasonal effect on harvest index (HI) of sunflower hybrids that was non significant. The sunflower hybrid variations with respect to HI were non-significant. Considerably high HI for Pioneer-64A93 might be achieved due to its genotypic dominance to utilize more photoassimilates for grain yield formation. These results also corroborate the studies carried out by other scientists [24, 25].

3.9. Achene Oil Content

Pioneer-64A93 produced the maximum grain oil content (GOC) (43.7%) followed by Hysun-38 (42.9%), while the minimum GOC (40.7%) was observed in Hysun-33 sunflower hybrid. The response to N fertilizer rates decreased with increasing application of N fertilizer. Maximum GOC (46.2%) were produced in N₁ treatment followed by N₂ (46.1%). The minimum GOC (40.6%) observed in N₅. This result shows that an increase in N fertilizer increases the grain yield but reduces the GOC [26, 27].

3.10. Nitrogen Utilization Efficiency (kg·kg⁻¹)

The differentiation of nitrogen use efficiency (NUE) in sunflower hybrid was non-significant during both years of experiments. Averaged over all, maximum NUE was (6.2 kg·kg⁻¹) observed by Hysun-38 followed by Hysun-33 (5.9 kg·kg⁻¹) and minimum value of NUE (5.7 kg·kg⁻¹) observed in Pioneer-64A93 sunflower hybrid (data not shown). Furthermore, significant variations were found in NUE in different N treatments, where increasing rates of N decreased the NUE over all. Thus, the highest NUE (11.3 kg·kg⁻¹) were found when when the application was 60 kg·N ha⁻¹. The minimum value of mean NUE (0.0 kg·kg⁻¹) was observed from plots fertilized with 0 kg·N·ha⁻¹ (N₁). Similar findings were also reported by [28,29].

4. Conclusion

From this study we can conclude that Hysun-38 should be planted to obtain higher achene yield and better quality oil contents, since it performed best with excellent characteristics under agro-climatic conditions of Gujranwala compared to Hysun-33 and Pioneer-64A93 hybrids. For maximum economic benefits, application of 180 kg·ha⁻¹ was better under well irrigated conditions compared to other different N rates evaluated. Further research may be required in this area (sub humid area) for sunflower crop to identify best agronomic management strategies under agro-climatic conditions of Gujranwala in order to achieve high yield and profitable edible oil production in the sub-humid region of Pakistan.

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