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SEED AND OIL DISTRIBUTION IN DIFFERENT CIRCLES OF MATURE SUNFLOWER HEAD

SHUAIB KALEEM AND FAYYAZ-UL-HASSAN*

Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan

Abstract

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. 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 were conducted at Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan to document the assimilate partitioning (as achene) and oil accumulation in different circles/whorls of sunflower heads as influenced by varying environments. Four sunflower hybrids were planted in randomized complete block design with two factors factorial (hybrids & circles) experiment with four replications. Each head was divided into three equal circles (outer, middle & central). Achene and oil distribution was separately recorded in each circle. All four hybrids produced heads of larger diameter in spring crop than those produced by autumn season crop. Outer circle produced higher number of achenes, those were heavier in weight and accumulated higher oil content in all four hybrids as compared to middle and central circle in spring crop, while oil content showed minor increase from outer to central circle in autumn crop, which showed the least number of rows and hull kernel ratio. Hull kernel ratio showed contrasting results as compared to other traits which progressively increased from outer to central circle in spring crop while consistently decreased in autumn crop in all the four hybrids. Number of achene, achene weight, hull kernel ratio and oil content in all three regions (outer, middle and central) of spring sown sunflower heads were more than those of autumn crop heads. Opposite relationship between head circles, hull kernel ratio and oil content was observed for both the seasons.

Introduction

Sunflower is one of the major and most important oilseed crops in the world due to its excellent oil quality and has the potential to narrow the existing gap between production and consumption of edible oil in Pakistan. Sunflower can perform well under various climatic and soil conditions. The wide range of adaptability of the crop makes it possible to have two sunflower crops in one year under different cropping systems of the country. Sunflower plant is unique in nature particularly during and after flowering, as its head always move with the movement of the sun, a mechanism which is called as heliotropism. A completely developed head usually have a small circular depression in the centre while middle and outer whorls are flat.

The sunflower head is not a single flower (as the name implies) but is made up of 1,000 to 2,000 individual flowers joined at a common receptacle. The flowers around the circumference are ligulate ray flowers without stamens or pistils; the remaining flowers are perfect flowers (with stamens and pistils). Anthesis (pollen shedding) begins at the periphery and proceeds to the center of the head (Putnam *et al.*, 1990). Similarly, maturation of sunflower seeds takes place from the perimeter to the center of sunflower head. (Weiss, 2000), References missing at the end i.e. References section of the paper, please add this at the end.

*Corresponding author E-mail: drsahi63@gmail.com; Fax: +92-51-9290160,

Apparently sunflower heads open and mature at the same time, however, close examination of head depicts that sunflower capitulum contains hundreds of florets or achenes. Each of them represents an individual sink. Photo assimilate transport depends on the physiological activity and the competition of these sinks, both changing in the course of ontogeny thus different whorls within a head fertilize and mature differently (Alkio *et al*., 2002), thus growth of achenes mainly depends on phloem transport from upper fully expanded, green leaves to the capitulum. Improved assimilate supply to growing achenes is regarded as the main factor for increase in yield of modern sunflower hybrids (Lopez Pereirz *et al*., 1999). Rawson *et al*., (1984) concluded that short day length during grain filling (autumn sowing) causes low harvest index based on dry matter accumulation thus restricted assimilate partitioning to seeds results limited seed yield. Similarly, Ploschuk & Hall (1995) reported thermal regime of sunflower grains on rate of grain filling and effects on sunflower capitulum position and concluded that position of seeds from pericarp to center in head of sunflower caused reduction in seed weight up to 21%.

Munshi *et al*., (2003) studied the physio-chemical properties of seeds located in different whorls of sunflower head and concluded that proportion of filled seeds decreased from outer to central whorl and found 10 fold decrease in filled to un-filled seed ratio. They further reported that dry weight of seeds and kernels decreased from outer towards the middle and central whorls though kernel and hull percentage did not differ significantly. Similarly, 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. The accumulation of oil during seed filling was considered to be dependent upon an unhampered supply of photo assimilates from the source i.e, foliage to the sink. Similarly, Alkio & Grimm (2003) observed the central part of poorly developed sunflower head remained un-filled due to various reasons creating empty achenes. They reported that before fertilization and seed filling, assimilates and nutrients are required for floret development and flowering. Following anthesis, if no fertilizations happens 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. Goffner *et al*. (1988) concluded that occurrence of empty achenes is highest in centre of capitulum and poor seed filling is related to poor vascularization of receptacle. Vascular bundles originating from the stem, run radially towards the periphery of capitulum and from there towards the centre of capitulum.

At the time of achene maturity, Baydar & Erbas (2005), this reference is missing in the references section at the end. Please add full reference at the end found heavier seeds contained in the outer region which gave the lowest husk ratio. They recorded almost equal oil percentage in achenes from outer and middle regions but lowest oil percentage in center. It was further reported that dry weight per seed was significantly affected by the positions of seeds on head which decreased from side (outer) to center (54.1, 45.4 and 38.3 mg from the side to center respectively, this was probably due to the early maturation and production of more filled seeds in the peripheral zones.

Climatic conditions and cropping system of the country warrant the possibility of having two crops of sunflower in a year, spring and autumn, however, it has been reported that spring crop gives higher seed yields than that of autumn crop (Qader *et al*., 2007). Both the crops (spring and autumn) being grown in opposite environmental conditions, all growth, developmental and grain filling phases in various circles of sunflower heads are affected accordingly. The present study was contemplated with the hypothesis that “seed position effects seed setting/distribution and oil accumulation in sunflower heads” being grown in two different seasons i.e., spring and autumn.

Material and Methods

Field experiments were conducted at Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi during spring and autumn 2007 to quantify the environmental effects on assimilate partitioning in different circles of sunflower heads. Spring crop was sown on 18^{th} March and autumn crop on 18^{th} August. Four sunflower hybrids, Alisson-RM, Parasio-24, MG-2 and S-278 were planted in randomized complete block design (as factor A) experiment with four replications in net plot size of 5x 6 m^2 having 8 rows. Row to row distance was maintained at 75 cm and plant to plant distance at 25 cm. Planting was done with the help of dibbler putting 2 seeds per hill by using seeds @ 5 kg ha^{-1}. After complete emergence one plant was maintained per hill by manual thinning. Recommended dose of fertilizer of 80 kg Nitrogen and 60 kg $P_2 O_5$ 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 8^{th} July, 2007 and 14^{th} 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). These measured circles were considered as factor B, thus making the whole experiment as two factor factorial (hybrids & circles). The number of achenes formed in each circle were counted and their averages were worked out. Achenes from each circle were removed and weighed separately with an analytical balance (Technic Instruments Ltd.,UK) and the average was worked out. Three random samples of hundred achene from each circle were taken and weighed to work out hundred achene weight for each hybrid. Kernels from the achene were separated and weight of hulls and kernels was recorded and hull to kernel ratio was calculated by using the formula:

$$\text{H-K ratio} = \frac{\text{Weight of hulls}}{\text{Weight of kernels}}$$

Achene from each circle were separately analyzed for oil content with NMR, thus oil content in each circle were recorded in respective circle. The collected data were subjected to statistical analysis by applying MSTATC, separately for both the seasons (Freed & 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

The differences among hybrids for head diameter were statistically significant ($p<0.05$) during spring (Table 2). The hybrid MG-2 produced the largest (18.18 cm) head though statistically at par with S-278 but significantly differed from rest of the hybrids. The hybrid Parasio-24 produced the smallest (15.5 cm) head. The head size of all the hybrids decreased during autumn. However, the symmetry was similar to that of spring crop. The hybrid MG-2 again produced the largest (13.78 cm) head and Parasio-24 the smallest one (10.46 cm) (Table 2).

Table 1. Meteorological data of two seasons 2007.

Month	Temperature (^oC)		Rainfall (mm)	Relative humidity (%)	Sunshine (hours) (mean)
	Mean max.	Mean min.			
	Spring 2007				
March	23.10	9.00			
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

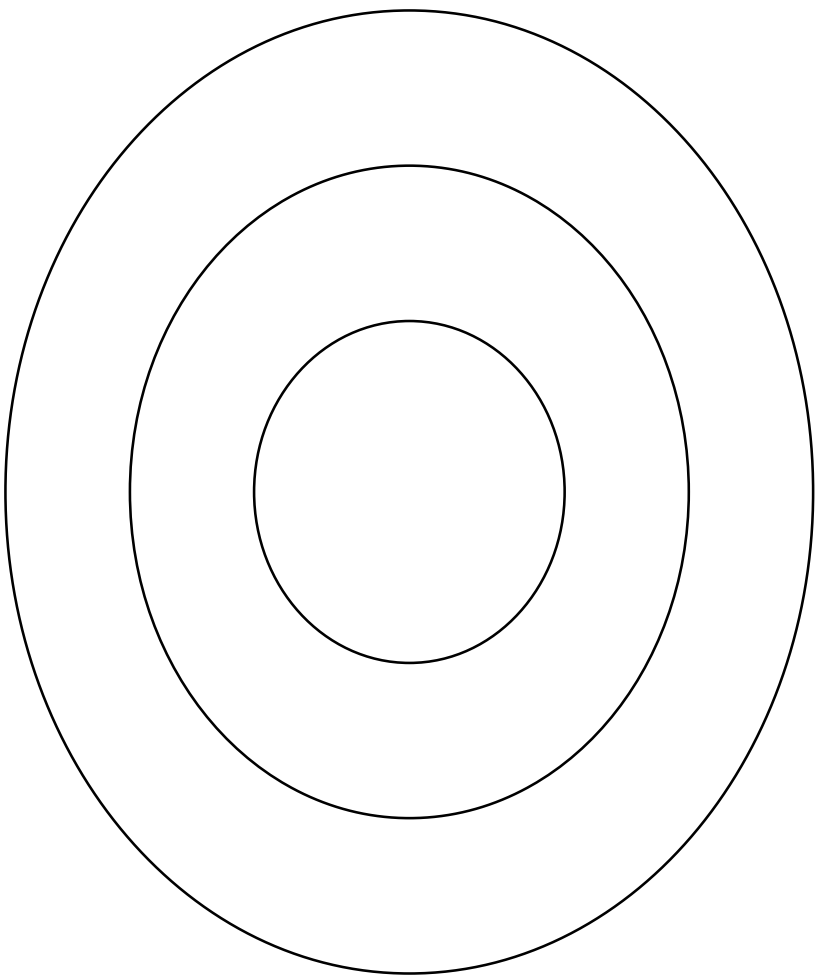

Fig. 1. Different circles of sunflower head (outer, middle & central).

Table 2. Head diameter, Number of achenes and HAW at maturity as influenced by varying environments.

Hybrids	Head diameter (cm)		Number of achenes						HAW (g)					
			Spring			Autumn			Spring			Autumn		
	Spring	Autumn	O	M	C	O	M	C	O	M	C	O	M	C
Alisson-RM	15.70bc	12.30b	426.50bc	408.25c	214.00e	190.05ab	143.70d	102.75ef	5.49a	4.43cde	3.63f	5.64ab	4.57de	3.70fg
Parasio- 24	15.50c	10.46c	423.50c	370.25d	224.00e	182.00abc	131.75de	88.50f	5.65a	4.98abc	3.93def	5.86a	5.10abc	4.28def
MG- 2	18.18a	13.78a	478.25a	461.50ab	248.00e	206.75a	164.50bcd	106.00e	5.59a	4.61cd	3.77ef	5.83a	4.70cde	4.12ef
S- 278	17.00ab	12.98b	471.50a	406.00cd	223.75e	205.65a	152.25cd	102.50ef	5.42ab	4.75bc	3.26f	5.60ab	4.95bcd	3.35g
LSD at 5% probability	1.437	0.763	37.14			33.53			0.677			0.673		

Any two means not sharing a letter common differ significantly
HAW= Hundred achene weight, O= Outer, M= Middle, C= Central

Table 3. HKR and Oil content (%) of sunflower as influenced by varying environments.

Hybrids	HKR						Oil percentage					
	Spring			Autumn			Spring			Autumn		
	O	M	C	O	M	C	O	M	C	O	M	C
Alisson-RM	0.40	0.43	0.47	0.46a	0.43a	0.36bcd	48.00a	47.56a	47.30a	42.09b	42.27b	42.42b
Parasio- 24	0.40	0.42	0.44	0.41abc	0.37bcd	0.34cd	49.85a	49.25a	49.09a	46.66a	47.40a	47.55a
MG- 2	0.40	0.41	0.49	0.43ab	0.40abc	0.38abcd	44.42b	43.41bc	41.02c	44.07ab	45.24ab	45.55ab
S- 278	0.39	0.44	0.45	0.40abc	0.38abcd	0.31d	48.85a	48.10a	47.70a	44.72ab	45.20ab	45.34ab
LSD at 5% probability	NS			0.0788			2.819			2.990		

Any two means not sharing a letter common differ significantly
HKR= Hull kernel ratio

The differences among hybrids for achenes distribution in outer circle were statistically significant ($p<0.05$) during spring. The hybrid MG-2 produced the maximum (478.3) achenes in outer circle which was statistically at par with S-278. The hybrid Parasio-24 produced the least number of achenes in outer circle which was statistically at par ($p<0.05$) with Alisson-RM. In middle circle the achenes distribution was more or less similar to that of outer circle with maximum (461.5) produced by MG-2 and minimum by Parasio-24. The differences among hybrids for achene distribution in central circle was statistically non significant but followed the same pattern of outer and middle circles for hybirds. In all the hybrids, maximum achenes were observed in the outer circle those decreased to the minimum in the centre of the head (Table 2). During autumn, the hybrids remained statistically at par for achene distribution in outer and middle circle. However, differences among hybrids for acheche distribution reached to the level of significance ($p<0.05$) in central circle (Table 2). The achen distribution decreased progressively from outer to the central circle, where MG-2 produced the maximum number of achenes in all three circles.

The differences among hybrids for hundred achene weight (HAW) in different head circles showed statistically significant differences ($p<0.05$) during spring (Table 2). Though, hybrids were statistically at par in outer circle, but reached to the level of significance in rest of the two circles. In all three circles Parasio-24 gave the maximum HAW while S-278 produced the minimum HAW in all three circles. During autumn, the trend for HAW was more or less similar, where differences among hybrids in outer circle remained statistically non significant but reached to the significance level in rest of the two circles. Again, Parasio-24 gave the maximum HAW in all three circles but minimum value in middle circle was observed for Alisson-RM while from central circle minimum value was recorded for S-278. HAW showed a progressive and statistically significant decrease from outer to central circle in all hybrids.

The difference among hybrids for hull kernel ratio (HKR) and among head circles remained statistically non significant ($p<0.05$) for spring crop, however, showed progressive increase from outer circle to the central circle (Table 3). Contrary to spring crop, differences among hybrids for HKR of autumn crop reached to the level of significance in middle and central circle but statistically at par in outer circle. HKR showed progressive decrease from outer to central circle in all the hybrids with the maximum value (0.46) recorded for Alisson-RM while the minimum (0.31) value observed for S-278 in central circle.

The differences for oil content among hybrids and among circles were statistically significant ($p<0.05$) during spring. The maximum value of oil content was observed for Parasio-24 in all three circles while MG-2 gave the minimum value (Table 3). A small decrease in oil content for all hybrids was observed from outer to central circle. During autumn, hybrids differed significantly for oil content. Contrary to spring crop, oil content increased from outer to central circle but remained statistically at par ($p<0.05$). Similar, to spring crop, in autumn, Parasio-24 accumulated the maximum oil content in all three circles while Alisson-RM remained at the bottom in terms of oil accumulation (Table 3).

Discussion

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 (Putnam *et al.*, 1990). The difference of 8 to 10 days from first to last anther warrant that temperature/environmental conditions varied for anther shedding on different days thus making the basis for difference in seed setting, development and oil accumulation. In the present study, significant differences for head diameter among hybrids may be related to genetic potential and make up of the hybrids. However, differences between two seasons could be result of overall environmental conditions where both the crops were grown. Taller plants with larger leaf area would have encouraged the larger head development of spring crop and opposite for autumn crop. Similar, conclusion has been drawn by Hassan *et al*., (2007), those related the larger heads of spring crop to overall plant structure and prevailing environmental conditions. Larger head of spring crop would have developed more seeds per head under ample supply of assimilates from well structured plants. The present investigation revealed a progressive reduction in total number of seeds in each circle which seems to be related to the total circumference covered by each circle, outer circle covered large distance as compared to rest two, thus total number of seeds were more in outer circle. However, overall reduction in all three sections of autumn crop may be related to head size. Usually, spring crop develops larger head as compared to autumn crop. Seed weight per head circle was higher in spring crop than that in autumn crop. Similar results were reported by Simangala & Giriraj (2003) that high temperature, low relative humidity, more sunshine hours and low disease incidence during flowering and seed setting period of spring crop resulted in increased seed setting, seed weight and seed yield.

Similarly, differences for hundred achene weight among hybrids may be a genetic one. However, hundred achene weight showed progressive reduction from outer to central circle for both the crops (spring & autumn) which shows that in central region either achenes were not fully mature or empty. Less mature achenes in centre may have resulted from any kind of failure of fertilization usually due to prevailing temperature and relative humidity. High temperature and low relative humidity have been considered as cause of poor pollination by Baydar & Erbas (2005). Similarly, (Miralles *et al*., 1997) concluded that seasons with high temperature and low relative humidity produced many empty and sterile achene thus low head fertility. However, these conclusions are contrary to that of Simangala & Giriraj (2003). It has also been concluded that poor seed set in central region of capitulum may be due to competition for space on the receptacle tissue underneath the disc florets and to preferential sequestration of metabolites towards the achenes in the former positions (Steer *et al*., 1988).

In our investigations, the hull kernel ratio progressively increased from outer to the central circle for spring crop but could not reach to the level of significance. However, autumn crop depicted opposite trend and showed significance among hybrids as well as among circles. The differences between seasons may be related to prevailing temperature and relative humidity as concluded by Baydar & Erbas (2005). The difference also depicted that more number of achenes in heads of spring crop would have developed higher competition for space, whereas, less number of seeds per head of autumn crop were free of such competition and got the required assimilates thus fully matured achenes were found. The opposite relationship (Fig. 2) between hull kernel ratio and head circles of two seasons support the above assumption. Thus, findings of present investigation are consistent to the conclusion of Munshi *et al*., (2003) who concluded that poor seed development in the central whorl is most probably due to inadequate vascular connections restricting the supply of water and assimilates and lack of space in the receptacle tissue for the expansion of florets and the development of achenes. Steer *et al*., (1988) demonstrated that achenes in all central whorl achieved a large size when competition from other whorls was reduced, implying that severe competition occurred under normal conditions.

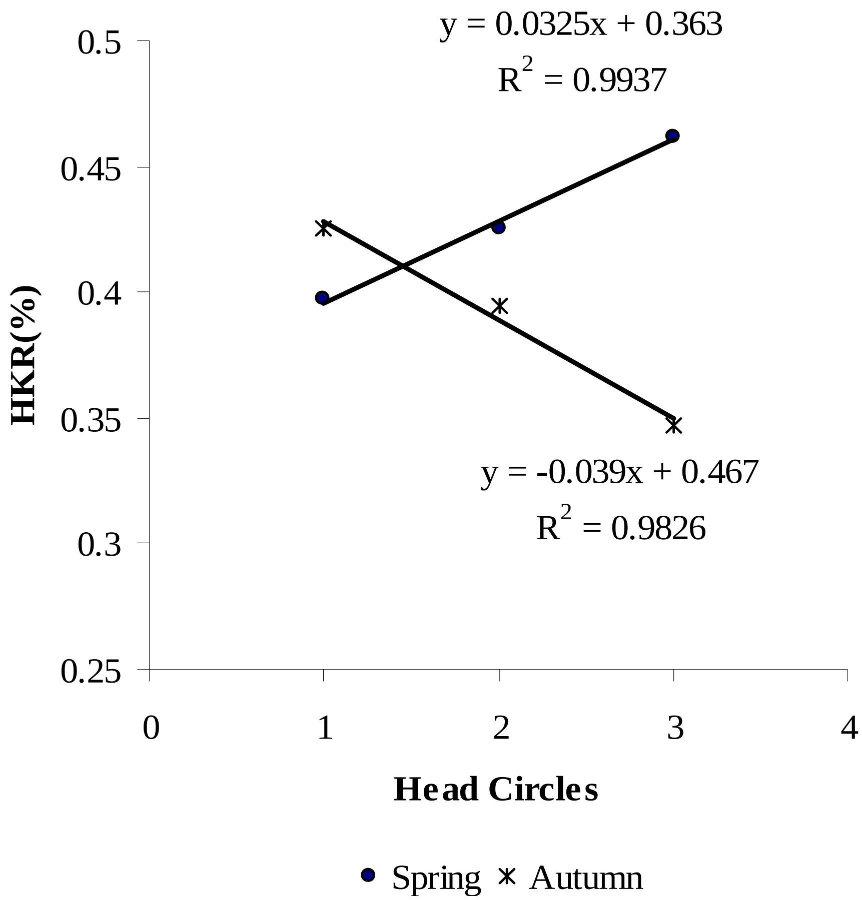

Fig. 2. Relationship between head circles and HKR.

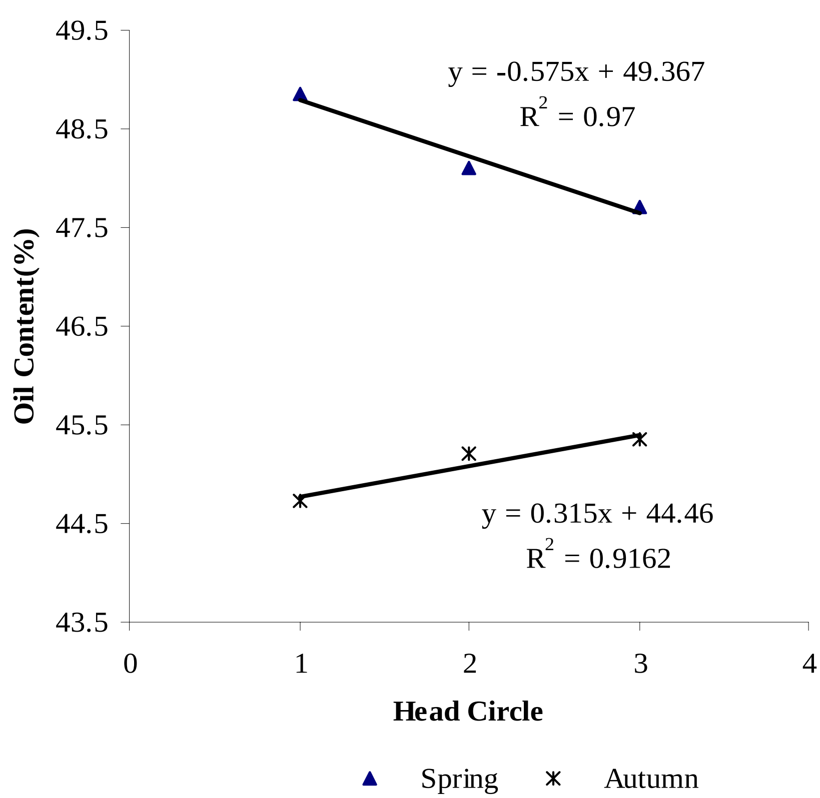

Fig. 3. Relationship between head circles and oil content.

Overall higher percentage of oil found in spring crop than that of autumn crop in the present study is consistent to the findings of Qadir *et al*., (2007). However, progressive reduction of oil content from outer to central circle of spring crop is in line to those of Munshi *et al*., (2003) those concluded that seeds 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 above, oil content from autumn crop showed minor increase from outer to central whorl which may be the result of less competition for space and assimilates as less number of seeds were recorded in autumn crop head. The opposite relationship (Fig. 3) between head circles and oil content of both the seasons is supportive to above assumption

It may be concluded from present investigation that distribution of achenes and oil in different head circles is combined function of growth, development and overall plant structure affected by environmental conditions. However, a more broad, comprehensive, meaningful breeding, agronomic and physiological strategy for the development of new hybrids having enhanced vascular connections is needed so as assimilates may partition actively and equally in all the regions of the head. This equal distribution of assimilates and maturity at one time may enhance the proportion of fully filled seed down to the centre of the capitulum.

References

Alkio, M. and E. Grimm. 2003. Vascular connections between the receptacle and empty achenes in sunflower (*Helianthus annus* L). *J. Exp. Bot*., 54: 345-348.

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 annus* L.). *Turk. J. Agric*., 29: 179-186.

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

Goffner, D., R.Cazalis, C. Percie du sert, J. Calmes and G. Cavalie. 1988. ^{14}C photo assimilate interception and seed production in sunflower as influenced by temperature and radiation. *Aust. J. Plant Physiol*., 11: 255-265.

Hassan, F.U., S.A. Hakim, G. Qadir, A. Manaf and S. Ahmad. 2007. Response of sunflower (*Helianthus annus* L) to sulphur and seasonal variation. *Int. J. Agric. & Bio*., 9: 499-503.

Lopez Pereira M., N. Trapani and V.O. Sadras, 1999. Genetic improvement of sunflower in Argentina between 1930 and 1995. II. Phenological development, growth and source-sink relationship. *Field Crop Res*., 63: 247-254.

Miralles, O.M., J.A. Valero and F.M. Olalla. 1997. Growth, development and yield of five sunflower hybrids. *Eur. J. Agron*., 6: 47-59.

Montgomery, D.C. 2001. *Design and Analysis of Experiments*. 5th Ed. John Willy and Sons, New York. p. 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. of Food and Agric*., 83(15): 1622-1626.

Ploschuk, E.L. and A.J. Hall. 1995. Capitulum position in sunflower affects grain temperature and duration of grain filling. *Field Crop Res*., 44: 111-117.

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, Wl 53706. USA.

Qadir, G., F.U. Hassan and M.A. Malik. 2007. Growing degree days and yield relationship in Sunflower(*Helianthus annuus* L.). *Int. J. Agric. & Biol.*, 9: 564-568.

Rawson, H.M., R.L. Dunstone, M.J. Long and J.E. Begg. 1984. Canopy development, light interception and seed production in sunflower as influenced by temperature and radiation. *Aust. J. Plant Physio.*, 11: 255-265.

Steer, B.T., P.J. Hocking and A. Low. 1988. Dry matter, minerals and carbohydrates in the capitulum of sunflower (*Helianthus annuus* L.), effects of competition between seeds and defoliation. *Field Crop Res.*, 18: 71-85.

Sumangala, S. and G. Giriraj. 2003. Seed yield, test weight and oil contents in sunflower genotypes as influenced by various pollination methods and seasons. *HELIA,* 26: 143-148.

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

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