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Determinants of Oil and Fatty Acid Accumulation in Peanut

FAYYAZ-UL-HASSAN[1] ABDUL MANAF AND M. EJAZ†
Department of Agronomy, University of Arid Agriculture, Rawalpindi–Pakistan
†*Barani Agriculture Research Institute, Chakwal–Pakistan*
[1]Corresponding author's e mail: drsahi@hotmail.com

ABSTRACT

The fluctuations in temperature and moisture availability affect the quantity and quality of seed oil. Fatty acid composition is a major determinant of oil quality. Seven peanut cultivars were tested at three locations i.e. Rawalpindi, Chakwal and Attock to determine the environmental effects on oil accumulation and fatty acid composition. Experiments were laid out in r andomized complete block design having four replications. Cultivars exhibited significant differences for oil, palmatic, oleic and linoleic acid. Locations showed non significant differences for oil but significant ones for fatty acids. Interactive effects of cultivars and locations for all the parameters were found to be significant. Significant variations for all the parameters among cultivars, locations and their interaction are attributable to temperature, moisture availability (rainfall distribution and intensity) and total sunshine hours particularly from flowering to maturity. It is concluded that these factors are the major determinants of oil and fatty acid accumulation in Peanut.

Key Words: *Arachis hypogea;* Fatty acid; Location; Temperature; Moisture; Sunshine.

INTRODUCTION

In general two apparently distinct types of peanut (*Arachis hypogea*) are grown commercially. One is upright with an erect central stem and vertical branches, the other recumbent with numerous creeping laterals. In Pakistan, out of the total area under peanut, 77% lies in Pothwar tract which contributes 92% in the total production of the country (Government of Pakistan, 2004). The environmental condition where it is grown (Pothwar tract) varies considerably in the pattern, precipitation and temperature. Rainfall in the northern parts of the region ranges between 1100 to 1500 mm while in the southern parts only receives 250-350 mm of rain annually. Its pattern in the Western and the Eastern areas (Jhelum and Attock) also ranges in 450-750 mm. Temperature fluctuates widely particularly during rainy days.

Peanut is considered to be little affected by day length being basically a day neutral plant. Bunch types are generally more severely affected by climatic variation within their normal range. Temperature in soil zone where pods develop, the geocarposphere, has the greatest effect on yield. The higher temperatures affect the reproductive growth adversely by increasing flower abortion and decreasing seed size (Talwar *et al.*, 1999). Fritchi *et al.* (1999) concluded that increasing temperature restricts forage production in peanut under limited moisture availability. The fluctuation of temperature and moisture availability affects the quantity and quality of oil accumulation in the seed. Moisture availability and amount at proper time is essential for good vegetative growth, since there is direct relationship between number of branches, flowers and subsequent pod formation. Moist soil also facilitates peg formation and penetration (Weiss, 2000). It is well documented that favorable moisture availability and high temperature increases the oil content while low temperature affects the fatty acid composition of the oil in other crops (Praveena *et al.*, 2000; Ahmad & Hassan, 2000).

Environmental factors such as temperature, moisture and humidity are considered to be important in the development of grain and fruits in almost all fruit and grain crops. Similarly, these environmental factors can affect both content and composition of oil in developing oilseeds. Fatty acid composition is a major determinant of oil quality. Oils high in unsaturates are desirable for both improved shelf life and potential health benefits. An overall ratio of 2:1 of unsaturated and saturated fatty acid is considered the best for human diet (Weiss, 2000).

A reasonable research work on the breeding and production technology of the Peanut has been done in the country. However, quantity and quality of accumulated oil in seeds has been scarcely studied. After the introduction of WTO regime it will not be possible to market any product without proper knowledge of quality parameters. The present study was undertaken to assess the impact of varying environments and earmark peanut cultivars for stability in the production of seed oil both in quantity and quality.

MATERIALS AND METHODS

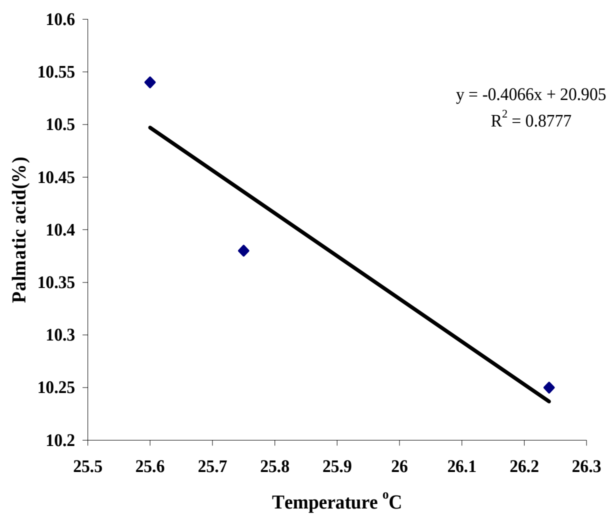
Field experiments were planned to investigate the impact of environment on oil content and fatty acid composition of various peanut cultivars. Trails were executed at three locations having different rainfall patterns and soil types. The experiments were conducted at the University of Arid Agriculture, Rawalpindi (UAAR), Groundnut Research Station (GRS), Attock and Barani Agricultural Research Institute (BARI), Chakwal. The land selected for conducting experiments was fallow during winter season. After winter rains fields were plowed with ordinary cultivator. Final seedbed preparation was done by giving one furrow turning plow followed by three ordinary plowings along with planking. The seeds were sown on March 27-31 and April 14, 2003, respectively at three locations. Seven cultivars viz. No. 334, Banki, Chakori, BARI-2000, BARD -479, SP-96 and SP-2000 were sown according to randomized complete block design with three replications in a plot size of 5.5 x 2.7 m. In each plot there were six rows; 45 cm apart each row. Recommended dose of fertilizer 20:80:40 NPK were incorporated at time of last plowing. Sowing was done by h and drill at 70 kg ha^{-1} seed rate. Weeds were controlled when required. At maturity samples of one kg kernel from each treatment were collected from two central rows on 14 and 26 November, and December 16, from UAAR, GRS and BARI experiments, respectively. Unshelled samples were sun dried for one week and shelled by hand. The shelled nuts were again sun dried for two days. Dried samples were analysed for oil determination with Nuclear Magnetic Resonance, Spectrometer (Warnsely, 1988), while the fatty acids in oil were analyzed by gas Chromatography (AIML - NUCON) after interesterification with methanolic KOH (Paquot, 1988). Data recorded were analyzed statistically using st andard analysis of variance techniques. Treatment means were compared with Duncan's New Multiple Range Test (Duncan, 1955), Weather data (temperature and rainfall) of all three sites were obtained from the meteorological office, Islamabad (Table I).

Table I. Monthly average temperature (^oC) and total rainfall (mm) at experimental sites

	Rawalpindi		Chakwal		Attock	
Months	**Temp.**	**Rainfall**	**Temp.**	**Rainfall**	**Temp.**	**Rainfall**
Mar.	18.9	43	22.2	8.3	22.5	36
Apr.	25.1	11.1	24.1	13	24.6	5
May	30.2	2.9	30.75	Nil	30.6	20.0
Jun	31.0	109.6	31.2	114	33.4	114
Jul.	31.7	108	31.0	62	33.9	6
Aug.	28.5	368	30.5	263	30.2	513
Sep.	24.4	170	25.8	128.5	26.6	117
Oct.	22.5	42.3	23.4	17.1	23.5	15
Nov.	19.6	Nil	18.9	Nil	16.9	Trace
Dec.	16.7	Nil	17.8	Nil	11.6	62

Source: Meteorological Office, Islamabad

Fig. 1. Relationship between average temperature from flowering to maturity and Palmatic acid



RESULTS

Oil content in different Peanut cultivars exhibited significant differences. The maximum oil content (53.06%) was found in SP-96 while cv. No. 334 accumulated the minimum oil content (49.83%) (Table II). Locations did not affect the oil content significantly. However, crop at Attock produced the maximum oil content (51.75%) followed by Rawalpindi (51.72%) and Chakwal (51.52%). Interaction of cultivars and locations were found to be statistically significant (Table II). The maximum oil content (53.88%) was observed in SP-96 sown at Rawalpindi which was significantly different from other combinations. The minimum oil content (49.81%) was recorded in BARD -479 sown at Chakwal which was at par with No. 334 at Chakwal, No. 334 and Banki at Attock. Significant differences among the cultivars were observed for palmatic acid. The highest percentage of palmatic acid (10.79%) was found in Chakori compared with rest of the cultivars followed by those of Banki, No. 334 and SP-96 which were statistically at par with each other. Similarly, BARD -479 was significantly higher than those of SP-2000 and BARI-2000. The lowest percentage of palmatic acid (9.95%) was observed in BARI-2000 among the lot (Table II). Locations exhibited significant differences with respect to fatty acids. The highest percentage of palmatic acid (10.54%) was recorded at Rawalpindi followed by Chakwal and Attock, although Chakwal and Attock showed insignificant difference (Table II). Interactive effects of cultivars x locations on palmatic acid was not evident (Table II). The highest percentage of palmatic acid (11.27%) was found in cultivar BARD-479 sown at Rawalpindi followed by No. 334 sown at Attock and BARD-479 at Chakwal. These cultivars showed palmatic acid almost those of Chakori, SP-96 and No. 334 sown at Chakwal, BARD-479 at Attock and SP-96 sown at Rawalpindi. The lowest percentage of palmatic acid (9.53%) was exhibited by No. 334 at Rawalpindi which was statistically at par with those of SP-2000 sown at Chakwal, Chakori, Banki BARI-2000 and SP-96 sown at Attock and those of Chakori, Banki and SP-2000

Table II. Oil content and fatty acid composition of peanut cultivars grown in pothwar

Cultivars	Oil (%)	Palmatic acid (%)	Oleic acid (%)	Linoleic acid (%)
SP-96	53.06 a	10.79 a	54.83 a	34.23 a
SP-2000	52.44 b	10.62 ab	54.78 a	32.75 b
BARI-2000	52.17 bc	10.55 abc	53.37 b	32.34 bc
BARD-479	51.80 c	10.42 bcd	52.19 c	31.31 cd
Chakori	51.25 d	10.22 cde	51.73 c	30.23 d
Banki	51.11 d	10.17 de	51.28 c	29.08 e
No. 334	49.83 e	9.95 e	49.34 d	28.99 e
SE	0.174	0.118	0.339	0.396
Locations				
Attock	51.75 NS	10.54 a	54.35 a	32.85 a
Rawalpindi	51.72	10.38 ab	51.99 b	31.81 b
Chakwal	51.51	10.25 b	51.17 c	29.17 c
SE	**0.302**	**0.205**	**0.588**	**0.686**
Interaction (cv.xlocations)				
Chakori x Chk	1.52 efg	10.97 abc	51.94 bc	31.69 de
No. 334 x Chk	50.52 hi	11.05 ab	50.46 cde	31.74 de
Banki x Chk	51.72 def	10.35 cdef	57.70 a	27.27 f
BARD-479 x Chk	49.81 i	11.12 a	51.03 cde	31.83 de
BARI-2000 x Chk	51.83 cde	10.44 bcde	52.17 bc	31.61 de
SP-2000 x Chk	47.87 j	10.10 defg	51.99 bc	33.58 bcd
SP-96 x Chk	51.91 cde	10.69 abcd	51.31 bcde	34.21 bc
Chakori x Atk	50.88 fgh	9.99 efg	57.72 a	24.68 g
No. 334 x Atk	50.54 hi	11.19 a	47.55 gh	35.05 b
Banki x Atk	50.69 ghi	9.65 g	51.18 bcde	32.22 cde
BARD-479 x Atk	52.38 bcde	10.92 abc	52.96 b	31.08 e
BARI-2000 x Atk	52.33 bcde	10.10 defg	49.70 ef	34.96 b
SP-2000 x Atk	51.60 efg	10.32 cdef	50.48 cde	32.76 cde
SP-96 x Atk	52.13 bcde	9.64 g	57.46 a	26.80 f
Chakori x Rwp	52.78 bc	9.90 efg	56.54 a	27.42 f
No. 334 x Rwp	52.41 bcde	9.53 g	58.06 a	26.42 fg
Banki x Rwp	51.92 cde	9.70 fg	57.97 a	26.81 f
BARD-479 x Rwp	52.98 b	11.27 a	48.31 fg	34.01 bc
BARI-2000 x Rwp	52.67 bcd	10.40 cde	49.94 def	33.57 bcd
SP-2000 x Rwp	52.65 bcd	10.00 efg	51.72 bcd	31.43 de
SP-96 x Rwp	53.88 a	10.85 abc	46.36 h	37.68 a
SE	0.075	0.045	0.291	0.269

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

sown at Rawalpindi. Rest of the cultivars exhibited varying degree of differences among one another sown at different locations.

The highest value (54.83%) of oleic acid was recorded in BARI-2000 which was statistically at par with SP-2000 but significantly different from rest of the cultivars. The lowest percentage of oleic acid (49.34%) was recorded in SP-96. The cultivars Banki, No. 334 and BARD-479 were statistically at par with one another (Table II). Oleic acid accumulation was also affected significantly by locations. The highest oleic acid (54.35%) was recorded at Attock followed by Chakwal, while Rawalpindi displayed the lowest value (Table II). Location x cultivar interaction showed significant differences for oleic acid. The highest oleic acid percentage (58.06%) was recorded in No. 334 sown at Rawalpindi, which was statistically at par with Chokari and SP-96 sown at Attock, Banki sown at Chakwal, Chakori and Banki sown at Rawalpindi (Table II). The lowest oleic acid percentage (46.36%) was observed in SP-96 at Rawalpindi which was statistically at par with No. 334 when sown at Attock but significantly lower than rest of the combinations.

The accumulation of linolic acid in different cultivars exhibited significant variations (Table II). The highest percentage of linoleic acid (34.23%) was recorded in SP-96 which was significantly different from rest of the cultivars. The cv. BARD -479 accumulated 32.75% of linoleic acid closely followed by No. 334 and Banki which were superior to rest of the cultivars. The lowest linoleic acid (28.99%) was recorded in BARI-2000 which was again statistically at par with SP-2000. Effects of locations on linoleic acid were also found to be significant. The produce of Rawalpindi gave the highest linoleic acid (32.85%) followed by Chakwal and Attock with the least (29.17%). All of the locations were significantly different from each other (Table II). Interactive effects of cultivars x locations on linoleic acid were found significantly different (Table II). The highest linoleic acid (37.68%) was recorded in SP-96 grown at Rawalpindi which was significantly higher than rest of the combinations. Lowest linoleic acid (24.68%) was observed in Chakori grown at Attock. Rest of the combinations varied at different levels.

DISCUSSION

Peanut plants are affected by low light intensity during early growth and flowering period. Cloudy weather during flowering reduces the number of flowers. An interaction between photoperiod and temperature has been noted with a cultivar variation (Bell & Wright, 1998). Oil accumulation in different oilseeds is affected by number of factors such as temperature, moisture availability, fertilization and their interaction. The significant differences exhibited by different cultivars for oil content in this study could be attributed to the genetic make up of a particular cultivars (type bunch or erect), its place of origin and the environmental conditions prevailing during the crop life cycle as these cultivars had diverse origin as well as genetic make up. Higher oil content of SP-96 and SP-2000 (Table II) may be related to their place of origin i.e. Swat, having a cooler climate as compared to the testing sites i.e. Pothwar. Demurin *et al.* (2000) found an increase in oil content with increase in temperature during flowering to maturity in Sunflower and Maize. They also reported that 1°C increase in temperature increased oil content by 1% oil in Sunflower. Higher oil content recorded at Attock with higher average temperature lent supportive from earlier findings that crops maturing at higher temperature would accumulate higher oil content (Weiss, 2000). Average monthly temperature of Attock was higher than rest of the locations from flowering to maturity (Table I). A significant interactive effects of cultivars x locations on oil content could be attributed to the number of factors such as temperature, moisture availability during flowering and soil type. Moisture stress during process of flowering and seed development has been reported to affect oil content negatively (Flagella *et al.*, 2002).

Significant differences for palmatic acid among cultivars are again attributable to the genetic makeup and place of their origin. All of the cultivars tested were bred at diverse centers having divergent temperature and moisture regimes. Cultivars Chakori, Banki and BARI-2000 were bred at Chakwal, SP-96 and SP-2000 originated at Swat while BARD -479 is that of Islamabad and No. 334 is of Rawalpindi origin. The range of palmatic acid recorded in this study was higher than that reported by Weiss, (2000) in Australian peanut cultivars. The significant differences for palmatic acid at different locations could be the effect of environmental conditions (temperature and moisture) particularly prevailing temperature at flowering and maturity. Flagella *et al.* (2002) observed a positive effect of irrigation on palmatic acid in sunflower. The significant linear relationship (Fig. 1) between average temperature from flowering to harvesting and palmatic acid supports earlier findings of Hassan *et al.* (2003). Average monthly temperature of Rawalpindi was recorded to be lower as compared to those of Chakwal and Attock particularly at flowering and maturity (Table I).

Fig. 2. Relationship between average temperature from flowering to maturity and Oleic acid

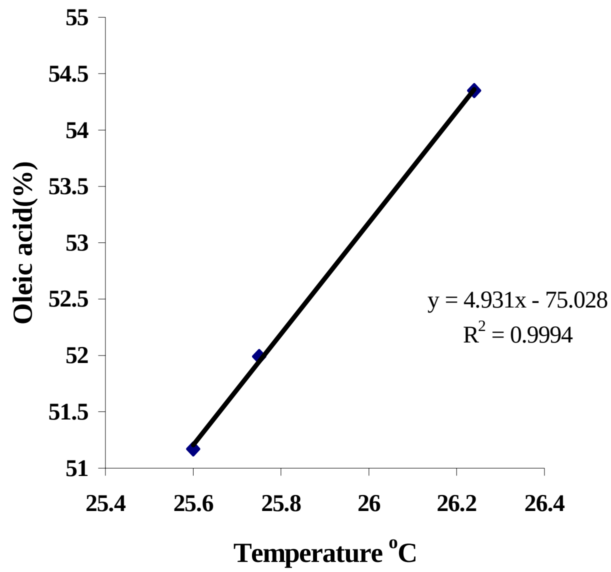
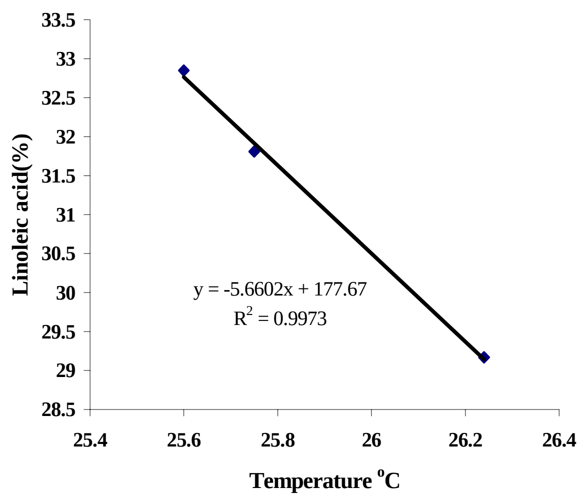
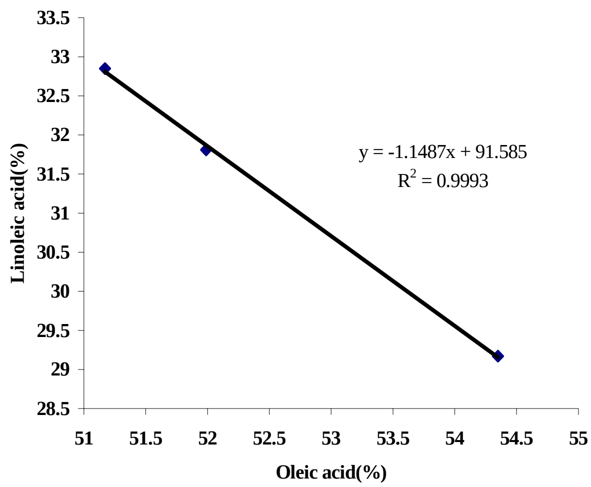


Fig. 3. Relationship between average temperature from flowering to maturity and Linoleic acid.



Oleic acid percentage recorded in different cultivars noted here was higher than those reported by Khan (1997) but similar to those reported by Weiss (2000) i.e. 52.3-60.1% in different peanut cultivars. The significant variations among different cultivars at different locations could be attributed to different genetic make up of the tested cultivars and subsequent response to different environmental conditions. These differences may be due to the environmental factors prevailing during growth period particularly from flowering to maturity. The significant linear (Fig. 2) relationship between oleic acid and average temperature from flowering to maturity are supportive to earlier findings. Demurin *et al.* (2000) concluded that each 1°C increase of temperature led to about 2% increase of oleic acid.

Fig. 4. Relationship between Oleic and Linoleic acid



Significant differences among cultivars for linoleic acid are also genetically related. Weiss, (2000) reported a range of 20 -40% linoleic acid in different cultivars. The type of groundnut (bunch or erect) of the cultivar is also considered responsible for variation of linoleic acid. In other crops such as Sunflower linoleic acid is considered to have inverse relationship with oleic acid. Changes in linoleic acid are reported to be most responsive to temperature (Hassan *et al.*, 2003). Crops maturing at low temperature accumulated higher percentage of linoleic acid as compared to those maturing at high temperature. Demurin *et al.* (2000) reported a negative correlation between oleic and linoleic acid percentage which are essentially influenced by temperature. Significant linear relationship (Fig. 3) between average temperature and linoleic acid and inverse relationship (Fig. 4) between oleic and linoleic acid are supportive to earlier findings.

In conclusion apart from soil type (clay, loam or silt) temperature variations, moisture availability (rainfall distribution & intensity) and sunshine hours particularly from flowering to maturity are the major determinants of oil and fatty acid accumulation in peanut.

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