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Growing Degree Days and Yield Relationship in Sunflower (*Helianthus annuus* L.)

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ABSTRACT

A field study was conducted to document the relationship between growing degree days, yield and yield components of sunflower hybrids. Five sunflower hybrids (Super-25, Parsun-1, SMH-9706, Award and Hysun-33) were sown on ten planting dates both during autumn and spring in a randomized complete block design with split plot arrangements replicated four times. Sunflower hybrids exhibited significant differences for yield, yield components and growing degree days. During autumn, amongst hybrids Hysun-33 accumulated the maximum growing degree days and remained at the top for achene yield and all yield components. During autumn, the crop planted on 11th July accumulated maximum growing degree days and produced the higher achene yield, larger head diameter, more number of achene per head. During spring, Hysun-33 again remained at the top for yield and yield components except that of head diameter for which hybrid Award over ruled rest of the hybrids. During spring season the crop planted on 16th of February accumulated the maximum growing degree days and produced the highest yield and yield related components. Overall, spring plantation accumulated more growing degree days in comparison with autumn planting, due to which the spring plantation exhibited higher achene yield and all the yield components

Key Words: Growing degree days; Relationship; Head diameter; Yield

INTRODUCTION

Temperature is a major environmental factor that determines the rate of plant growth and development. Genotypes behave differently under different environmental conditions. Sunflower is a temperate zone crop but it can perform well under various climatic and soil conditions. It can withstand early frost in autumn that usually kills maize and soybean. Khalifa *et al*. (2000) concluded that wide geographic, morphological and habitat wise diversity of sunflower, extending from very hot areas in the south west of US to very cold areas in eastern Canada, might have developed the unique characteristics of sunflower tolerance to both low and high temperatures and accounted for wide adaptation of the crop.

Having wide adaptability, different sunflower hybrids require different total number of cumulative degree-days or growing degree days for growth, development and maturity. All physiological and morphological developments occurring in plant are markedly influenced by temperature. Different planting dates might cause different environmental conditions from emergence to grain filling. The most common temperature index used to estimate plant development is growing degree days (GDD), or heat unit (HU). The accumulation of GDD determines the maturity of crop, yield and yield components. Sur and Sharma (1999) reported 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, Beard and Geng (1982) concluded that lower yields associated with late planting in sunflower have been due to warmer temperature during the early growth period, which promotes excessive early stem growth. According to Robinson (1971) a wide range of sunflower cultivars are available, each with specific GDD requirements, ranging from 1140 to 1400 growing degree days using a 7°C base temperature.

Under favorable climatic conditions two crops (spring and autumn) of sunflower can be harvested. The spring sunflower is sown under low temperature of January and February and grows vegetatively under a range of low to medium temperature of February and March, before entering into reproductive stage. The reproductive stage develops under high temperature of May while it matures and is harvested under high temperature of June/July. Contrary to spring, autumn crop is sown at high temperature and high humidity of July - August. Its germination and early vegetative growth undergoes high to medium temperature of August and September before entering into reproductive stage. The reproductive phase of autumn crop takes off at medium temperature of October. It matures and is harvested under low temperatures of November. So, the two opposite sets of environmental conditions prevail from germination to maturity of sunflower when grown during spring and autumn.

Temperature variations in the field can be created by planting crops at different dates in the season, thus crop will grow at different temperature, sunshine and relative humidity. The present study was contemplated to investigate

relationship of growing degree days with yield and yield components in different sunflower hybrids. Difference in temperature for growth, development and maturity was created by planting sunflower hybrids at different dates during both the seasons i.e. spring and autumn thus giving a wide range of temperature from sowing till maturity.

MATERIALS AND METHODS

Field experiments were conducted in autumn, 2003 and spring, 2004 at the University of Arid Agriculture, Rawalpindi, Pakistan. The experimental area lies at 33°38'N and 73°04'E, particular fields were summer and winter fallow, respectively. Seed beds were prepared by giving 2-3 ploughing and planking with last ploughing. Five sunflower hybrids (Super 25, Parsun-1, SMH 9706, Award and Hysun 33), five planting dates in autumn (11th, 23rd July, 6th, 16th and 26th August), five planting dates in spring (16th February, 3rd, 15th March, 9th and 27th April) were arranged in a randomized complete block design in split plot arrangements with four replications. The planting dates were in main plots and genotypes in subplots. Uniform dose of fertilizer @ 80 kg N and 50 kg P_2O_5 per hectare was applied in the form of DAP and Urea, incorporated in the soil during seedbed preparation. The row-to-row distance was maintained at 75 cm and plant-to-plant distance at 25 cm in net plot size of 5 m x 3 m. The seeds were sown with the help of dibbler putting two seeds per hill. After emergence one plant per hill was maintained. Weeds were kept under control by hand weeding throughout crop life cycle. The cumulative growing degree days from emergence till maturity were calculated from weather data recorded (Table I) through out crop life cycle by the equation of Dwyer and Stewart (1986).

$$CHU = \sum_{t_2}^{t_1} \left[\left(T_{\max} + T_{\min} \right) \Big/ 2 - 8 \right]$$

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

T_{max} and 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). At maturity central two rows were harvested on 15th, 21st , 29th of October, 4th, 15th of November for autumn and 10th, 15th, 25th of June, 20th, 25th of July for spring crops respectively. Harvested plants were placed with wall for complete drying which also helped transfer of photosynthates to the sink. Head diameter was measured with the help of vernier caliper at the time of maturity. Heads were thrashed manually and grains cleaned with small blower. The numbers of seeds were counted with the help of seed counter. The seed weight was determined with a electronic balance. The seed yield per plot was recorded which was converted into kg ha^{-1}. The data thus recorded during study were subjected to Fisher's analysis of variance technique. Treatment means were compared for significance using Duncan's Multiple Range Test at 5% level of probability (Steel & Torrie, 1980).

RESULTS

Hybrids under evaluation exhibited significant differences for growing degree days (GDD) accumulation during both the seasons. During autumn, Hysun-33 accumulated the maximum (1598) GDD while Super-25 had the minimum (1469). Similarly, planting dates had statistically significant differences for GDD accumulation, the 11th July planting had accumulated the maximum (1626) those progressively decreased to minimum (1380) with late planting (Table II). During spring, again Hysun-33 accumulated the maximum (1900) GDD. Planting dates also affected the growing degree days accumulation significantly with maximum (1948) from early planted crop and least from late planted (1575) (Table II). Overall during spring plantation accumulated more GDD than that of autumn planted.

Significant differences were observed among sunflower hybrids for head diameter during autumn. The hybrid Hysun-33 was at the top with head diameter (16.0cm) and significantly differed from all other hybrids. The smallest (13.8 cm) head diameter was recorded in case of hybrid SMH-9706 that was statistically at par with Parsun-1 (14.4 cm). The influence of planting date on head diameter was statistically significant. The largest head diameter (15.6 cm) was produced in case of the crop planted on 11th of July but it was statistically at par with all of the other planting dates except the crop planted on 26th of August that had the least value (12.9 cm) (Table II). The head diameter differences among the hybrids under evaluation during spring season were statistically significant. The hybrid Award produced the maximum (15.1cm) head diameter that was statistically different from all other hybrids. The minimum (13.6 cm) head diameter was produced by the hybrid SMH-9706 that was statistically at par with Parsun-1 (13.9 cm). The crop planted on 16th of February produced the maximum (15.9 cm) head diameter that was statistically at par with the crop planted on 3rd of March (15.6 cm) but statistically different with all the other plantings. The minimum (10.1 cm) head diameter was observed for the crop planted on 26th of April that was statistically different from the other plantings (Table III). The hybrids differed significantly for number of achenes per head during autumn (Table II). The hybrid Hysun-33 produced the maximum (579.0) number of achenes per head that was statistically at par with the hybrid Award (564.6) but significantly different from other hybrids. The least number of achenes per head were recorded in case of the hybrid Super-25 (442.7) that was statistically at par with hybrid Parsun-1 (464.0) and the hybrid SMH-9706 (501.8). Planting dates had significant differences for the number of achenes per head. The crop planted on 11th of July produced the highest (677.8) number of achenes per head that was

Table I. Mean minimum and maximum temperature ^{o}C and rainfall recorded during autumn 2003 and spring 2004

Month /year	Temperature (ºC)			Rainfall
	Max.	Min.	Mean	(mm)
July / 03	34.6	23.5	29.05	312.2
August / 03	33.3	23.6	28.45	267.4
September / 03	32.1	21.8	26.95	258.1
October / 03	30.6	13.4	22.0	2.9
November / 03	24.5	7.3	15.9	17.3
December / 03	19.6	4.8	12.2	45.0
February / 04	22.3	6.2	14.25	37.00
March / 04	30.5	11.9	21.2	Trace
April / 04	32.8	17.3	25.05	92.3
May / 04	36.9	19.4	28.15	12.00
June /04	36.4	22.7	29.55	124.3
July /04	35.2	23.4	29.3	161.9

Table II. GDD, yield and yield components of sunflower hybrids during autumn

Hybrids	GDD	HD (cm)	AH^{-1}	HSW (g)	yield (kg ha^{-1})
Super-25	1469.0e	14.9 bc	442.7 b	5.3 a	1597.0 bc
Parsun-1	1514.0d	14.4 cd	464.0 b	4.3 c	1390.0 d
SMH-9706	1561.0c	13.8 d	501.8 b	4.8 b	1514.0 cd
Award	1578.0b	15.3 b	564.6 a	5.5 a	1689.0 ab
Hysun-33	1598.0a	16.0 a	579.0 a	5.5 a	1760.0 a
SE	4.38	0.22	19.97	0.14	45.50
Sowing dates					
11th July	1626.0a	15.6 a	677.8 a	4.9 a	1999.0 a
23rd July	1610.0b	15.4 a	602.1 b	5.0 a	1806.0 b
6th Aug	1605.0b	15.2 a	499.9 c	5.1 a	1737.0 b
16th Aug	1498.0c	15.2 a	434.5 d	5.2 a	1460.0 c
26th Aug	1380.0	12.9 b	337.8 e	5.3 a	947.40 d
SE	4.38	0.22	19.97	0.14	45.50

Table III. GDD, yield and yield components of sunflower hybrids during spring

Hybrids	GDD	H.D (cm)	AH^{-1}	HSW(g)	yield (kg ha^{-1})
Super-25	1656.0c	14.06 b	602.10 c	8.03 bc	2024.0
Parsun-1	1800.0b	13.94 c	672.00 b	7.60 c	2172.0 b
SMH-9706	1782.0b	13.64 c	709.80 b	7.55 c	1985.0 b
Award	1890.0a	15.10 a	659.10 bc	8.29 ab	2150.0 b
Hysun-33	1900.0a	14.18 b	781.00 a	8.61 a	2832.0 a
SE	11.24	0.29	22.79	0.17	106.36
Sowing dates					
16th Feb	1948.0a	15.96 a	839.50 a	8.34 a	2796.0 a
3rd March	1910.0b	15.68 a	761.60 b	8.20 a	2519.0 ab
15th March	1849.0c	14.70 b	761.00 b	8.15 a	2462.0 b
9th April	1746.0d	14.43 b	717.10 b	7.99 a	2234.0 b
27th April	1575.0e	10.14 c	344.90 c	7.41 b	1047.0 b
SE	11.24	0.29		22.79	0.17

Abbreviations: GDD (growing degree days), HD (head diameter), A/H.(achene per head), HSW (hundred seed weight).

*Any two means not sharing a letter in the column are significantly different at 5% probability level.

significantly different from other planting dates. The minimum (337.8) number of achenes per head was produced by the crop planted on 26th of August (Table II). The data showed that the difference between the hybrids under evaluation during the spring season was statistically significant. The hybrid Hysun-33 produced the maximum (781.0) number of achenes per head that was statistically different from all other hybrids. The minimum number of achenes per head (602.1) was produced by the hybrid Super-25 that was statistically at par with Award (659.1) (Table III).

The crop planted on 16th of February produced the maximum (839.5) number of achenes per head that was significantly different from other plantings. It was followed by the 3rd March planting date (761.6) that was statistically at par with 15th March (761.0) and 9th April (717.1) plantings. The minimum (344.9) number of achenes per head was observed for the crop that was planted on 27th of April and it was statistically different from all the other plantings (Table III). The data presented in Table II showed that the differences for 100 seed weight of the hybrids under evaluation were statistically different. Among the hybrids, Award (5.57 g) had the maximum 100 seed weight that was statistically at par with the hybrids Hysun-33 (5.52 g) and Super-25 (5.35 g) but they differed significantly from all the other hybrids. The hybrid Parsun-1 produced the minimum (4.39) 100-achene weight. The planting dates exhibited non-significant effects on 100 seed weight (Table II). While the differences for 100 seed weight for the hybrids under evaluation during spring 2004 were statistically significant (Table III). Among the hybrids, Hysun-33 (8.61 g) had the maximum 100 seed weight that was statistically at par with the hybrid Award (8.29 g) but significantly different from the other hybrids. The hybrid SMH-9706 produced the minimum (7.55 g) 100 seed weight. Furthermore, planting dates also exhibited significant differences for 100 seed weight (Table III). The maximum (8.34 g) 100 seed weight was produced by the crop planted on 16th of February that was statistically at par with all the other planting dates except 27th April planting which produced the minimum (7.41 g) value of the 100 achene weight.

During autumn season, the hybrids under evaluation differed significantly from each other for achene yield (Fig. 1). The highest yield (1760.0 kg ha^{-1}) was obtained from the hybrid Hysun-33 that was statistically at par with the hybrid Award (1689.0 kg ha^{-1}). The minimum (1390.0 kg ha^{-1}) achene yield was produced by the hybrid Parsun-1. The achene yield was also affected significantly by the planting date. The highest achene yield (1999.0 kg ha^{-1}) was observed in the crop planted on 11th of July that was significantly different from all the other planting dates. It was followed by the crop planted on 23rd of July (1806.0 kg ha^{-1}) that was at par with the crop planted on 6th of August (1737.0 kg ha^{-1}). The lowest achene yield (947.4 kg ha^{-1}) was recorded in case of the crop planted on 26th of August.

The hybrids under evaluation differed significantly for achene yield during spring 2004 (Fig. 2). The highest achene yield (2832.0 kg ha^{-1}) was obtained from the hybrid Hysun-33 that was statistically different from all the other hybrids that were at par with each other. The effect of planting date on the achene yield was also found significant. The highest achene yield (2796.0 kg ha^{-1}) was observed from the crop planted on 16th of February was at par with

the crop planted on 3rd of March but different from all the other planting dates. The lowest achene yield (1047 kg ha^{-1}) was recorded by the crop planted on 27th of April.

DISCUSSION

Environmental factors, especially temperature, are the key factor which influences plant growth and development. Significant differences among different hybrids for GDD depicted that different hybrids have varying maturity periods. However, higher GDD accumulated for early planting during both the seasons provided the clue that the best sowing time of a particular crop is early planting to have good output. Environmental factors, especially temperature during the period of seed development and maturation, might have affected yield and yield attributes. Killi and Altunbay (2005) reported that head diameter was significantly affected by date of planting. In present study, the maximum head diameter was observed from crop, which was planted earlier during both of the season, which progressively decreased to the minimum when the temperature decreased or increased. The head diameter decreased gradually by delaying the planting. Ahmad and Quresh (2000) reported the similar results and concluded that head diameter decreased significantly with delay in planting from first January to first April. The results of present study showed that when the temperature decreased or increased towards the maturity of the crop the number of achene per head decreased. The number of achenes per head decreased gradually due to the delay in planting date. Differences among different planting dates might be due to the different climatic conditions that are based on temperature prevailing during the crop life cycle. The results of present study are in line with Killi and Altunbay (2005) who observed that number of achenes per head reduced significantly as planting was delayed.

The present study showed that different sunflower hybrids produced the different 100 achene weight, the result also showed that the hybrids which remained for longer duration in the field produced the more achene weight as compared to the hybrids which remained for shorter period of time. Andrade (1995) reported that seed weight decreased due to the change in planting dates. The differences in 100 seed weight might be due to the environmental conditions, which prevailed during crop life cycle. Killi and Altanbay (2005) observed that 1000 seed weight was significantly affected by the planting dates. The crops planted during the early part of the year Feb-April passed through lower temperature during early phases and completed their life cycle taking longer period, due to which it had higher 100 seed weight and the crops planted during the later part of the year, July-August, had higher temperature during the early phases and completed their life cycle rapidly therefore had lower 100 seed weight. Allam *et al.* (2003) also found significant differences for 1000 achene weight planted on different planting times and concluded that late planting of

Fig.1. Relationship between growing degree days and achene yield during autumn

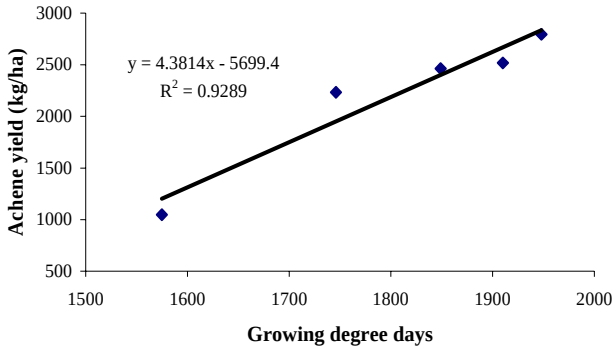
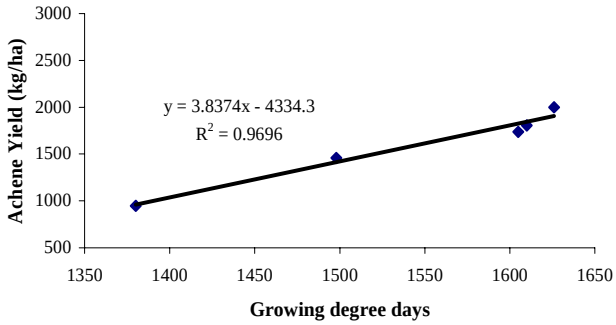


Fig. 2. Relationship between growing degree days and achene yield during spring



sunflower during autumn season would result in reduction of all the yield attributes.

The achene yield is the function of combined effect of all the yield components under the influence of a particular set of environmental conditions. The achene yield decreased gradually with the delay in planting date. The achene yield variation may be attributed to the interactive effects of the environmental variables. Thus result of present study are in line with Killi and Altunbay (2005) who found significant differences in achene yield for different date of plantings. The delay in the planting gradually decreased the yield. Singh *et al*. (1999) also concluded that seed yield and yield component values were generally the highest with February sowing followed by January. These results are in conformity with the findings of Sur and Sharma (1999) who stated that during autumn season yields were reduced by delay in planting as the late planted crop experienced lower temperature during seed filling period. Linear relationship (Fig. 1 & 2) between GDD and yield during both the seasons i.e. autumn and spring are in line with above findings.

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