Pak. J. Bot., 38(4): 1137-1147, 2006.

OIL AND FATTY ACID ACCUMULATION IN SUNFLOWER AS INFLUENCED BY TEMPERATURE VARIATION

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Abstract

Field experiments were conducted at the University of Arid Agriculture, Rawalpinid during autumn, 2003 and spring, 2004 to document the oil and fatty acid composition of sunflower hybrids in response to temperature variations. Five sunflower hybrids (Super-25, Parsun-1, SMH-9706, Award and Hysun-33) were sown on ten planting dates both in autumn and spring. Experiment design was randomized complete block with split plot arrangements replicated four times. Planting dates were kept in main plots and hybrids in subplots. Sunflower hybrids exhibited significant differences for oil and fatty acid composition. In autumn, amongst hybrids Hysun-33 performed better for oil and oleic acid while Award remained at the top for palmatic and linoleic acid. However, in spring, Super-25 accumulated the highest oil and linoleic acid while Hysun-33 was the best for stearic and oleic acid. Planting dates also influenced oil and fatty acid composition significantly. Overall, spring plantation accumulated higher oil and oleic acid in comparison with autumn planting. However, autumn planting accumulated less oil but higher linoleic acid which depicted an inverse relationship of oleic and linoleic acid. In autumn, late August planting accumulated the maximum linoleic and the minimum oleic acid. In spring, late April planting exhibited the highest oleic and least linoleic acid.

Introduction

Various environmental variables affect plant growth and development differently. It has been concluded that temperature regulates plant growth and development processes. The rate of plant development is mainly temperature driven (Ritche & Ne Smith, 1991). Temperature is major environmental factor that determine the rate of plant development as well as oil accumulation in sunflower. 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 heat units for growth, development and maturity. All physiological and morphological developments occurring in plant are markedly influenced by temperature. Different sowing times might cause different environmental conditions during grain filling and oil synthesis. In particular, the fatty acid composition is known to differ with cultivars and environmental conditions (Connor & Sadras, 1992). The most common temperature index used to estimate plant development is growing degree days (GDD), or heat unit (HU). The accumulation of these heat units determines the maturity of crop as well as performance and quality of produce. Ahmad & Hassan (2000) found higher oil contents in sunflower hybrids matured and harvested at higher temperature of June as compared to those matured and harvested in April. Similarly, Skoric (1992) indicated that oil concentration in the seed depends upon the daily mean temperature in addition to the availability of water during seed filling period. Oleic acid content is essentially influenced by temperature during seed development. Each 1°C increase in temperature leads to about 2% increase in oleic acid. A strong negative correlation exists between oleic and linoleic acid. A low oleic phenotype would essentially be high linoleic one (Demurin *et al*., 2000).

Temperature variations in the field can be created by sowing 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 temperature effects on oil and fatty acid accumulation in different sunflower hybrids. Difference in temperature for growth, development and maturity was created by sowing sunflower hybrids at different dates in 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. The experimental area lies at 33°38'N and 73°04'E. 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 heat units for different growth stages were calculated by the equation of Dwyer & Stewart (1986).

$$CHU = \sum_{t_2}^{t1} [(Tmax + Tmin)/2 - 8]$$

$$\text{Where } [(Tmax+Tmin)/2-8]>0$$

Tmax and Tmin 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 sun dried for seven days. Heads were thrashed manually and grains cleaned with small blower. Seed oil contents were determined by following the NMR (Nuclear Magnetic Resonance apparatus) Model MQA- 7005, Oxford Instruments USA (Granlund & Zimmerman, 1975), while fatty acids (stearic, palmatic, oleic and linoleic acids) composition were determined by gas liquid chromatograph (GLC). 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 percent level of probability (Steel & Torrie, 1980).

Table 1. Mean minimum and maximum temperature and rainfall recorded during autumn 2003 and spring 2004.

Month /year	Temperature (ºC)			Rainfall (mm)
	Max.	Min.	Mean	
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 2a. Oil content of sunflower hybrids as influenced by different planting dates in autumn 2003.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
11th July	48.29 fgh*	51.91 cd	51.26 cde	45.18 jk	54.21 ab	50.17 A
23rd July	49.26 efg	42.61 l	50.19 def	42.61 l	55.29 a	47.99 B
6th August	48.72 fgh	45.88 ijk	52.88 bc	45.58 jk	42.29 l	47.07 C
16th August	46.95 hij	42.49 l	44.62 k	51.07cde	48.81 fgh	46.79 CD
26th August	49.83 ef	49.74 ef	44.69 k	38.84 m	47.64 ghi	46.15 D
Mean	48.61 B	46.53 C	48.73 B	44.66 D	49.65 A	

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

Results

Significant differences were observed among sunflower hybrids for oil content. The highest oil content (49.7%) was recorded in Hysun-33 in autumn followed by the SMH-9706 (48.7%) which was statistically at par with Super-25 (48.6%). The lowest oil content (44.7%) was recorded in Award. Significant differences among the planting dates were also observed for oil content in autumn. Crop planted on 11th of July accumulated the highest oil (50.2%) among the planting dates. The least oil (46.1%) was gained by the crop planted on 26th of August, which was similar to the crop planted on 16th of August. Interaction between the planting times and sunflower hybrids was also significant (Table 2a). Hybrids differed significantly for oil content planted in spring. The highest oil content (55.9%) was recorded in Super-25 followed by the Award (54.9%). The lowest oil content (49.9%) was recorded in SMH-9706. Planting dates in spring also affected oil content. Crop planted on 9th of April accumulated the highest oil content (54.5%), which was statistically at par with those planted on 15th of March (54.1%) and 27th of April (54.0%). The least oil (51.7%) was gained by the crop planted on 3rd of March (51.7%), which was statistically at par with the crop planted on 16th of February (52.2%). Interaction between the planting date and sunflower hybrids was also significant (Table 2b).

Table 2b. Oil content of sunflower hybrids as influenced by different planting dates in spring 2004.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
16th February	54.88 cd*	53.34 def	49.30 hi	52.21 efg	51.44 fgh	52.23 B
3rd March	58.23 ab	54.14 cde	45.12 k	51.27 fgh	49.85 gh	51.72 B
15th March	52.78 def	58.26 ab	46.45 jk	54.93 cd	58.22 ab	54.13 A
9th April	59.35 a	47.55 ij	56.11 bc	58.21 ab	51.33 fgh	54.51 A
27th April	54.21 cde	52.24 efg	52.49 def	57.63 ab	53.51 def	54.02 A
Mean	55.89 A	53.11 C	49.89 D	54.89 B	52.87 C	

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

Table 3a. Palmatic acid (%) of sunflower hybrids as influenced by different planting dates in autumn 2003.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
11th July	5.59 cd*	7.24 a-d	5.63 cd	6.68 a-d	6.02 bcd	6.23 B
23rd July	5.63 cd	7.05 a-d	6.43 a-d	7.79 ab	5.30 d	6.44 B
6th August	7.99 ab	8.08 ab	6.84 a-d	8.37 a	6.63 a-d	7.58 A
16th August	8.38 a	7.50 abc	7.01 a-d	7.54 abc	6.37 a-d	7.36 A
26th August	6.45 a-d	7.26 a-d	6.47 a-d	7.07 a-d	7.78 ab	7.00 AB
Mean	6.81 AB	7.43 A	6.48 B	7.49 A	6.42 B	

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

Table 3b. Palmatic acid (%) of sunflower hybrids as influenced by different planting dates in spring 2004.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
16th February	7.66 ab*	6.21 abc	7.56 ab	6.07 abc	7.76 a	7.05 A
3rd March	6.95 abc	6.15 abc	7.11 abc	5.95 abc	6.19 abc	6.47 AB
15th March	6.05 abc	6.34 abc	7.70 ab	6.45 abc	5.43 c	6.39 AB
9th April	7.12 abc	6.63 abc	6.08 abc	6.05 abc	6.57 abc	6.49 AB
27th April	6.56 abc	5.89 abc	7.04 abc	5.14 c	5.64 bc	6.05 B
Mean	6.87 AB	6.24 BC	7.10 A	5.93 C	6.32 ABC	

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

Hybrids exhibited significant differences for palmatic acid in autumn.The highest (7.49 %) of palmatic acid was recorded in Award, which was statistically at par with the Parsun-1 (7.43%) and Super-25 (6.81%). The lowest (6.42%) palmatic acid was recorded in Hysun-33, which was statistically at par with SMH-9706 (6.5%). Significant differences were observed among planting dates for palmatic acid in autumn. Crop planted on 6th of August gained the highest palmatic acid (7.58%) which was statistically at par with the crop planted on 16th (7.36%) and 26th of August (7.00 %) but different from rest of planting dates. The least palmatic acid (6.23%) was gained by the crop planted on 11th of July, which was statistically at par with the crop planted on 23rd of July (Table 3a). In spring, hybrids exhibited significant differences for palmatic acid. The highest palmatic acid (7.10%) was recorded in SMH-9706 which was statistically at par with Super-25 (6.87%) and Hysun-33 (6.32%), while Award accumulated the lowest (5.93%). In spring, significant differences among the planting dates were also observed for palmatic acid. Crop planted on 16th of February gave the highest palmatic acid (7.05%) which was statistically at par with other planting dates except that of 27th April, which exhibited the least value (6.05%). Interaction between the planting date and sunflower hybrids was also significant (Table 3b).

Table 4a. Stearic acid (%) of sunflower hybrids as influenced by different planting dates in autumn 2003.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
11th July	3.84 a-d*	4.10 a-d	3.72 a-d	2.96 d	3.54 a-d	3.63 C
23rd July	3.46 bcd	4.14 a-d	3.19 cd	4.24 a-d	3.97 a-d	3.80 BC
6th August	4.29 a-d	4.53 a-d	5.00 abc	3.15 cd	5.38 a	4.47 AB
16th August	3.16 cd	3.93 a-d	4.90 abc	3.22 cd	4.42 a-d	3.92 BC
26th August	4.45 a-d	3.85 a-d	5.44 a	5.18 ab	5.38 a	4.86 A
Mean	3.84 AB	4.11 AB	4.45 AB	3.75 B	4.54 A	

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

Table 4b. Stearic acid (%) of sunflower hybrids as influenced by different planting dates in spring 2004

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	.Mean
16th February	2.58 abc*	3.33 abc	2.76 abc	3.13 abc	3.25 abc	3.01 A
3rd March	2.54 abc	2.71 abc	2.88 abc	2.81 abc	2.49 abc	2.68 A
15th March	2.64 abc	2.53 abc	3.21 abc	2.41 bc	2.64 abc	2.68 A
9th April	2.34 c	2.35 c	2.71 abc	2.67 abc	3.50 abc	2.71 A
27th April	2.36 c	3.77 a	2.39 bc	3.29 abc	3.66 ab	3.09 A
Mean	2.49 B	2.94 AB	2.79 AB	2.86 AB	3.11 A	

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

Hybrids differed significantly for stearic acid planted in autumn (Table 4a). The highest stearic acid (4.54%) was found in Hysun-33, which was statistically at par with rest of the hybrids except Award (3.75%). In autumn, planting dates exhibited significant differences for stearic acid (Table 4a). The highest stearic acid (4.86%) was recorded in the crop planted on 26th of August, which was statistically at par with the crop planted on 6th of August (4.47%). The lowest (3.63%) stearic acid was recorded in the crop planted on 11th of July, which was statistically at par with the crops planted on 23rd of July (3.80 %) and 16th of August (3.92%) (Table 4a). In spring, hybrids exhibited significant differences for stearic acid. The highest stearic acid (3.11%) was accumulated by Hysun-33, while super-25 had the lowest (2.49 %). However, in spring planting dates exhibited non-significant differences for stearic acid (Table 4b).

Hybrids differed significantly from each other for oleic acid in autumn. Hybrid Hysun-33 accumulated significantly higher oleic acid (24.7%) than other hybrids except Super-25 (24.5%) while Award gave the lowest (16.9%) oleic acid. In autumn, planting dates significantly affected oleic acid. The crop planted on 11th of July exhibited the highest (35.5%) oleic acid. The lowest (12.8%) oleic acid was observed from the crop planted on 26th of August (Table 5a). Hybirds differed significantly from each other for oleic acid accumulation of crop planted in spring. The sunflower hybrid Hysun-33 accumulated significantly higher (59.4%) oleic acid, while hybrid Super-25 gave the lowest (46.4 %) oleic acid. Planting dates in spring significantly affected oleic acid. The crop planted on 27th of April gave the highest (60.1%) oleic acid, which was significantly different from all other planting dates. The lowest (42.1%) oleic acid concentration was observed in the crop planted on 16th of February (Table 5b).

Table 5a. Oleic acid (%) of sunflower hybrids as influenced by different planting dates in autumn 2003.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
11th July	40.44 a*	35.77 b	38.79 a	22.58 d	40.18 a	35.55 A
23rd July	34.51 b	30.57 c	29.04 c	23.17 d	39.45 a	31.35 B
6th August	21.05 de	13.71 g	14.60 g	13.74g	17.88 f	16.20 C
16th August	13.62 g	19.35 ef	13.69 g	12.80 g	13.62 g	14.62 D
26th August	13.06 g	12.12 g	14.32 g	12.48 g	12.34 g	12.87 E
Mean	24.54 A	22.31 B	22.09 B	16.95 C	24.69 A	

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

Table 5b. Oleic acid (%) of sunflower hybrids as influenced by different planting dates in spring 2004.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
16th February	28.80 o*	42.51 m	43.43 m	49.58 ij	46.32 kl	42.13 E
3rd March	43.21 m	44.91 lm	39.37 n	61.03 bc	57.67 de	49.24 D
15th March	55.36 efg	48.92 jk	51.95 hi	54.22 fgh	61.22 bc	54.33 C
9th April	47.93 jk	55.83 efg	56.91 def	57.81 de	61.41 bc	55.98 B
27th April	56.77 def	58.80 cd	53.11 gh	61 .78 b	70.14 a	60.12 A
Mean	46.41 E	50.19 C	48.95 D	56.88 B	59.35 A	

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

Sunflower hybrids accumulated significantly different linoleic acid in autumn. The highest (70.1%) linoleic acid was recorded in Award, which was significantly different from rest of the hybrids. The lowest (60.5%) value of linoleic acid was recorded in Parsun-1, which was statistically at par with the Super-25 (61.7%). Planting dates exhibited significant differences for linoleic acid in autumn (Table 6a). The highest linoleic acid (73.1%) was recorded from crop planted on 26th of August and the minimum linoleic acid (51.2 %) from crop planted on 11th of July. Sunflower hybrids significantly differed from each other for linoleic acid in spring. The hybrid Super-25 contained significantly higher linoleic acid (41.8%) than rest of the hybrids, while hybrid Hysun-33 gave the lowest (30.3%) linoleic acid. In spring, planting dates significantly affected linoleic acid. All the planting dates differed significantly from each other. The crop planted on 16th of February produced the highest (45.9%) linoleic acid. The lowest (28.4%) linoleic acid concentration was observed in the crop planted on 27th of April. The interaction between the planting date and sunflower hybrids was also significant (Table 6b).

Discussion

Environmental factors, especially temperature during the period of seed development and maturation, might have affected oil content in maturing cultivated sunflower seed. The effect of temperature on oil content however has been variable. Higher oil content at high temperature has been reported by Ahmad & Hassan (2000). In the present study, the maximum oil content was observed from crop which matured at high temperature which progressively decreased to the minimum from the crop maturing at low temperature. Results of the present study are in conformity with Ahmad *et al*., (2001a) and Vega *et al*., (2002) who concluded that the planting date and maturity at high temperature were the major source of variation for oil yield. The hybrids which have the higher percentage during autumn have a lesser value during spring planting. Differences among hybrids may be the combined effect of temperature and genetic make up of the particular hybrid. Solangi *et al*., (1999) found significantly different achene oil content in two sunflower hybrids.

Table 6a. Linoleic acid (%) of sunflower hybrids as influenced by different planting dates in autumn 2003.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
11th July	47.45 ef*	43.21 g	48.53 ef	66.28 b	50.60 de	51.21 D
23rd July	55.11 c	45.97 fg	53.11 cd	64.73 b	48.69 ef	53.52 C
6th August	67.15 b	73.13 a	72.37 a	73.18 a	65.45 b	70.26 B
16th August	64.83 b	65.64 b	72.04 a	73.34 a	73.56 a	69.88 B
26th August	73.87 a	74.45 a	72.06 a	72.82 a	72.54 a	73.15 A
Mean	61.68 CD	60.48 D	63.62 B	70.07 A	62.17 C	

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

Table 6b. Linoleic acid (%) of sunflower hybrids as influenced by different planting dates in spring 2004.

Hybrid/ planting date	Super-25	Parsun-1	SMH-9706	Award	Hysun-33	Mean
16th February	58.39 a*	44.57 c	46.19 c	39.63 d	41.12 d	45.98 A
3rd March	45.06 c	39.84 d	49.41 b	28.12 ij	32.71 fg	39.03 B
15th March	34.07 ef	40.81 d	35.47 ef	35.72 e	30.53 ghi	35.32 C
9th April	40.63 d	33.12 efg	32.89 efg	30.50 ghi	27.80 ij	32.99 D
27th April	30.93 gh	28.85 hij	35.51 ef	27.13 j	19.44 k	28.37 E
Mean	41.82 A	37.44 C	39.89 B	32.22 D	30.32 E	

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

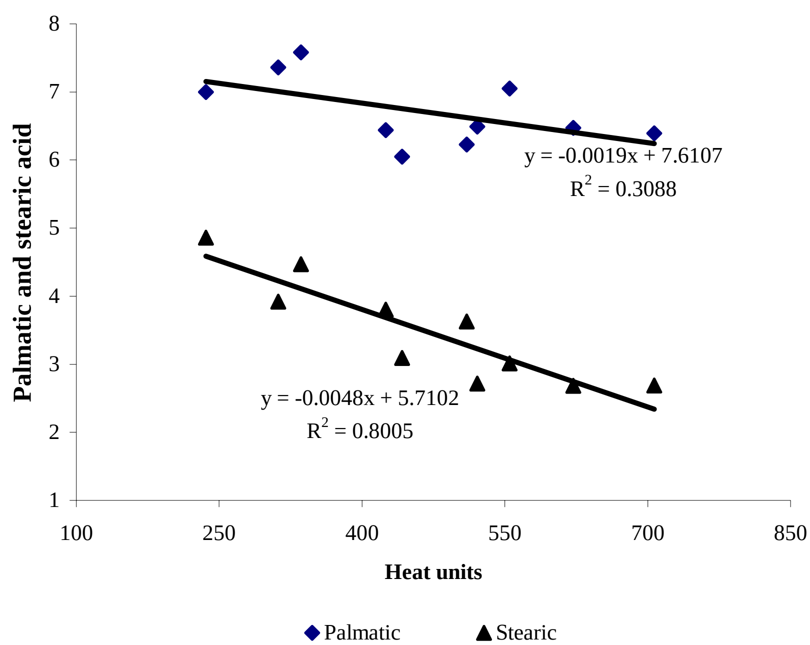

Fig 1. Relationship between heat units, palmatic and stearic acid.

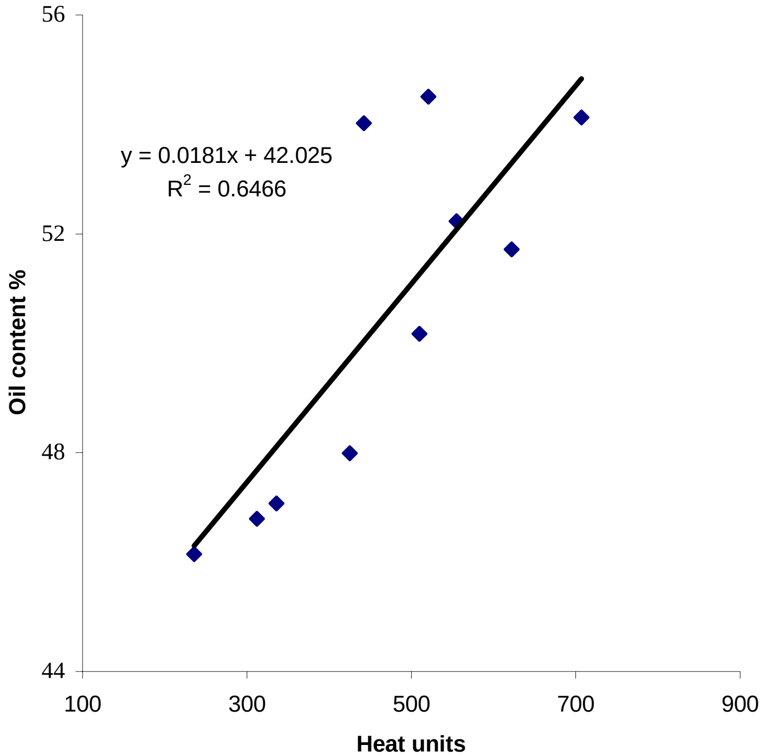

Fig. 2. Relationship between heat units and oil content.

Sunflower oil consists of different types of saturated and unsaturated fatty acids (palmitic acid, stearic acid, oleic acid, linoleic acid etc.). The palmatic acid and stearic acid are the major saturated fatty acids whereas oleic and linoliec acids unsaturated. The quality of sunflower oil is generally associated with the relative concentration of oleic and linoleic acid. A probable reason for low and high palmatic acid concentration in oil of different sunflower hybrids may be the effect of temperature during the physiological maturity stage. The results showed that when the temperature increased towards the maturity of the crop the palmatic acid decreased. Inverse relationship of heat unit and palmatic acid (Fig. 1) is in line with finding of Ahmad *et al*., (2001a) who found significant variations among sunflower hybrid for palmatic acid**.** Stearic acid content in oil varied from 2.7% to 3.1%. These little differences for stearic acid among the hybrids showed the genetic homogeneity for particular character which is little influenced by hybrids, as reported by Ahmad & Hassan (2000). However, Khalil *et al*., (2000) observed significant differences for stearic acid. Higher stearic acid percentage might be due to lower temperature during its growing season. Ahmad & Hassan (2000) also depicted that lower temperature and lesser growing degree days favor the higher stearic acid accumulation. Significant relationship (Fig. 1) between heat units and steric acid are supportive to above findings**.**

Fatty acid composition of sunflower in particular and other oil seed crops in general, are influenced by temperature, mainly regulating the ratio of oleic and linoleic acid (Garaces *et al.*, 1989). The results showed that overall oleic acid was more during the spring planting as compared to the autumn plantings, this is in conformity with Ahmad & Hassan (2000) who reported that oleic acid increased with increasing maturity temperature. The probable reason for the increase and decrease of oleic and linoleic acid of different sunflower hybrids may be the effect of temperature and moisture during the growing season (Figs. 3 & 4). Such variations among hybrids have also been observed by Ahmad *et al.*, (1999). The differences for oleic and linoleic acid among planting dates might be due to the differences in environmental conditions prevailing during the crop growing season. The findings of the present study are similar to the conclusion of Flagella *et al*., (2002) who reported that sunflower maturation under different environmental conditions would accumulate different concentration of oleic acid. Similarly, variations in linoleic acid content have also been observed by Ahmad *et al*., (2001b) in autumn planted sunflower hybrids. However, Roberston (1981) reported that linoleic acid content varied inversely with the oleic acid content. Significant but opposite response of oleic acid and linoleic acid to heat unit (Figs. 3 & 4) is supportive to earlier findings.

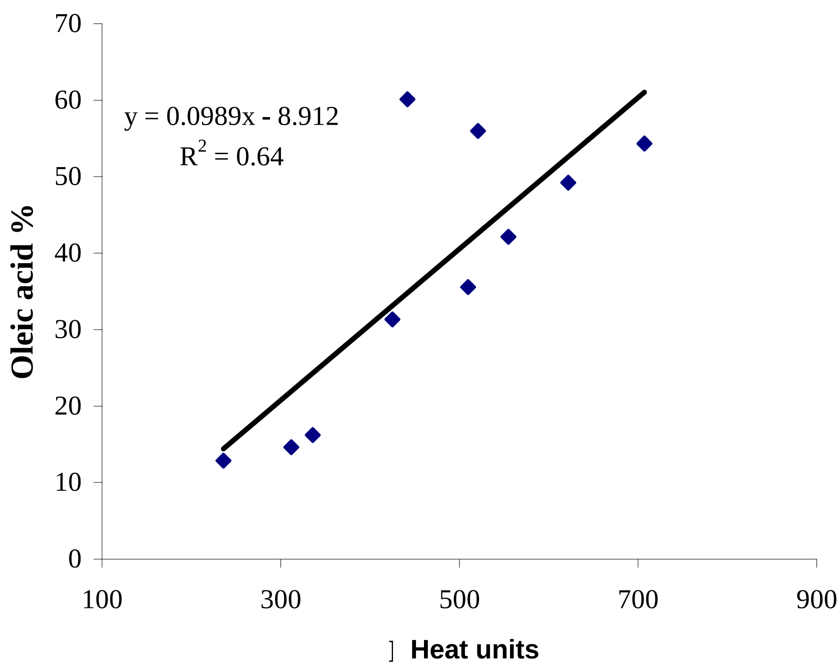

Fig. 3. Relationship between heat units and oleic acid.

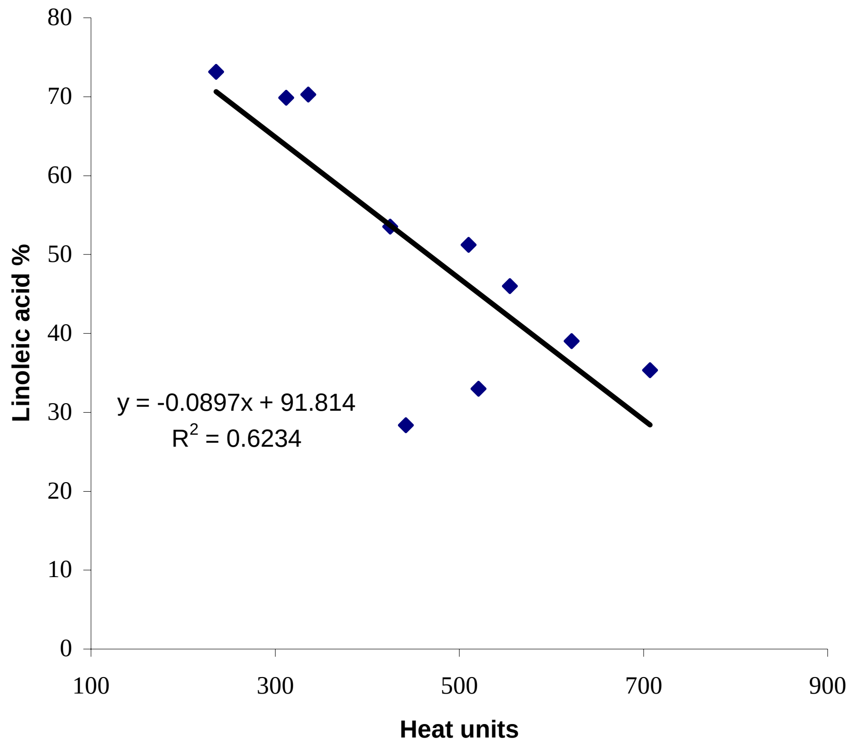

Fig.4. Relationship between heat units and Linoleic acid .

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(Received for publication 24 March 2006)