Response Of Sunflower To Environmental Disparity

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Abstract: Sunflower crop has an evolutionary benefit of being able to maintain high level of viability in a variety of environments. Field experiments, one each in spring and autumn were executed at Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan for two years (2007& 08) to document the effect of growing degree days on performance of sunflower hybrids. Four Sunflower hybrids, Alisson-RM, Parasio-24, MG-2 and S-278 were planted in Randomized Complete Block Design with four replications during spring and autumn. The data on yield and yield attributes of sunflower like number of achenes per head, hundred achenes weight, biological and achene yield along with achene oil content was recorded. All parameters were influenced by prevailing temperature. Amongst hybrids, MG-2 produced the maximum values for all parameters during both the seasons (spring & autumn). Overall, spring planted crop exhibited significantly higher values for achenes per head, biological yield, achene yield and oil content in comparison with autumn planting, which may be attributed to accumulation of more growing degree days during the season.
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1. Introduction

Temperature is a basic factor that affects the course of life, specifically the physiological time. Thermal time gives a measure of physiological time as it relates to many poikilothermic species of plants (Trudgill *et al.* 2005). Most crop species are adapted to particular temperature ranges which is major environmental factor influencing their distribution (Atkinson and Porter, 1996), but a key factor which influences plant growth, development and productivity (Kaleem *et al.*, 2009). Expression of different yield and yield attributes under varying seasons is considered due to the different climatic conditions those are based on temperature prevailing during the crop life cycle (Killi and Altanbay, 2005).

Although sunflower is a temperate zone crop but it can perform well under various climatic and soil conditions. A number of plant's developmental, morphological and physiological adaptations to the environment, influence sunflower yield and oil (Hassan *et al*., 2005). World wide cultivation under very hot and cold conditions might have developed the unique properties of sunflower tolerance to both low and high temperature (Khalifa *et al*., 2000). Sunflower is a C_4 plant having higher physiological activity but is sensitive to cold temperatures and called as warm season plant as compared to C_3 plants (Brouder *et al*., 2008).

Environmental disparity alters morphological, physiological, quantitative and qualitative expressions of sunflower which are affected by extreme growing conditions. All physio-morphic developments occurring in plant are markedly influenced by temperature as the primary factor governing the growth (Chan *et al.*, 1998). Having wide adaptability, different sunflower hybrids require different total number of cumulative degree-days or growing degree days for growth, development and maturity (Qadir *et al.*, 2007). The most common temperature index used to estimate plant development is growing degree days (GDD). A linear relationship between GDD and rate of plant development has been reported by Lu *et al.* (2001). GDD can be used to classify plants for their flowering, estimate maturity/harvest and to predict the duration between two stages (Bonhomme, 2000). Sur and Sharma (1999) recorded that the total growing degree days decreased from 1731 to 1621 with delay in planting, as the late sown crop experienced lower temperature during the seed filling period. However, Kaleem, *et al.*, (2009) concluded that lower yield associated with late planting in sunflower was due to warmer temperature during the early growth period, which accelerated stem growth and early switching over from vegetative to reproductive stage.

Reproductive phase of sunflower crop is more sensitive to cold condition resulting in floral abortion, infertile pollens, poor seed set and empty seeds with reduced seed size that affects the total output (Clarke and Siddique, 2004). Autumn sowing with high temperatures and low relative humidity at the time of pollination, affects pollen health and vigor, causing poor pollination, produces less weight, empty and sterile achenes, thus influencing sunflower head fertility and achene yield (Miralles *et al.*, 1997). Sunflower biomass production is positively correlated with temperature and photoperiod. Biological and achene yield was affected at maturity due to temperature and photoperiod during development under different seasons as higher biomass and seed yield was recorded in spring sowing than in autumn sowing (Villalobos *et al*., 1996). Spring and autumn sowings of sunflower performed differently. Seed yield along with growth and development was significantly affected with delayed sowing because of lesser efficiency of components contributing in sunflower yield (Kaleem *et al*., 2009).

Planting sunflower crop in different seasons causes temperature variations in the field, thus crop will grow in different environmental variables like temperature, sunshine, rainfall and relative humidity. Sowing in two season (spring & autumn) created difference in temperature for growth, development and maturity, thus a wide range of temperature may be encountered from sowing till maturity during both the seasons. The present investigation was thus contemplated to investigate relationship of growing degree days with yield and yield components of sunflower crop sown during spring and autumn seasons.

2. Materials and methods

Field experiments were conducted at Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan, located at 33^o and 38^o N and 73^o and 04^o E, during 2007 and 2008 (spring and autumn in each year). The soil of experimental site was loam type in texture having sand 43%, silt 46% and clay 11%, pH 7.4 and EC 0.66 m S cm^{-1}. Available NPK status in the soil before sowing was 300, 5.00 and 140 mg kg $^{-1}$ respectively. The particular experimental site was winter fallow prepared for sowing by giving one soil inverting plough, thereafter, ploughed thrice with tractor mounted cultivator and planked with last ploughing. Recommended dose of fertilizer of 80 kg Nitrogen and 60 kg P_2O_5 per hectare was applied in the form of Urea and DAP at the time of last ploughing. Spring crop was sown on 18th March for each year while autumn crop was sown on 18th August for each year. Four sunflower hybrids (Alisson-RM, Parasio-24, MG-2 and S-278 were sown by using seed @ 5kgs / ha. Seeds were sown with dibbler by putting two seeds at each pre-marked spot. Plant to plant distance was maintained 25 cm and row to row 75 cm in net plot size of 5x3 m^2. After complete emergence, one plant was maintained per hill. Weeds were kept under control by hand weeding through out crop life cycle.

The cumulative growing degree days from emergence till maturity were calculated from meteorological data obtained from Meteorology Department located near experimental site (Table I) through out crop life cycle by the equation of Dwyer and Stewart (1986).

CHU= $\sum_{t1}^{t2}[(T_{max}+T_{min})/2-8]$

where $[(T_{max}+T_{min})/2-8]>0$

$T_{max}+T_{min}$ were daily maximum and minimum air temperatures in degree centigrade and t_1 and t_2 were the time intervals. Base temperature for sunflower development is 8°C (Sadras & Hali, 1988).

To record the data for number of achenes head^{-1}, ten heads were taken at random from each plot. The number of achenes were counted and the average was worked out. Similarly, to record HAW (hundred achenes weight), five samples of hundred achene were taken randomly from the total seed lot of each plot, then weighed using digital electronic balance and average was worked out. Two central rows of 5m length were harvested after complete maturity from the each plot for biological yield (on 8.7.2007, 5.7.2008 during spring and 14.11.2007, 21.11.2008 during autumn. Harvested plants were sundried for 15 days during autumn, 9 days during spring season and weighed with the help of spring balance to obtain biological yield per plot and then per hectare yield was computed. For achene yield, plants already harvested from two central rows and then sundried for different days according to season were threshed manually. Achene yield per plot was recorded which was converted into kg ha^{-1}. Similarly, achene oil concentration was determined by using the NMR (Nuclear Magnetic Resonance system), Model MQA-7005, Oxford Institute, USA, as described by Granland and Zimmerman, (1975). The equipment was standarderized with six different oil contents having the samples previously analyzed.

2.1 STATISTICAL ANALYSIS

The collected data were subjected to statistical analysis by applying MSTATC, separately for both the years (Freed and Eisensmith, 1986). Analysis of Variance Techniques were employed to test the significance of data. Least Significant Difference Test at 5% probability was used to compare the means **(**Montgomery**,** 2001).

3. RESULTS

3.1 Number of Achenes Head^{-1}

Hybrids under evaluation exhibited statistically significant differences for yield and yield components during both the seasons. As regards number of achenes head^{-1}, the hybrids differed significantly during spring & autumn seasons (Table 3). The hybrid MG-2 produced the maximum (1182.50, 641.37) number of achenes head^{-1} during both seasons respectively. The least number of achenes head^{-1} were observed from Parasio-24 (761.62, 452.12) which was statistically ($p< 0.05$) at par with hybrid Alisson-RM (801.75). Comparison of years showed non significant differences during spring while statistically significant differences were achieved during autumn (Table 3). The interaction of hybrids x years was statistically significant. The maximum (1326.50) number of achenes head^{-1} were produced by the hybrid MG-2 during spring 2007 and autumn 2008 (715.00) while Parasio-24 gave the minimum (742.25) number of achenes head^{-1} during spring 2007 and 387.50 number of achenes head^{-1} during autumn 2007.

3.2 Hundred Achenes Weight

The differences among hybrids for HAW showed statistically non significant differences during the both (spring and autumn) seasons. Comparison of years and interaction of hybrids x years were also statistically non significant (Table 4).

3.3 Biological Yield

Non significant differences among hybrids for biological yield was observed during spring season (Table 5). However, during autumn hybrids exhibited statistically significant differences. The hybrid MG-2 produced the highest (10162.25 kg ha^{-1}) biological yield which was statistically ($p<0.05$) significant from rest of the hybrids, whereas, the lowest (5842.75 kg ha^{-1}) biological yield was recorded from hybrid Parasio-24 during autumn. Comparison of years for biological yield exhibited statistically non significant differences during spring while statistically significant differences during autumn season (Table 5). The interaction of hybrids x years were statistically significant for both the seasons (spring and autumn). The maximum biological yield (14752.75 kg ha^{-1}) was obtained from MG-2 during spring 2007 and biological yield of 10604.50 kg ha^{-1} was recorded from same hybrid during autumn 2008 while Parasio-24 gave the minimum biological yield (10710.00 kg ha^{-1}) during spring 2007 and 5463.00 kg ha^{-1} during autumn 2007 was observed from same hybrid.

3.4 Achene yield

Similarly, statistical differences among hybrids for achene yield were recorded during spring & autumn (Table 6). The highest achene yield (4360.72, 1984.00 kg ha^{-1}) was obtained from the hybrid MG-2 during two seasons respectively. The lowest achene yield (3303.25, 1311.55 kg ha^{-1}) produced by Parasio-24 during both the seasons respectively. Comparison of the years showed statistically significant differences during both, spring and autumn seasons (Table 6). The interaction of hybrids x years were statistically significant for both the seasons (spring and autumn). The maximum achene yield (4725.25 kg ha^{-1}) was recorded from MG-2 during spring 2007 while achene yield of 2171.72 kg ha^{-1} was recorded from same hybrid during autumn 2008. The hybrid Parasio-24 gave the minimum achene yields of 2199.45 kg ha^{-1} and 1059.90 kg ha^{-1} during spring 2008 and autumn 2007 respectively.

3.5 Oil contents

In present study, statistical differences among hybrids for oil contents were recorded during the both spring and autumn seasons (Table 7). The maximum oil content (48.39, 46.46 %) was exhibited by hybrid MG-2 during spring and autumn, respectively. Comparison of the years showed statistically non significant differences during spring while significant differences were exhibited during autumn season (Table 7). Oil content recorded during autumn 2008 was 3.10 % higher as compared to those observed during autumn 2007. The interaction of hybrids x years was statistically significant for both the seasons (spring and autumn). The maximum (49.2, 47.2 %) oil content was recorded from the hybrid Parasio-24 during spring 2007 and from MG-2 during autumn 2007, respectively, while the minimum (39.18, 38.20 %) was recorded from Alisson-RM during spring 2008 and autumn 2007, respectively.

Table 1: Meteorological data of two years, Spring, Autumn 2007 and Spring, Autumn 2008

	SPRING 2007					SPRING 2008				
MONTH	Temperature (°C) Max (Mean)	Temperature (°C) Min. (Mean)	Rain fall (mm)	RH (%) (Mean)	Sun shine (Hours) (Mean)	Temperature (°C) Max. (Mean)	Temperature (°C) Min. (Mean)	Rain fall (mm)	RH (%) (Mean)	Sun shine (Hours) (Mean)
March	23.1	9.0	143.2	47.0	7.4	29.7	11.8	19.1	57.0	7.9
April	34.0	15.9	18.0	44.0	10.7	29.7	15.8	92.9	59.3	7.7
May	37.0	19.8	80.6	42.0	10.0	37.2	20.8	10.1	40.0	9.9
June	37.6	23.0	22.3	51.0	9.5	35.6	22.3	225.0	62.4	7.5
July	35.2	21.5	262.5	68.0	9.3	35.0	22.8	432.5	69.6	7.4
	AUTUMN 2007					**AUTUMN 2008**				
Aug	34.2	21.8	485.0	72.0	8.3	33.3	23.0	221.0	66.6	7.5
Sep	32.9	19.4	201.0	68.0	7.8	32.3	19.7	66.0	51.8	8.1
Oct	31.5	12.6	0.00	54.0	9.6	31.0	15.4	24.0	43.8	7.9
Nov	26.0	8.2	10.0	71.0	7.0	25.2	8.1	18.0	50.5	8.5
Dec	-	-	-	-	-	20.8	5.5	71.7	55.9	6.4

Table 2: GDD accumulated during spring and autumn seasons (Means of two years)

S#	**Growth Weeks**	**GDD accumulated (Spring Season)**		**GDD accumulated (Autumn Season)**	
		during the week	**Total GDD**	**during the week**	**Total GDD**
1	1	67.60	67.60	116.95	116.95
2	2	92.45	160.05	137.25	254.2
3	3	90.65	250.7	125.00	379.2
4	4	112.25	362.95	139.00	518.2
5	5	132.35	495.30	134.00	652.2
6	6	128.25	623.55	116.3	768.5
7	7	143.00	766.55	104.6	873.1
8	8	140.60	907.15	93.5	966.6
9	9	150.25	1057.4	106.15	1072.75
10	10	125.50	1182.9	101.22	1173.97
11	11	149.70	1332.6	88.15	1262.12
12	12	162.35	1494.95	77.65	1339.77
13	13	163.90	1658.85	47.86	1387.63
14	14	151.80	1810.65	-	-
15	15	142.11	1969.7	-	-
16	16	159.05	2128.75	-	-
Grand Total GDD			**2128.75**		**1387.63**

Table 3: Number of Achenes Head $^{-1}$ of sunflower hybrids during two seasons of 2007 and 2008

Hybrids	Spring			Autumn		
	2007	2008	Mean	2007	2008	Mean
Alisson-RM	756.50 c	847.00 c	**801.75 B**	442.50 c	647.50 a	**545.00 B**
Parasio-24	742.25 c	781.00 c	**761.62 B**	387.50 c	516.75 b	**452.12 C**
MG-2	1326.50 a	1039.00 b	**1182.50 A**	567.75 b	715.00 a	**641.37 A**
S- 278	1269.00 a	873.00 bc	**1071.00 A**	387.75 c	653.75 a	**520.75 BC**
Mean	**1023.56**	**884.81**		**446.37 B**	**633.25 A**	

*Any two means not sharing a letter in common differ significantly at 5% probability level

Table 4: Hundred Achene weight (HAW) (g) of sunflower hybrids during two seasons of 2007 and 2008

Hybrids	Spring			Autumn		
	2007	2008	Mean	2007	2008	Mean
Alisson-RM	5.39 NS	5.25	**5.32 NS**	4.60 NS	4.88	**4.74 NS**
Parasio-24	5.63	5.30	**5.47**	4.98	5.04	**5.01**
MG-2	5.42	5.24	**5.33**	4.96	5.08	**5.02**
S- 278	5.46	5.20	**5.33**	4.89	4.96	**4.92**
Mean	**5.47**	**5.24**		**4.85**	**4.99**	

*Any two means not sharing a letter in common differ significantly at 5% probability level

Table 5: Biological yield (kg ha^{-1}) of sunflower hybrids during two seasons of 2007 and 2008

Hybrids	Spring			Autumn		
	2007	2008	Mean	2007	2008	Mean
Alisson-RM	12720.50 ab	12885.00 ab	**12802.75**	6099.00 c	9185.00 b	**7642.00 B**
Parasio-24	10710.00 b	11505.00 ab	**11107.50**	5463.00 c	6222.00 c	**5842.75 C**
MG-2	14752.75 a	13980.00 ab	**14366.37**	9720.00 b	10604.50 a	**10162.25 A**
S- 278	14172.50 a	13012.50 ab	**13592.50**	6540.00 c	9275.00 b	**7907.50 B**
Mean	**13088.93**	**12845.62**		**6955.50 B**	**8821.75 A**	

*Any two means not sharing a letter in common differ significantly at 5% probability Level

Table 6: Achene yield of sunflower hybrids during two seasons of 2007 and 2008

Hybrids	Spring			Autumn		
	2007	2008	Mean	2007	2008	Mean
Alisson-RM	3419.05 cd	3487.10 cd	**3453.07 BC**	1260.00 de	1928.50 ab	**1594.25 AB**
Parasio-24	3207.00 d	3399.50 cd	**3303.25 C**	1059.9 e	1563.20 bcd	**1311.55 B**
MG-2	4725.25 a	3996.20 bc	**4360.72 A**	1796.10 abc	2171.72 a	**1984.00 A**
S- 278	4215.75 ab	3718.05 bcd	**3966.90 AB**	1387.80 cde	2050.72 a	**1719.26 AB**
Mean	**3891.76 A**	**3650.21 B**		**1375.98 B**	**1928.53 A**	

*Any two means not sharing a letter in common differ significantly at 5% probability Level

Table 7: Achene oil contents (%) of sunflower hybrids during two seasons of 2007 and 2008

Hybrids	Seasons					
	Spring			Autumn		
	Years			Years		
	2007	**2008**	**Mean**	**2007**	**2008**	**Mean**
Alisson-RM	44.25 ab	39.18 b	**41.71C**	38.20 f	41.70 de	**39.95 B**
Parasio-24	49.20 a	46.74 a	**47.97B**	44.52 bc	45.22 ab	**44.87 A**
MG-2	47.90 a	48.88 a	**48.39A**	47.22 a	45.70 ab	**46.46 A**
S- 278	47.07 a	46.94 a	**47.00B**	40.00 ef	42.60 cd	**41.30 B**
Mean	**47.10**	**45.43**		**42.48 B**	**43.80 A**	

*Any two means not sharing a letter in common differ significantly at 5% probability level

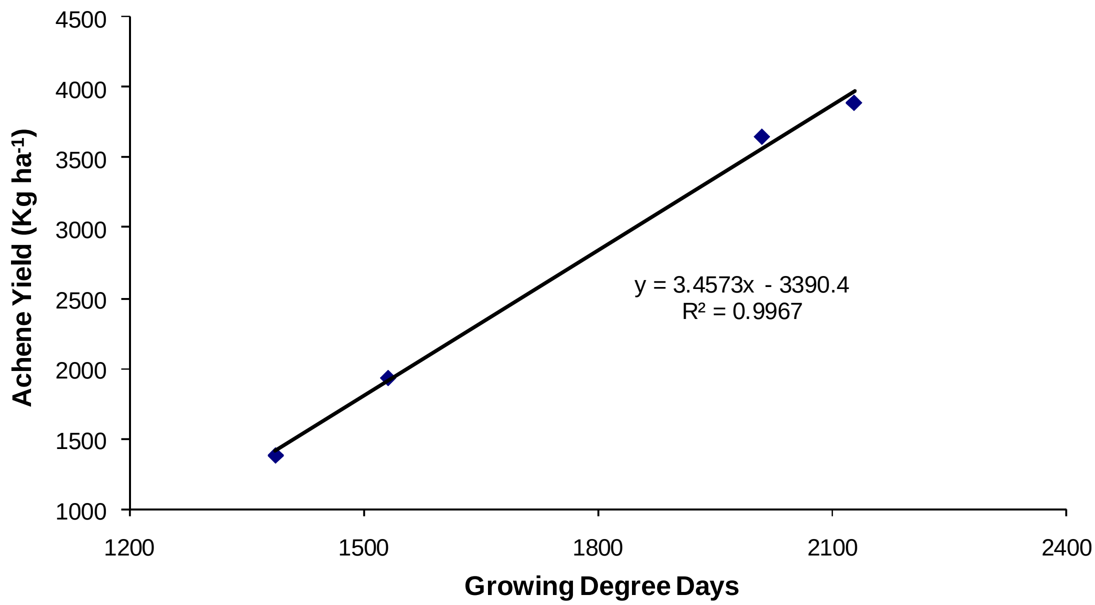

Fig. 1: Relationship between growing degree days and achene yield (Means of two years)

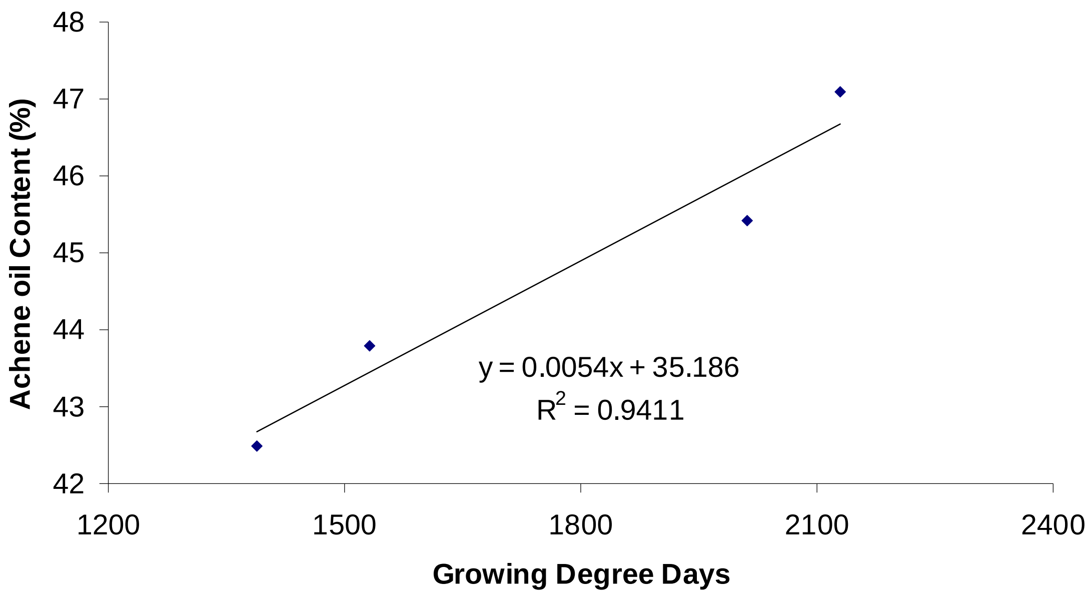

Fig. 6: Relationship between growing degree days and achene oil content (%) (Means of two years)

4. DISCUSSION

Sunflower productivity largely depends on the prevailing weather conditions throughout the life cycle of the crop. The primary factor governing crop growth rate is temperature (Baydar and Erbas, 2005). Temperature is a major environmental factor that determines the rate of plant growth and development (Qadir *et al.* 2007). Higher GDD accumulated for spring planting during both the years (Table 2) provided the clue that the best sowing time of a particular crop is spring planting to have good yield (Kaleem *et al.* 2010a). Environmental factors, especially temperature during the period of achene development and maturity, might have affected achene yield, yield attributes and oil content (Kaleem *et al.* 2010b). The accumulation of GDD determines the maturity of crop, yield and yield components. Sur and Sharma (1999) observed that the total GDD decreased from 1731 to 1621 with delay in planting, as the late sown crop experienced lower temperature during the seed filling period. In present study, 2128.75 GDD during spring and 1387.63 during autumn were accumulated during two seasons those may have caused the differences in out put of different parameters. Linear relationship between GDD and yield components have been reported by Lu *et al.* (2001), Agele (2003), Clarke and Siddique (2004) and Qadir *et al.* (2007).

Results presented in table 5 exhibited higher biological yield for hybrids during spring than that from autumn season. The differences among the hybrids for biological and achene yield may be due to genetic potential of the hybrids which showed its results under prevailing environmental conditions, accumulating more GDD during spring than during autumn induced higher yield out put in spring. Lower temperature at reproductive stage of the crop during autumn might have depressed assimilate utilization and greater restriction on biomass production and reduction in the duration of seed filling resulted reduced assimilate partitioned to seeds, thus lesser yield from autumn crop. The results of present study are in agreement with the findings of Villalbos *et al.* (1996) who concluded that sunflower biomass production was positively co-related with accumulated heat units. Baydar and Erbas (2005) also concluded that higher achene production is attributed to interaction of environmental factors, those partitioned photosynthates in achenes. These results are in conformity with those of Sumangala and Giriraj (2003) who concluded that favorable growing conditions during flowering and seed setting period characterized by optimum temperature and more sunshine hours for spring crop resulted in maximum achene yield. Kumar *et al.* (2008) also found that higher prevailing temperatures contribute the positive correlation with the seed yield regarding oil seed crop. Linear relationship (Fig. 1) between GDD and achene yield during both the seasons i.e. spring and autumn are in line with above findings.

Differences among hybrids for achene oil content in varying seasons may be attributed to their genetic potential as well as interactive effects of environmental variables during achene development and crop physiological maturity. More heat units accumulation along with long sunshine hours during spring, increased oil content than during autumn. Our results are in line with those of Demurin *et al.* (2000) who found an increase in achene oil content with increase in temperature during flowering to maturity in sunflower and reported that 1^{o}C increase in temperature increased achene oil content by 1% in sunflower. Similarly, Weiss, (2000) concluded that crops maturing at higher temperature would accumulate higher oil content. Qadir *et al.* (2006) concluded that temperature is a major environmental factor that determines the rate of development as well as oil accumulation in sunflower and recorded higher achene oil content from spring sunflower crop which matured at higher temperature, ultimately accumulating more heat units. Linear relationship (Fig. 2) between GDD and achene oil content during both the seasons i.e. spring and autumn is also supportive to the above findings.

5. CONCLUSION

It is concluded from present results that economically successful sunflower crop should be planted during spring. However, autumn crop can be sown in case of failure of any summer crop (July-August) as an alternate crop with half of recommended inputs.

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