HELIA, **32**, Nr. 50, p.p. 135-144, (2009) UDC 633.854.78:631.53.01.026
DOI: 10.2298/HEL0950135G

PHYSICAL CHARACTERISTICS AND BIOCHEMICAL COMPOSITION OF SEEDS INFLUENCED BY THEIR POSITION IN DIFFERENT WHORLS OF SUNFLOWER HEAD-EFFECT OF STORAGE

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Received: April 11, 2008
Accepted: June 02, 2009

SUMMARY

The effect of storage on biochemical composition of seeds located in different whorls of sunflower head at maturity has been studied. The proportion of filled seeds, yield parameters such as weight of seeds, kernels and oil per whorl and dry weight of seeds and kernels decreased from the peripheral towards the central whorls. Dry matter, oil and starch contents decreased after 180 days of storage at room temperature. The content of total soluble sugars increased while that of reducing sugars decreased in peripheral whorls from first to ninth positions during storage for 180 days. The storage of seeds located in central whorls lowered the proportion of oleic acid with a corresponding increase in linoleic acid after 180 days. Thus, the seeds located in peripheral whorls were more productive and better for storage purposes than those in central whorls.

Key words: **sunflower seeds, whorl position, storage, dry matter, oil and carbohydrates**

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a major oilseed crop, ranking third after groundnut and mustard. The accumulation of oil during seed filling depends on an unhampered supply of photoassimilates from the source, *i.e.*, foliage, to the sink, *i.e.*, seeds, located in the inflorescence, which is a disc-shaped head or capitulum. The seeds in the capitulum are arranged in spiral whorls and they mature progressively from the periphery to the center. Opening of all florets on a single head is usually completed in 10-15 days. Consequently, the development of seeds in each whorl of the inflorescence takes place under varying environmental conditions,

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which are expected to have a direct bearing on the seed quality, as in mustard (Munshi and Kochar, 1994; Munshi and Kumari, 1994), sunflower (Munshi *et al.*, 2003) and soybean (Guleria *et al.*, 2008). Poor seed set, which often occurs in the central region of the sunflower capitulum, may be due to competition between the peripheral and central seeds (Keiller and Morgan, 1988) for space on the receptacle tissue underneath the disc florets and to preferential sequestration of metabolites towards the seeds in the former positions (Steer *et al.*, 1988).

Storing of sunflower seeds from harvest to next planting is a real problem in sub-humid plains of northern India. The crop is usually harvested in summer and has to be stored through warm and humid monsoon period that results in the loss of viability and vigor (Tewari and Gupta, 1981). Seed usually lose their germinability during period of prolonged storage (Gidrol *et al.*, 1989). The problem of storage becomes more complicated when the seeds belong to different positions on the sunflower head. Sandhu *et al.*, (2006) have shown that seeds located in the peripheral region are fast-germinating, depleting the metabolites faster from cotyledons towards better development of embryonic axis in comparison with seeds located in central whorls of the sunflower head. This paper reports the results of physical and biochemical analyses of seeds located at different whorls of sunflower head. The analyses were conducted at maturity and after 180 days of storage.

MATERIALS AND METHODS

Sunflower (*Helianthus annuus* L. *cv.* PSFH 118) seeds were procured from the Oilseed Section, Department of Plant Breeding, Genetics and Biotechnology, Punjab Agricultural University, Ludhiana and University seed farm at Nabha, India. The crop was raised in a plot 9 m × 3 m in size, with 60 cm distance between rows and 30 cm between plants, following the recommended package of practices. The sunflower heads at maturity were brought to the laboratory. Seeds were removed from each whorl of the sunflower head and those from different heads were pooled separately. The seeds were air-dried by putting in cloth bags and thereafter stored in glass bottles at room temperature. The seed samples were drawn at 0 and 180 days of storage (DOS), in triplicate, and subjected to physical and biochemical analyses. The total seeds in each whorl were counted and kernels were separated from the hulls. Whole seeds, kernels and hulls were weighed separately. A weighed quantity of seeds was oven dried at 60°C for 48 h to constant weight. After drying, the tissue was immediately placed in desiccators before the final weight. A portion of separated seeds was crushed and boiled in several ml of isopropanol to inactivate phospholipases, then homogenized in 20 volumes (w/v) of chloroform/methanol (2:1 v/v) and stored at 0-4°C until used for lipid extraction. A portion of the tissue was put into boiling 80% ethanol and stored for carbohydrate analysis. Samples were divided into three replicates, each with duplicate observations. The extraction of lipids was done by the method of Folch *et al.* (1957). A suitable aliquot of lipid extract was evaporated to dryness to determine the lipid content by weighing. The methods used for the estimation of fatty acid composition and the extraction and estimation of starch, total soluble sugars and reducing sugars were similar as described earlier (Munshi *et al.*, 1990).

RESULTS AND DISCUSSION

The total numbers of seeds in the peripheral whorls were highest in the first to the third whorl and the number of seeds and number of the filled seeds decreased markedly from the peripheral to the central whorls. Correspondingly, the proportion of unfilled seeds increased from the peripheral to central whorls of the head and the ratio of filled to unfilled seeds decreased more than 10 folds from peripheral to the central whorls (Figure 1).

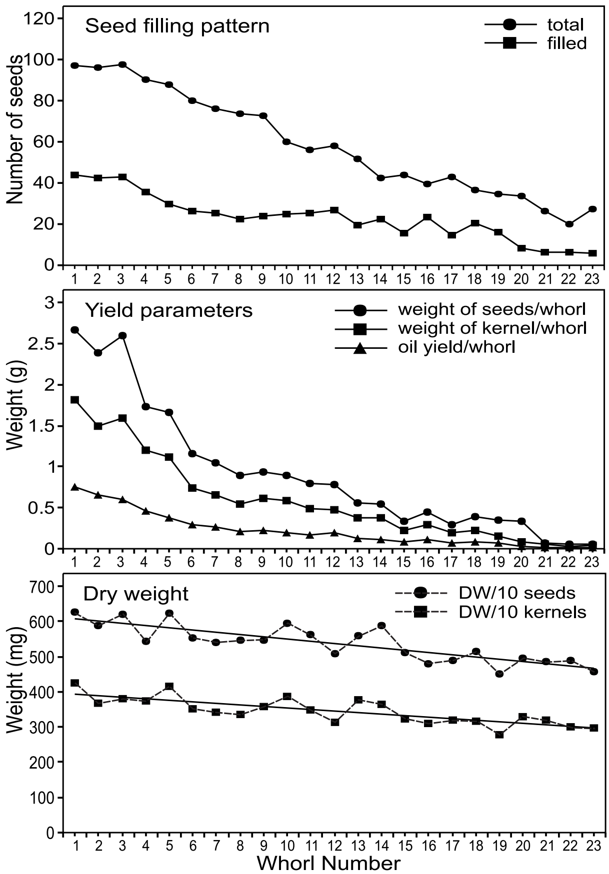

Figure 1: Seed filling patterns, yield parameters and dry weight of seeds/kernels located in various whorls of the sunflower head at maturity. Whorl number 1-23 stands for peripheral to central whorls.

The total weight of seed/whorl, total weight of kernels/whorl and total oil yield/whorl decreased significantly from the peripheral to central ones (Figure 1). This was probably due to longer maturation period and production of more filled seeds in the peripheral whorls of the head than in the central whorls. Similar observations were recorded by Sekhargouda *et al.* (1996) and Munshi *et al.* (2003). Alkio and Grimm (2003) showed that empty achenes are both structurally and functionally connected with receptacle tissue. However, empty achenes in the central whorls have been suggested to be due to constraints in the supply of water and assimilates or lack of space towards the center of receptacle tissue for the expansion of florets and developing seeds (Bettrano *et al.,* 1994). A hollow space was seen in the center of the capitulum when a vertical cut was made from the top down through the stem. Steer *et al.* (1988) claimed that seeds in all the central whorls achieved a larger size when competition from other whorls was reduced, implying that severe competition occurred between seeds under normal conditions.

The dry weight of seeds as well as kernels decreased from peripheral to central whorls (Figure 1), though the kernel percentage and hull percentage did not vary significantly (data not given) with the different whorls of sunflower head. Reduced availability of assimilates and late maturation of seeds in central whorls as compared with peripheral ones was most likely the cause of the decreased dry weight of the former seeds or kernels. Similar observations have been made by Ivanov *et al.* (1980).

The higher oil yield in the peripheral whorls (Figure 1) may be due to the environmental conditions and the longer span of seed development available for rapid oil filling and the corresponding formation of small and empty seeds in the central whorls. Looking at the process of anthesis, the opening of florets started from the peripheral whorls at a slow rate (one in 1-2 days) owing to a lower max/min (21/6.5°C) air temperature, and this rate was increased to two to three florets in a day in the central whorls of the sunflower head because of the increase in max/min (27/10°C) temperature. Thus, the seeds in the central whorls were growing in a higher environmental temperature than those in peripheral ones. Consequently, the seeds in the peripheral whorls have longer time available for rapid oil filling (10-12 days) than the seeds in the central whorls. A similar pattern of variability between various positions on the inflorescence has already been observed in developing and mature mustard seeds (Munshi and Kochar, 1994; Munshi and Kumari, 1994) and various nodal positions of soybean stem axis (Guleria *et al.,* 2007). Therefore, the environmental conditions at the time of anthesis and the period of seed development are expected to contribute significantly to dry matter and oil accumulation in seeds and also to the development of vascular connections in the receptacle tissue of the sunflower capitulum.

The dry matter content of the seeds on g/100g FW basis did not vary considerably from the peripheral to central whorls of the sunflower head (Figure 2). However, the expression of data on 10-kernel basis revealed a higher content in the peripheral whorls, which decreased towards central whorls (Figure 2).

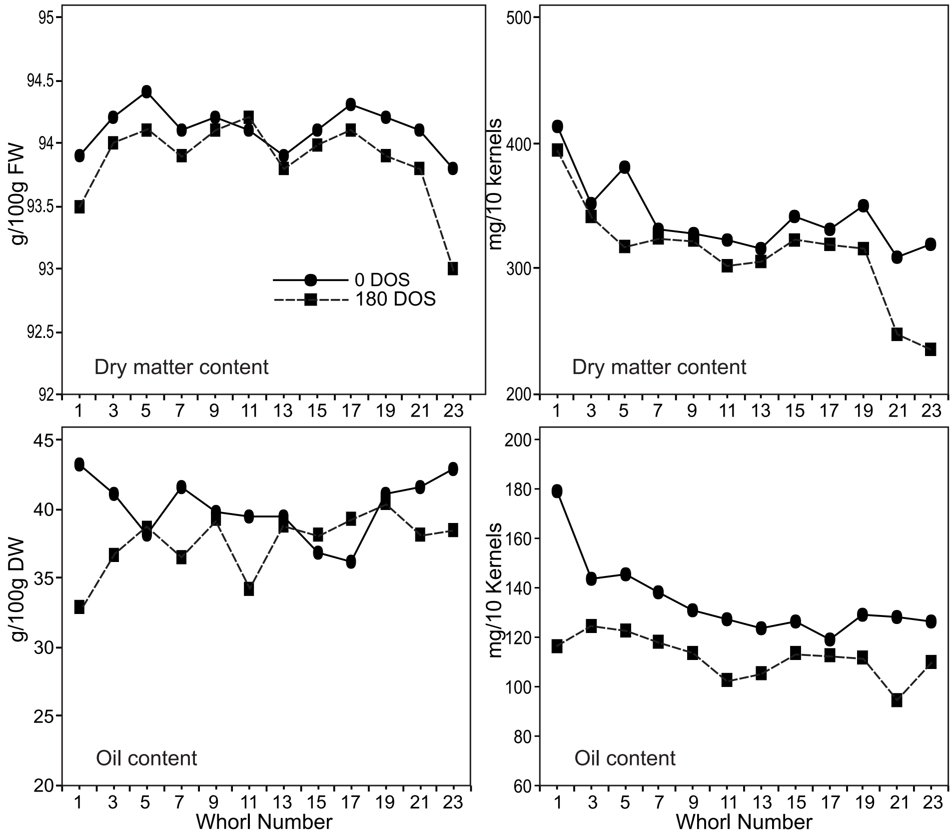

Figure 2: Effect of storage on dry matter and oil content of seeds located in various whorls of the sunflower head at maturity.

A similar trend of whorl-wise variation was followed after 180 DOS. These results are similar to those of Shekhargouda *et al.* (1996) and Karadogan *et al.* (1998). A decrease in dry matter content in 10 kernels from peripheral to central whorls of the sunflower head might be due to variability in seed filling during seed development at each whorl (Munshi *et al.*, 2003) as the seeds in peripheral whorls have longer time available for rapid seed filling than those in the central whorls as discussed above for seed/kernel weight. The values of dry matter decreased after 180 DOS in comparison to 0 DOS both when the data were expressed in g/100g FW and mg/10-kernel basis. Such decrease in dry matter content in sunflower kernels during storage was expected to be due to the presence of lipase and lipoxygenase enzymes during storage (Angelo and Ory, 1983; Kersie *et al.*, 1988). As a consequence of the higher proportion of unfilled seeds towards the central whorls of the sunflower head (Figure 1), the decrease of dry matter would further be intensified during storage.

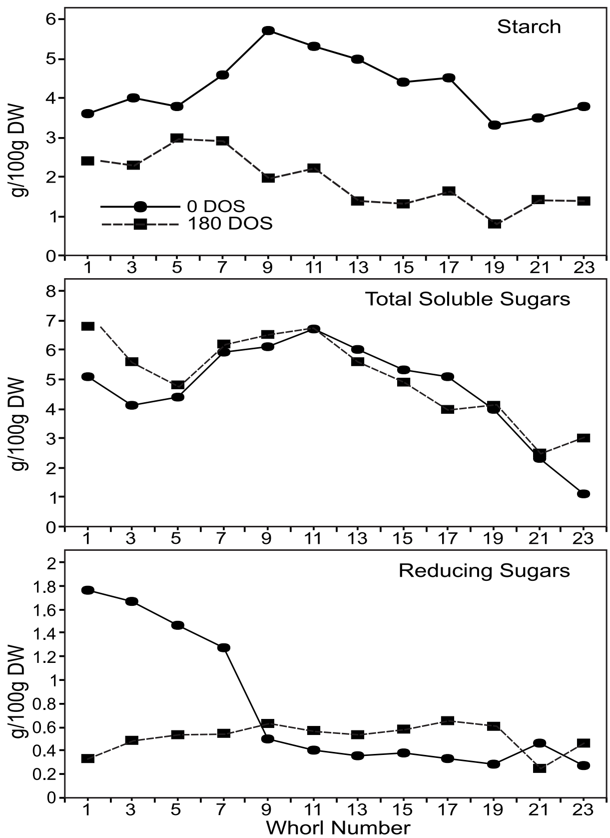

Figure 3: Effect of storage on starch, total soluble sugars and reducing sugars content of seeds located in various whorls of the sunflower head at maturity.

The seed oil content in different whorls of the sunflower head decreased from peripheral to central whorls when data were expressed on 10-kernel basis but did not vary much when expressed on dry weight basis (g/100 g dry weight), obviously because of the small seeds (less seed weight) in central whorls. Dharamlingam and Basu (1989) and Munshi *et al.* (2003) also reported that the dry matter and oil-filling patterns are influenced by seed position in the whorls of the sunflower capitulum. The seeds in peripheral positions showed a double sigmoid pattern of oil accumulation in comparison with a sigmoid pattern shown by the seeds in the middle and central positions on the sunflower head (Kaushal, 2000). The oil content on 10-kernel basis showed a significant decrease at all positions on the sunflower head during storage from 0 to 180 DOS (Figure 2). This decrease in lipid content between seed positions in the whorls and during storage for six months is suggested to be due to factors explained in earlier discussions (Steer *et al.*, 1988; Alkio and Grimm, 2003) and additionally, to lipid degradation during storage (Kersie *et al.*, 1988).

In order to ascertain the pattern of assimilate supply during seed development between different whorls on sunflower head, determinations of starch and soluble sugars in kernels were consisted which revealed a decrease from peripheral to central whorls except some rise from fifth to ninth whorl and a spurt decrease in reducing sugars content from first to ninth whorl and up to central whorl at maturity. The starch content decreased and total soluble sugars increased from first to ninth whorl during storage of seeds for 180 days as compared with 0 DOS. The content of reducing sugars decreased in peripheral whorls (first to ninth) and increased from ninth to twenty-third whorl during storage from 0 to 180 DOS. The increase in total soluble sugars at 180 DOS in peripheral whorls of the sunflower head might be due to the degradation of oligosaccharides including starch into soluble sugars during storage (Locher and Bucheli, 1998). The low levels of starch and soluble sugars in the central whorls of the sunflower head might be due to the limited period of seed filling available at these positions during seed development while the decrease of starch during storage might result from degradation by α-amylase during storage (Thomas, 1979). Thus, the data on carbohydrates suggested that the assimilate supply to central whorls was poor and it lasted for a limited seed-filling period, the associated metabolism depriving the seeds of the precursors for lipid accumulation contributing to poor storability of seeds.

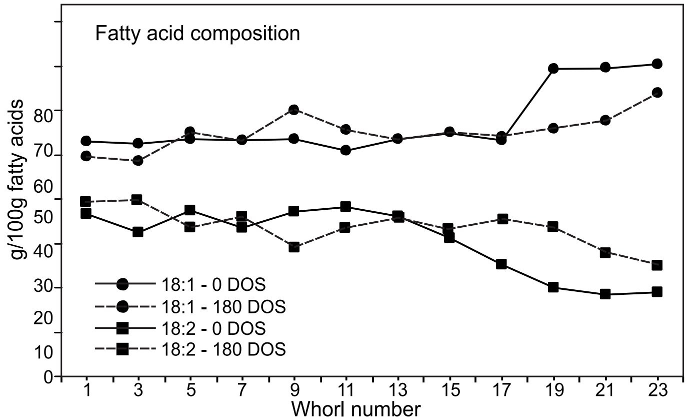

Figure 4: Effect of storage on fatty acid composition of seeds located in various whorls of the sunflower head at maturity.

The proportion of oleic acid increased and that of linoleic acid decreased correspondingly in the seeds in central whorls of the sunflower head (Figure 4). However, the proportions of palmitic and stearic acids did not show much variation with whorl position of the seeds (data not given). The decrease in linoleic acid might be due to slowed down desaturation reactions in the central whorls of the sunflower head in comparison with peripheral whorls. However, the storage of seeds of central whorls for 180 days lowered the proportion of oleic acid while increasing that of linoleic acid in comparison with 0 DOS which might be due to desaturation of oleic to linoleic acid (Figure 4). This implies that the seeds in central whorls are trying to maintain membrane integrity during storage, but not to the extent of peripheral whorls, as linoleic acid is an integral membrane component (Ichihara and Noda, 1981) and also superimposes the lipoxygenase activity during storage (Kersie *et al.*, 1988).

CONCLUSSION

The above data suggested that the seeds in the peripheral whorls are more productive in terms of various yield parameters and quality attributes in comparison with those in central whorls. Additionally, the storability of seeds from peripheral whorls was better than that of seeds from central whorls. The results indicated that it is necessary:

1. to enhance the oil filling in central whorls of the sunflower head during seed development phase by applying growth regulators, to encourage assimilate transport towards the seeds in central whorls,
2. to enhance the storability of seeds from time of harvest to next sowing, *i.e.*, to achieve increased viability of seeds, and
3. if possible, to harvest seeds from peripheral whorls separately from the rest of the sunflower head in order to achieve higher storability until next sowing.

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CARACTERÍSTICAS FÍSICAS Y COMPOSICIÓN BIOQUÍMICA DE SEMILLAS INFLUENCIADAS POR SUS POSICIONES EN DIFERENTES CÍRCULOS FLORALES DEL CAPÍTULO DE GIRASOL - EFECTO DEL ALMACENAMIENTO

RESUMEN

Se estudió el efecto del almacenamiento sobre la composición bioquímica de semillas de girasol localizadas en diferentes círculos florales del capítulo a madurez. La proporción de granos llenas, parámetros del rendimiento como peso de grano, pepita y aceite y peso seco de granos y pepitas decrecieron de la periferia hacia los círculos florales del centro del capítulo. La materia seca y contenidos de almidón y aceite decrecieron después de los 180 días de almacenaje a temperatura ambiente. El contenido total de azúcares solubles se incrementó mientras que el contenido de azúcares reductores decreció en los círculos florales periféricos desde la posición primera a novena durante el almacenamiento por 180 días. El almacenamiento de semillas localizadas en los círculos florales centrales disminuyó la proporción de ácido oleico con el correspondiente incremento en ácido linoleico después de 180 días. Por lo tanto, las semillas localizadas en los círculos florales periféricos fueron más productivas y mejores para propósitos de almacenamiento que aquellas en los círculos florales centrales.

CARACTÉRISTIQUES PHYSIQUES ET COMPOSITION BIOCHIMIQUE DE LA GRAINE DÉPENDANT DE SA POSITION SUR LE CAPITULE DU TOURNESOL - EFFET DE L'ENTREPOSAGE

RÉSUMÉ

L'effet du stockage sur la composition biochimique des graines provenant de différentes spirales du capitule de tournesol à maturité a été étudié. La proportion de graines remplies, des composantes du rendement comme le poids de graines, d'amandes, et d'huile par spirale le poids sec des graines et des amandes décroît de la périphérie du capitule vers le centre. La matière sèche, la teneur en, huile et en amidon décroît après 180 jours de stockage à température ambiante. Le stockage des graines situées dans les spirales centrales a diminué la teneur en acide oléique avec une augmentation correspondante de la teneur en acide linoléique, après 180 jours. Ainsi, les graines situées dans les spirales périphériques ont été plus productives et plus adaptées au stockage que celles situées dans les spirales centrales.