PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 10 (4): 373-377, 2011
ISSN 1680-5194

Oil and Oil Quality in Different Circles of Mature Sunflower Head as Influenced by Varying Environments

S. Kaleem[1], F.U. Hassan[2], M.A.A.H.A. Bukhsh[1], I. Mahmood[2], R. Ullah[3], M. Ahmad[2] and A. Wasaya[2]
[1]Agriculture Adaptive Research Complex, Dera Ghazi Khan, Pakistan
[2]Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan
[3]Soil and Water Testing Laboratory, Rajanpur, Pakistan

Abstract: Sunflower crop has an ability to maintain high level of viability in varying environments. Prevailing temperature at pollination and after anthesis affects pollen health, fertilization process and ultimately the seed filling and assimilate partitioning that varies in different circles/whorls of sunflower heads. Field experiments one each in spring and autumn 2007 were conducted at Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan to evaluate and document the oil and fatty acid accumulation in different circles/whorls of sunflower heads as influenced by varying environments. Sunflower hybrid S-278 was planted in randomized complete block design with four replications. Each head was divided into three equal circles (outer, middle and central) at maturity, thereafter, oil and fatty acid distribution was separately determined in each circle. Oil and fatty acid accumulated in three circles differed significantly. Outer circle accumulated higher oil content during spring which decreased to the minimum in central circle while, autumn season showed contrasting results in which oil contents progressively increased from outer to central circle. The maximum oleic acid was observed in outer circle which decreased to minimum in central circle during the both spring and autumn seasons, however, linoleic acid consistently increased from outer to central circle during both the seasons. Thus, oleic and linoleic acid depicted inverse relation with circles. Saturated fatty acid (palmatic acid and stearic acid) did not depict any consistent pattern for accumulation in different circles during both the seasons. Overall, spring planted crop exhibited significantly higher values for oil and oleic contents in comparison with autumn planting, which may be attributed to higher temperature, sunshine hours and accumulation of more growing degree days during the spring.

Key words: Varying environments, oil, fatty acid, spring, autumn, distribution, accumulation, circles

INTRODUCTION

Sunflower crop is one of the major non-conventional oilseed crops in the world due to its excellent oil quality. Sunflower seeds posses the genetic characteristics required to develop oil with a unique fat profile. Sunflower can perform well under various climatic and soil conditions. Sunflower oil is a combination of mono-unsaturated and polyunsaturated fats with low saturated fat levels. Sunflower oil is liquid at room temperature. Fatty acid composition is a major determinant of oil quality mainly with percentage of oleic and linoleic acid. Oil quality is mainly affected by genotypes and environmental conditions especially temperature and sunshine hours having major influence on oil quality (Izquierado *et al*., 2002). High degree of adaptability, wide range of climatic conditions, high photosynthetic capacity and harvest index allow sunflower crop to be productive in broad range of environments (Kaleem and Hassan, 2010). Environmental variations affect and modify plant attributes like growth, development and assimilation through physio-morphic functions (Kaleem *et al*., 2010).

Sunflower plant has unique features particularly during and after flowering, as due to natural phenomenon called heliotropism, its head always move with the movement of the sun. The sunflower head is a composite flower and made up of 1,000 to 2,000 individual flowers joined at a common receptacle. Pollen shedding called anthesis begins at the periphery and proceeds to the center of the head (Putnam *et al*., 1990). Different circles (whorls) within a head fertilize and mature differently, thus growth of achenes mainly depends on phloem transport from upper fully expanded, green leaves to the capitulum (Alkio *et al*., 2002). Similarly, maturation of sunflower achenes occurs from the perimeter to the center of sunflower head (Weiss, 2000).

Sunflower crop is better adapted to warmer temperatures and longer growing season (Johnston *et al*., 2002). Experimental studies have revealed that sunflower can be grown successfully in two seasons (spring and autumn) in Pakistan due to its wide range of adaptability, however, spring crop yields higher than autumn crop in terms of achene yield, oil and oil quality (Qader, 2006). Nayyer *et al*. (2007) observed higher values of crop growth rate, net assimilation rate, oil and oil quality in warmer conditions as compared to lower values obtained in cold conditions. Demurin *et al*. (2000) found that oleic acid content is essentially influenced by temperature during seed development, each 1°C

Corresponding Author: S. Kaleem, Agriculture Adaptive Research Complex, Dera Ghazi Khan, Pakistan

increase of temperature leads to about 2% increase of oleic acid. Oil and fatty acid composition in seeds are important targets in sunflower breeding.

Many physiological and qualitative processes are usually sensitive to cold stress which is main reason for the reduction of growth yield and assimilate accumulation of crops (Kaleem *et al.*, 2010). The low temperature which usually prevails in most time of the autumn season, creates an imbalance between source of energy and metabolic sink. Assimilate utilization is more depressed in lower temperature, imposing a greater restriction on biomass production and oil accumulation than at optimum temperature (Paul *et al.*, 1990). Following anthesis, if there is no fertilization or the embryo is aborted due to environment, the assimilate demand is reduced, ultimately causing the vascular tissues of this head region to degenerate leading to empty achenes influencing oil and oil quality. At the time of achene maturity, heavier achenes were observed in the outer region with maximum oil and oleic contents probably due to the early maturation and production of more filled seeds in the peripheral zones (Baydar and Erbas, 2005). Munshi *et al.* (2003) studied the physio-chemical properties of seeds located in different whorls of sunflower head and concluded that oil content was higher in outer than those of middle and central whorls which was concluded to be the effect of environmental conditions and the span of seed development. Both the crops of sunflower (spring and autumn) being grown in opposite environmental conditions, all growth, developmental and grain and oil filling phases in various circles of sunflower heads are thus influenced accordingly. The present experiment was demonstrated and evaluated with the hypothesis that "seed position in different circles of mature sunflower heads effects oil and fatty acid accumulation differently in varying environments" being grown in two different seasons i.e., spring and autumn.

MATERIALS AND METHODS

Planting of sunflower: During spring and autumn 2007 field experiments were conducted at Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan, located at 33° and 38° N and 73° and 04° E to quantify the environmental effects on assimilate partitioning and oil and fatty acid accumulation in different circles of sunflower heads. Spring crop was sown on 18th March and autumn crop on 18th August. Sunflower hybrid, S-278 was planted in randomized complete block design with four replications in net plot size of 5 x 6 m^2.

Soil analysis and conduction of experiment: According to soil analysis report, 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} while, available NPK status in the soil before sowing was 300, 5.00 and 140 mg kg^{-1} respectively. Row to row distance was kept at 75 cm and plant to plant distance at 25 cm. Planting was done with the help of dibbler, putting two seeds per hill by using seeds @ 5 kg ha^{-1} and after complete emergence one plant was maintained per hill by manual thinning. 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. Weeds were kept under control manually throughout the crop life cycle. Meteorological data during the course of experiment was also recorded (Table 1). Ten randomly selected heads of spring and autumn crops from each plot were harvested/removed on 8th July, 2007 and 14th November 2007, respectively. Head diameter was measured with measuring tape (Sublime Sports Ltd., Sialkot, Pakistan) then heads were equally divided into three circles (Outer (O) Middle (M) and Central (C) and these circles were measured (Fig. 1).

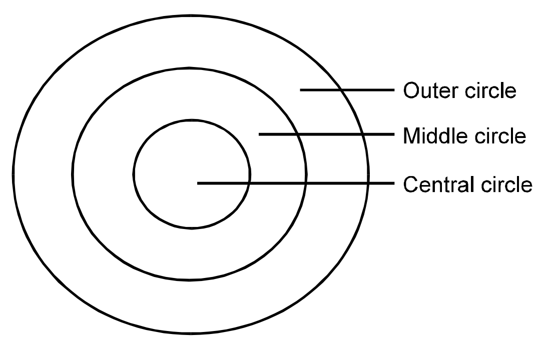

Fig. 1: Circles of sunflower head

Table 1: Meteorological data during spring and autumn 2007

Month	Temperature (°C) Max. (Mean)	Min. (Mean)	Rainfall (mm)	Relative humidity (%) (Mean)	Sunshine (Hours) (Mean)
Spring 2007					
March	23.10	9.00	81.00	60.00	8.20
April	34.00	15.90	18.00	44.00	10.70
May	37.30	19.80	80.60	42.00	10.00
June	37.60	23.00	22.30	51.00	9.50
July	35.20	21.50	262.50	68.00	9.30
Autumn 2007					
August	34.20	21.80	485.00	72.00	8.30
September	32.80	19.40	201.00	68.00	7.80
October	31.50	12.60	0.00	54.00	9.60
November	26.00	8.20	10.00	71.00	7.00

Table 2: Oil and fatty acid distribution in different circles of sunflower head during spring and autumn 2007

	Oil content (%)		Palmatic acid (%)		Stearic acid (%)		Oleic acid (%)		Linoleic acid (%)	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
O	48.85[a]	35.66[e]	5.56[ab]	5.06[b]	2.60	3.24[NS]	52.44[a]	41.32[c]	35.31[e]	46.20[c]
M	48.10[a]	39.00[d]	5.77[ab]	5.00[b]	2.82	2.89	51.39[b]	38.20[d]	36.11[d]	47.31[b]
C	44.26[c]	45.34[b]	6.10[a]	5.69[ab]	2.53	2.87	50.97[b]	38.02[d]	36.40[d]	53.40[a]
LSD at 5% probability	1.034		0.972		-		1.013		0.359	

Any two means not sharing a letter in common differ significantly. O = Outer, M = Middle, C = Central

Oil and fatty acid determination: For oil extraction and fatty acid determination achenes from each circle were separated with hand. Achenes from each circle were separately analyzed for oil content with NMR (Nuclear Magnetic Resonance system), Model MQA-7005, Oxford Institute, USA, by standardizing the equipment with six different oil contents having the samples previously analyzed, thus oil content in each circle were recorded (Warnsely, 1998). The fatty acids in oil were analyzed by a gas chromatograph (AIML-NUCON) after intersterilification with methanolic KOH. In this method, fatty acids were converted to methyl esters prior to analysis by Gas Chromatography (GC). Fatty acids were detected by chromatographic retention time by comparison with authentic standards (Paquot, 1988).

Statistical analysis: The collected data were subjected to statistical analysis by applying MSTATC, separately for both the seasons (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).

RESULTS AND DISCUSSION

According to the data presented in Table 2, the differences for oil content among circles were statistically significant ($p<0.05$) during spring and oil content consistently decreased from outer to central circle. The maximum (48.85%) value of oil content was observed in outer circle while central circle gave the minimum value of 44.26%. A small decrease in oil content was observed from outer to central circle whereas, contradictory results were recorded during autumn season. During autumn, circles also differed significantly for oil content. Contrary to spring crop, oil content increased from outer to central circle during autumn. The maximum (45.34%) oil content was accumulated in central circle while outer circle gave the minimum (35.66%) value (Table 2).

Statistically ($p<0.05$) significant differences were exhibited among circles regarding palmatic acid for both the seasons (Table 2). Palmatic acid accumulation in different circles showed a small increase from outer to central circle during spring however, no consistent pattern was visible during autumn season. The maximum (6.10%) palmatic acid was observed in central circle while outer circle gave the minimum value of 5.56% during spring. Similarly, during autumn maximum (5.69%) palmatic acid was accumulated in central circle (Table 2). Statistically ($p<0.05$) similar results were exhibited among circles for stearic acid (Table 2). The maximum (2.82, 3.24%) stearic acid was accumulated in middle and outer circles during spring and autumn, respectively.

Similarly, statistical ($p<0.05$) differences were exhibited among circles regarding oleic acid for the both spring and autumn seasons (Table 2) in which oleic acid accumulation in different circles showed a small increase from central to outer circle. The maximum (52.44, 41.32%) oleic acid was accumulated in outer circles while, minimum (50.97, 38.02%) values were observed in central circles during spring and autumn, respectively.

Statistically ($p<0.05$) significant differences were exhibited among circles regarding linoleic acid for both the seasons (Table 2). Linoleic acid accumulation in different circles showed a small increase from outer to central circle during the both seasons. The maximum (36.40, 53.40%) linoleic acid was accumulated in central circles while, minimum (35.31, 46.20%) values were observed in outer circles during spring and autumn, respectively.

Prevailing temperature at anthesis affects pollen health, fertilization process, seed filling, oil and fatty acid accumulation in different circles/whorls of sunflower head. In temperate regions, sunflower requires approximately 11 days from planting to emergence, 33 days from emergence to head visible, 27 days from head visible to first anther, 8 days from first to last anther and 30 days from last anther to maturity (Kaleem and Hassan, 2010). In this way, difference of eight to ten days from first to last anther make the basis for difference in seed setting, development, oil and fatty acid accumulation due to different environmental conditions for anther shedding.

In the present study, significant differences were recorded for oil content among circles during the both spring and autumn seasons and these differences for oil content could be result of overall environmental conditions where both the crops were grown at different temperature conditions and growing degree days

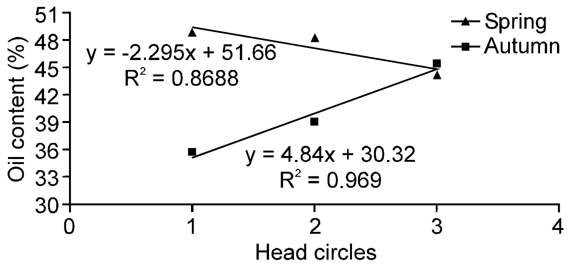

Fig. 2: Relationship between head circles and oil content

accumulated during crop life cycle. Spring crop received higher temperature during flowering than autumn crop at flowering (Table 1). Higher oil contents during spring in all the circles than in autumn is in accordance with the findings of Demurin *et al.* (2000) who reported that increase of 1°C in temperature during flowering to maturity in sunflower caused increase of 1% in oil content of sunflower. Gradual reduction of oil content from outer to central circle of spring crop is in conformity with those of Munshi *et al.* (2003) those concluded that achenes in outer region grew at slow rate than those in central region thus time available to outer region seeds was more than those of central region. Slow accumulation for longer period of time would increase the total oil content. However, contrary to it, oil content from autumn crop showed minor increase from outer to central whorl which could be the result of less competition for space and assimilates as less number of seeds was recorded in autumn crop head. Opposite relationship (Fig. 2) between head circles and oil content during spring while, direct relationship during autumn is supportive to above assumption.

Regarding palmatic acid accumulation, inconsistent pattern was observed among circles in present experimentation. Comparison of the seasons regarding palmatic acid exhibited lesser accumulation during autumn in about all the circles than that of spring. The lesser palmatic acid values during autumn might be due to low temperature prevailed during seed development and maturation (Table 1) which is in conformity with the findings of Weiss (2000) who concluded that crops maturing at higher temperature would accumulate higher oil and fatty acid content. Similarly, inconsistent pattern of stearic acid accumulation in present investigation is similar to the findings of Baydar and Erbas (2005) those reported that the accumulation pattern for saturated fatty acid was about same with slight fluctuations.

Higher oleic acid was accumulated during both the seasons in outer circles which progressively decreased from outer to central circles. Our results are in conformity with those of Baydar and Erbas (2005) who found that less mature achenes in centre may have resulted from any kind of failure of fertilization usually due to prevailing temperature and relative humidity, thus recorded less assimilation, oil and oleic accumulation in central

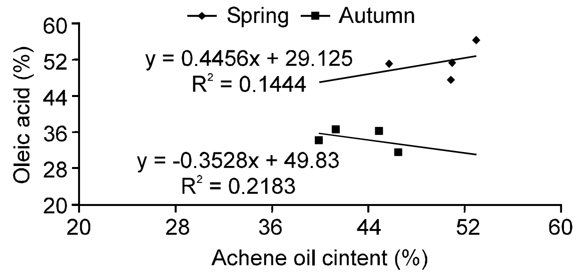

Fig. 3: Relationship between achene oil content and oleic acid during spring and autumn seasons

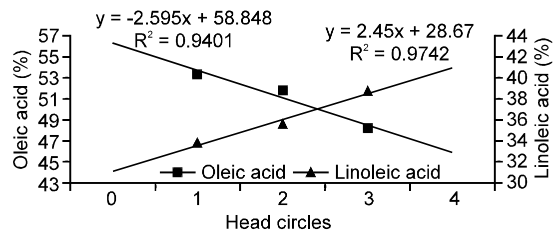

Fig. 4: Relationship between oleic and linoleic acid

whorls than the outer ones. Direct relationship between oleic and oil contents during spring while, inverse relationship between oleic and oil contents during autumn (Fig. 3) is supportive to above assumption. Seed development and seed maturation takes place from peripheral towards central whorl on a single head. Progressive decrease of oleic acid from outer to central circle is in accordance to results of Kaleem and Hassan (2010) those concluded that peripheral seeds mature earlier at higher temperatures than middle towards centre at the last, thus all three whorls mature at varying temperature, accumulated varying oleic content.

According to the results in Table 2, central circles accumulated higher linoleic acid those progressively decreased from central to outer circles for both the seasons. The results for linoleic acid in different circles of sunflower head remained opposite to those observed for oleic acid which are in accordance to the findings of Demurin *et al.* (2000) who expressed a negative correlation between oleic and linoleic acid contents, essentially influenced by temperature. An opposite relationship between oleic and linoleic acid in present investigations is supportive to our findings (Fig. 4).

Conclusion: Accumulation of oil and fatty acid in different head circles is combined function of growth, development and plant structure, affected by environmental variables. It can be concluded from the present investigations that both oil contents of sunflower seeds and composition of oil vary with the position of seeds in the flower heads and prevailing season. The outer circle has the potential to accumulate maximum oil and oleic acid contents during the both spring and autumn seasons. Similarly, spring season accumulated the higher oil and fatty acid contents as compared to lower during autumn season except for linoleic acid. For equal distribution of assimilations and accumulation of oil and fatty acid in all the regions of the sunflower head, further research work in this connection is necessary for the development of new hybrids.

REFERENCES

Alkio, M., W. Diepenbrock and E. Grimm, 2002. Evidence for sectorial photoassimilate supply in the capitulum of sunflower (*Helianthus annuus* L). New Phytologist, 156: 445-456.

Baydar, H. and S. Erbas, 2005. Influence of seed development and seed position on oil, fatty acids and total tocopherol contents in sunflower (*Helianthus annuus* L.). Turk J. Agric., 29: 179-186.

Demurin, Y., D. Skoric, I. Veresbaranji and S. Jocic, 2000. Inheritance of increased oleic acid content in sunflower seed oil. Helia, 23: 87-92.

Freed, R.D. and S.P. Eisensmith, 1986. MSTAT Microcomputer Statistical program. Michigan State University of Agriculture and Applied Science, Michigan, USA.

Izquierado, N., L. Aguirrezabal, F. Andrade and V. Pereyra, 2002. Night temperature affects fatty acid composition in sunflower oil depending on the hybrid and the phenological stage. Field Crop Res., 77: 115-126.

Johnston, A.M., D. Tanaka, P. Miller, S. Brandt, D. Nielsen, P. Lafond and N.R. Riveland, 2002. Oil seed crops for semi arid cropping systems in the Northern Great Plains. Agron. J., 94: 231-240.

Kaleem, S., F.U. Hassan, A. Razzaq, A. Manaf and Amir Saleem, 2010. Growth rhythms in sunflower (*Helianthus annuus* L.) in response to environmental disparity. Afr. J. Biotechnol., 9: 2242-2251.

Kaleem, S. and F.U. Hassan, 2010. Seed and oil distribution in different circles of mature sunflower head. Pak. J. Bot., 42: 3005-3014.

Montgomery, D.C., 2001. Design and Analysis of Experiments. 5th Edn., John Willy and Sons, New York, pp: 64-65.

Munshi, S.K., B. Kaushal and R.K. Bajaj, 2003. Compositional changes in seeds influenced by their positions in different whorls of mature sunflower head. J. Sci. Food Agric., 83: 1622-1626.

Nayyer, H., G. Kaur, S. Kumar and H.D. Upadhyaya, 2007. Low temperature effects during seed filling on chickpea genotypes: Probing mechanism affecting seed reserves and yield. J. Agron. Crop Sci., 193: 334-336.

Paquot, 1988. Standard Methods for Analysis of Oils, Fats and Derivates. Pergamon Press, Paris, France.

Paul, M.J., D.W. Lawlor and S.P. Driscall, 1990. Effect of temperature on photosynthesis and carbon fluxes in sunflower and rape. J. Expt. Bot., 41: 547-555.

Putnam, D.H., E.S. Oplinger, D.R. Hicks, B.R. Durgan, D.M. Noetzel, R.A. Meronuck, J.D. Doll and E.E. Schulte, 1990. Alternate Field Crops Manual: Sunflower. Extension Service, University of Wisconsin-Madison, WI 53706. USA.

Qader, G., 2006. Morpho-Genetic expression of sunflower under varied temperature and moisture regimes. Ph.D. Agri. Thesis, Deptt. of Agron., Univ. of Arid Agric. Rawalpindi-Pakistan.

Warnsely, J., 1998. Simultaneous determination of oil and moisture in seed by NMR. Lipid Tech., 10: 6.

Weiss, E.A., 2000. World Oilseed Crops. Longman Group Ltd., London, pp: 356.