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Full Length Research Paper

Effect of growing degree days on autumn planted sunflower

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Sunflower (*Helianthus annus* L.) having high degree of adaptability under wide range of climatic conditions, allow the crop to be productive in broad range of environments. Field experiments in autumn were laid out at Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan for two years (2007 and 2008), to document the effect of growing degree days (GDD) on the 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 autumn season. The data on growing degree days accumulation during autumn and their effect on achene, oil yield and yield components of sunflower like number of achenes per head, hundred achenes weight, biological and achene yield was recorded. All these agronomic characters as well as oil characteristics were influenced by prevailing temperature. GDD collected during autumn season was the same for both years of study. Amongst hybrids, the hybrid MG-2 showed the maximum values for all the agronomic as well as oil parameters during the autumn season. At the late planting of sunflower during autumn season, crop completes its life cycle in short duration and accumulates less heat units, thus, achene and oil yield along with yield attributes are affected accordingly.

Key words: Growing degree days (GDD), yield and yield components, sunflower.

INTRODUCTION

Environmental variables, especially temperature, are the key factor which affects plant growth, development and productivity (Kaleem et al., 2009). Differences of yield attributes in varying seasons might be due to the different climatic conditions that are based on temperature prevailing during the crop life cycle (Kll and Altunbay, 2005).

Most crop species are adapted to particular set of temperature, as temperature is a major environmental factor influencing their distribution (Atkinson and Porter, 1996). Combined effects of environmental factors not only modify plant phenology, but also cause many physiological and qualitative changes. Environmental variations affect crop growth, development, yield, oil and fatty acid accumulation through agronomic, physiological and qualitative functions of the crop plant (Kaleem et al., 2010a). A number of plant's developmental and physio-morphic adaptations to the environment, influences sunflower yields and oil quality (Hassan et al., 2005). Although, sunflower is a temperate zone crop, it can perform well under various climatic and soil conditions.

Crop display and yield characteristics are influenced by environmental disparity (Kaleem et al., 2010b). Sunflower crop sown during autumn season could accumulate lesser heat units and influenced the physio-morphic attributes of sunflower crop from germination to maturity (Qadir et al., 2007). Sunflower is a C_4 plant having higher physiological activity but is sensitive to cold temperatures, prevailed in autumn planting and called as warm season plant when compared with C_3 plants (Bruder et al.,

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Abbreviations: HAW, Hundred achene weight; **GDD,** growing degree days.

Table 1. Meteorological data of two years, autumn 2007 and 2008.

Month	Autumn 2007					Autumn 2008				
	Temperature (°C)		Rainfall (mm)	RH (%) (Mean)	Sunshine (Hour) (Mean)	Temperature (°C)		Rainfall (mm)	RH (%) (Mean)	Sunshine (Hour) (Mean)
	Maximum (Mean)	Minimum (Mean)				Maximum (Mean)	Minimum (Mean)			
August	34.2	21.8	485.0	72.0	8.3	33.3	23.0	221.0	66.6	7.5
September	32.9	19.4	201.0	68.0	7.8	32.3	19.7	66.0	51.8	8.1
October	31.5	12.6	0.00	54.0	9.6	31.0	15.4	24.0	43.8	7.9
November	26.0	8.2	10.0	71.0	7.0	25.2	8.1	18.0	50.5	8.5
December	-	-	-	-	-	20.8	5.5	71.7	55.9	6.4

2008), as according to Kaleem et al. (2009) quantitative parameters like stem diameter, plant height, biological yield and achene yield of all sunflower hybrids were 26.14 to 56.18% higher in spring when compared with autumn season.

The most common temperature index used to estimate plant development is growing degree days (GDD) (Qadir et al., 2006). GDD are used to classify plants for their flowering dates to estimate harvest maturity and to predict the duration between two developmental stages (Bonhomme, 2000). There is a linear relationship between GDD and rate of plant development (Lu et al., 2001). Seasonal variation alters morphological, physiological, quantitative and qualitative expressions of sunflower which are influenced by extreme growing conditions. All physio-morphic functions occurring in plant are markedly influenced by temperature as the primary factor governing the growth and development was temperature (Chan et al., 1998). As sunflower has wide range of adaptability, different sunflower hybrids require different total number of cumulative growing degree days for growth, development and maturity (Qadir et al., 2007). Total GDD decreased from 1731 to 1621 with delay in planting, as the late sown crop experienced lower temperature during the seed filling period (Sur and Sharma, 1999). The trend of physio-morphic and quality parameters may be related to the variable temperature during the crop growth period as it remained high at the start which gradually decreased as season proceeded, thus, influencing these attributes (Kaleem et al., 2010b).

All the physio-morphic attributes were significantly affected with delayed (autumn) sowing, because of lesser efficiency of components contributing in sunflower yield (Kaleem et al., 2009) as reproductive phase of sunflower crop is more sensitive to cold stress resulting in floral abortion, infertile pollens, poor seed set and empty seeds with reduced seed size that affects the production potential of sunflower crop (Clarke and Siddique, 2004).

Sunflower growth and productivity is affected in relation to prevailing growing environment and the crop will be influenced with the environmental variables like temperature, photoperiod, rainfall and relative humidity. This study was thus, planned to investigate the effect of growing degree days on the yield and yield components of sunflower crop sown during autumn season.

MATERIALS AND METHODS

Field experiments were conducted at Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan during 2007 and 2008 in autumn season. The soil was loamy in texture having sand 43%, silt 46% and clay 11%. Before sowing, available N, P, K status in the soil was 300, 5.00 and 140 mg kg^{-1}, respectively. Soil preparation was done by giving one soil inverting plough and then ploughed thrice with tractor mounted cultivator and planking was done 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. Autumn crop was sown on 18th August for each year. Four sunflower hybrid varieties (Alisson-RM, Parasio-24, MG-2 and S-278) were planted by using seed at 5 kgs ha^{-1}. Planting was done with the help of dibbler by putting two seeds at each spot. Plant to plant distance was maintained as 25 cm and row to row as 75 cm in net plot size of 5 × 3 m^2. Plant population was maintained after complete emergence and one plant was kept per hill. Through out crop life cycle, weeds were kept under control by hand weeding. The cumulative GDD from emergence till crop maturity were calculated from meteorological data recorded (Table 1) through out crop life cycle as given in the equation of Dwyer and Stewart (1986).

$$CHU = \Sigma^{t1}_{t2} [(T_{max}+T_{min})/2-8] \quad (1)$$

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

Where, Tmax+Tmin are daily maximum and minimum air temperatures in degree centigrade and t_1 and t_2 are the time intervals. For sunflower development, base temperature is 8°C (Sadras and Hali, 1988).

For recording number of achenes $head^{-1}$ data, ten heads were taken at random from each plot. The number of achenes was counted and the average was worked out. As regards HAW (hundred achenes weight), three samples of hundred achene were taken at random from the total seed lot of each plot, then weighed by using the digital electronic balance and average was worked out. After complete maturity, two central rows of plants with mature heads of 5 m length (as the plot length was 5m) were harvested from each plot for biological yield (on 14.11.2007 and 21.11.2008). Harvested plants were sun dried for 15 days (sun drying took much days as the prevailing temperature was low along with shorter photoperiod as depicted in Table 1 and weighed with the help of spring balance to obtain dry matter data per plot and then converted per hectare yield was computed. To record achene yield, plants already harvested from two central rows and then sundried were threshed manually. Achene yield per plot was recorded and then converted into kg ha^{-1}. Achene oil percentage was determined by using the method of NMR (Nuclear Magnetic Resonance system), Model MQA-7005, Oxford Institute, USA, as described by Granland and Zimmerman (1975). This equipment was standarderized with six different oil contents having the samples previously analyzed.

During the experiments, meteorological data was also recorded as described in Table 1. The collected data on various parameters were subjected to statistical analysis by applying MSTATC, separately for both the years (Freed and Eisensmith, 1986). ANOVA (analysis of variance) techniques were employed to test the significance of data and least significant difference test was used to compare the means (Montgomery, 2001).

RESULTS

Results reveal that hybrids under evaluation showed statistically significant differences for yield and yield components during the autumn season (except HAW) under the influence of varying growing degree days (GDD) accumulation. As regards data for number of achenes head^{-1}, the hybrids differed significantly in achene production (Table 3). As seen in Table 3, in overall mean, the hybrid MG-2 produced the maximum (641.37) number while Parasio-24 gave the least number of achenes head^{-1} (452.12) which was statistically ($p < 0.05$) similar with hybrid S-278 (520.75). Comparison of years exhibited statistically significant differences (Table 3). The interaction of hybrids × years was also statistically significant. The maximum (715.00) number of achenes head^{-1} was produced by the hybrid MG-2 during autumn 2008, while Parasio-24 gave the minimum (387.50) number of achenes head^{-1} during autumn 2007.

The differences among hybrids for HAW depicted statistically non significant differences (Table 4). Comparison of the years and the interaction of hybrids × years also showed statistically non significant differences for HAW.

Hybrids exhibited statistically significant differences regarding biological yield data presented in Table 5. The hybrid MG-2 produced the highest (10162.25 kg ha^{-1}) biological yield which was statistically ($p < 0.05$) significant from the rest of the hybrids, whereas, the lowest (5842.75 kg ha^{-1}) biological yield was recorded from hybrid Parasio-24. Comparison of years for biological yield depicted statistically significant differences (Table 5). The interaction of hybrids × years was also statistically significant. The maximum biological yield (10604.50 kg ha^{-1}) was obtained from MG-2 during autumn 2008, while Parasio-24 gave the minimum biological yield (5463.00 kg ha^{-1}) during autumn 2007.

Statistically significant differences among hybrids for achene yield were achieved (Table 6). The hybrid MG-2 gave the highest achene yield (1984.00 kg ha^{-1}), while minimum (1311.55 kg ha^{-1}) was recorded from Parasio-24 which was statistically ($p < 0.05$) similar with rest of the hybrids except MG-2. Comparison of the years and the interaction of hybrids × years were also statistically significant (Table 6). The maximum achene yield (2171.72 kg ha^{-1}) was obtained from MG-2 during autumn 2008, while Parasio-24 gave the minimum achene yield (1059.90 kg ha^{-1}) during autumn 2007

Statistical differences among hybrids for achene oil contents were recorded in this study (Table 7). The highest achene oil content (46.46%) was obtained from the hybrid MG-2. Comparison of the years showed statistically significant differences. Achene oil content produced during 2008 was 3.10% higher when compared with achene oil content observed during 2007 in autumn. The interaction of hybrids × years was also statistically significant. The maximum (47.2 %) achene oil content was recorded from the hybrid MG-2 during autumn 2007, while the minimum (38.20 %) achene oil content was recorded from Alisson-RM during autumn 2007.

DISCUSSION

The accumulation of GDD determines the maturity of crop, yield and yield components. The primary factor governing the crop growth rate is temperature (Kaleem et al., 2009). Sunflower yield and yield attributes largely depend on the prevailing weather conditions throughout the life cycle of the crop (Baydar and Erbas, 2005). Different weather parameters (Table 1) influence growth and developmental expressions of crop differently (Kumar et al., 2008).

Environmental factors, especially temperature during the period of achene development and maturation, affected achene, oil yield and yield characteristics (Kaleem et al., 2010a). Temperature is a major environmental factor that determines the rate of plant growth and development (Qadir et al., 2007). To have good yield and yield attributes, the accumulation of GDD plays a vital role, however, lower GDD (Table 2) are accumulated for autumn planting (Kaleem et al., 2010b). Total GDD decreased from 1731 to 1621 with delay in planting, as the late sown crop experienced lower temperature during the seed filling period (Sur and Sharma, 1999).

Different sunflower hybrids require different total number of cumulative degree-days or growing degree days for growth, development and maturity. In this study, it is evident from the results presented in Table 3 that different sunflower hybrids during autumn had different

Table 2. GDD accumulated throughout the crop life period (Means of two years).

S/N	Growth week	GDD accumulated (autumn season)	
		During the week	Total GDD
1	1	116.95	116.95
2	2	137.25	254.2
3	3	125.00	379.2
4	4	139.00	518.2
5	5	134.00	652.2
6	6	116.3	768.5
7	7	104.6	873.1
8	8	93.5	966.6
9	9	106.15	1072.75
10	10	101.22	1173.97
11	11	88.15	1262.12
12	12	77.65	1339.77
13	13	47.86	1387.63
Grand total GDD			1387.63

Table 3. Number of Achenes Head^{-1} of sunflower hybrids during autumn 2007 and 2008.

Hybrid	Autumn		
	2007	2008	Mean
Alisson-RM	442.50^{c}	647.50^{a}	545.00^{B}
Parasio-24	387.50^{c}	516.75^{b}	452.12^{C}
MG-2	567.75^{b}	715.00^{a}	641.37^{A}
S- 278	387.75^{c}	653.75^{a}	520.75^{BC}
Mean	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 autumn 2007 and 2008.

Hybrid	Autumn		
	2007	2008	Mean
Alisson-RM	4.60^{NS}	4.88	4.74^{NS}
Parasio-24	4.98	5.04	5.01
MG-2	4.96	5.08	5.02
S- 278	4.89	4.96	4.92
Mean	4.85	4.99	

number of achenes head^{-1} (comparatively lower count) which is in accordance with the findings of Nazir et al. (1986) those found gradual decrease in number of achenes head^{-1} during autumn due to lesser GDD accumulation. Clarke and Siddique (2004) concluded that reproductive phase of crop was sensitive to cold condition in autumn planting.

Results presented in Table 4 show lower HAW which are in conformity with the findings of Agele (2003) who concluded that due to poor environment-driven resource capture and less GDD, lesser HAW was recorded during autumn season.

Dry matter accumulation, presented in Table 5 expresses the total dry matter accumulated during crop life cycle, affected by varying GDD accumulated at regular intervals in autumn season. Results (Table 5) reveal that the differences among the hybrids for biological yield might be due to genetic potential of the hybrids under prevailing weather conditions, accumulating different GDD during crop life cycle. Further, lower temperature at

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

Hybrid	Autumn		
	2007	2008	Mean
Alisson-RM	6099.00^{c}	9185.00^{b}	7642.00^{B}
Parasio-24	5463.00^{c}	6222.00^{c}	5842.75^{C}
MG-2	9720.00^{b}	10604.50^{a}	10162.25^{A}
S- 278	6540.00^{c}	9275.00^{b}	7907.50^{B}
Mean	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 autumn 2007 and 2008.

Hybrid	Autumn		
	2007	2008	Mean
Alisson-RM	1260.00^{de}	1928.50^{ab}	1594.25^{AB}
Parasio-24	1059.9^{e}	1563.20^{bcd}	1311.55^{B}
MG-2	1796.10^{abc}	2171.72^{a}	1984.00^{A}
S- 278	1387.80^{cde}	2050.72^{a}	1719.26^{AB}
Mean	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 autumn 2007 and 2008.

Hybrid	Autumn		
	2007	2008	Mean
Alisson-RM	38.20^{f}	41.70^{de}	39.95^{B}
Parasio-24	44.52^{bc}	45.22^{ab}	44.87^{A}
MG-2	47.22^{a}	45.70^{ab}	46.46^{A}
S- 278	40.00^{ef}	42.60^{cd}	41.30^{B}
Mean	42.48^{B}	43.80^{A}	

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

reproductive stage of the crop during autumn (Table 1) might have depressed assimilate utilization and greater restriction on biomass production in sunflower. The results of this study are in accordance with the findings of Villalbos et al. (1996) who reported that sunflower biomass production was positively co-related with accumulated heat units as lesser biomass is produced at cold temperature (Paul et al., 1990).

The results of this study depicted that sunflower hybrids in autumn season produced the different achene yield**.** As all the hybrids remained relatively for shorter duration in the field, so produced lesser achene yield due to minimum translocation of photosynthesis captured at lower PAR and GDD accumulation during autumn. Baydar and Erbas (2005) also concluded that higher achene production is attributed to interaction of environmental factors, those partitioned photosynthesis in achenes. Lower achene yield during autumn may be attributed to reduction in the duration of seed filling in which assimilate partitioned to seeds was reduced. Low temperature, lesser radiation with reduced light accumulation by the crop and low sunshine hours with higher rains may have caused lesser achene productivity in autumn season (Table 1). 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 than lower in autumn planting. Kumar et al. (2008) also found that higher prevailing temperatures contribute the positive correlation with the seed yield regarding oil seed crop.

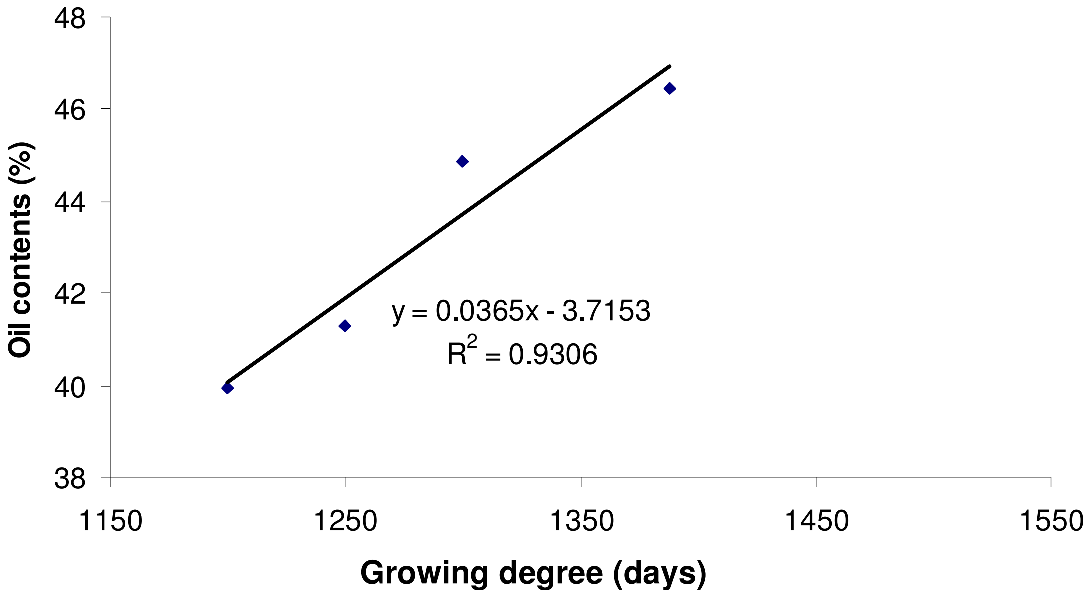

Figure 1. Relationship between growing degree days and achene oil content (%) (means of two years).

Differences among hybrids for achene oil content may be attributed to their genetic potential as well as interactive effects of environmental variables during achene development and crop physiological maturity (Kaleem et al., 2010a). Lesser GDD accumulation along with short sunshine hours decreased oil percentage during autumn. Our results are in line with those of Demurin et al. (2000) who found decrease in achene oil content with decrease in temperature during flowering to maturity in sunflower and reported that 1°C decrease in temperature decreased achene oil content by 1% in sunflower and vice versa. Similarly, Weiss, (2000) concluded that crops maturing at lower temperature would accumulate lower oil content. Temperature is a major environmental factor that determines the rate of development as well as oil accumulation in sunflower and lower achene oil content is recorded from autumn sunflower crop which matured at lower temperature, ultimately accumulating less heat units (Qadir et al., 2006). Linear relationship (Figure 1) between GDD and achene oil content during autumn is also supportive to the above findings.

Conclusion

To have good output in terms of yield and yield characteristics, GDD accumulation plays a vital role. Differences among various sunflower attributes might be due to the different climatic conditions that are based on temperature prevailing during the crop life cycle. It is therefore, concluded on the basis of mentioned results that late planting of sunflower during autumn season would result in reduction in achene and oil yield along with yield attributes as the crop completes its life cycle in short duration, accumulating less heat units.

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