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Oil and fatty acid distribution in different circles of sunflower head

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ABSTRACT

Prevailing temperature at anthesis influences pollen health, fertilisation, seed filling, oil and fatty acid accumulation in different circles of sunflower head. Field experiments were conducted, during 2007 and 2008, at Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan, to document oil and fatty acid distributions in different circles of sunflower head. Hybrid S-278 was planted in randomised complete block design with a two factors factorial experiment, with four replications. At maturity, heads were divided into three equal circles (outer, middle and central); thereafter, oil and fatty acid distributions were separately determined in each circle. Oil and fatty acid concentrations in three circles differed significantly. The outer circle accumulated high oil and oleic contents which decreased to a minimum in the central circle; however, linoleic acid consistently increased, from outer to central circle, during both the years.

1. Introduction

Sunflower oil extracted from achenes is commonly used in food, as a frying medium, and in cosmetic formulations, as an emollient. Oil is light in taste and appearance. It is a combination of mono-unsaturated and polyunsaturated fats with low saturated fat levels. Oil is liquid at room temperature. Fatty acid composition is a major determinant of oil quality, mainly with good percentages of oleic and linoleic acid. Fatty acid composition is mainly affected by genotypes and environmental conditions, temperature having a major influence on oil quality (Izquierado, Aguirrezabal, Andrade, & Pereyra, 2002).

Sunflower is a temperate crop but it can perform well under various climatic and soil conditions. It is a short duration crop maturing in 100–120 days. Temperature is a major environmental factor that determines the rate of plant development. Fluctuations in temperature and moisture availability affect the quantity and quality of oil accumulation (Hassan, Manaf, & Ejaz, 2005). Variation in unsaturated fatty acids profile is strongly influenced by both genetics and climate. Demurin, Skoric, Veresbaranji, and Jocic (2000) concluded that oleic acid content is essentially influenced by temperature during seed development; each 1 °C increase of temperature leads to about 2% increase of oleic acid. Oil and fatty acid composition in seeds are important targets in sunflower breeding.

A completely developed head usually has a small circular depression in the centre while middle and outer whorls are flat. Anthesis (pollen shedding) begins at the periphery and proceeds to the centre of the head (Putnam et al., 1990). Similarly, maturation of sunflower seeds takes place from the perimeter to the centre of sunflower head and seeds maturing at higher temperature would accumulate higher oil content (Weiss, 2000). Different whorls within a head fertilise and mature differently (Alkio, Diepenbrock, & Grimm, 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 Pereira, Trapani, & Sadras, 1999).

Munshi, Kaushal, and Bajaj (2003) studied the physiochemical properties of seeds located in different whorls of sunflower head and concluded that the proportion of filled seeds decreased from outer to central whorl. A 10-fold decrease in filled to un-filled seed ratio was observed, due to which oil content was higher in the outer than in the middle and central whorls. The higher oil content in the outer whorl 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 to the sink. Similarly, Alkio and Grimm (2003) observed poorly developed or un-filled achenes in the central part of the sunflower head. They further concluded that, before fertilisation and seed filling, assimilates and nutrients are required for floret development and flowering. Following anthesis, if no fertilisation occurs 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. Vascular bundles originating from the stem run radially toward the periphery of the capitulum and from there toward the centre of the capitulum. The occurrence of empty achenes is

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highest in the centre of the capitulum and poor seed filling is related to poor vascularisation of receptacle; thus, oil and oil quality are affected more in this portion of the head (Goffner, Cazalis, Percie du sert, Calmes, & Cavalie, 1988).

At the time of achene maturity, heavier seeds were observed in the outer region, probably due to the early maturation and production of more filled seeds in the peripheral zones (Baydar & Erbas, 2005). Although quite abundant literature is available on breeding, agronomic, physiological and quality aspects of different hybrids grown in different parts of the world, information related to distribution of oil and fatty acids in different circles of sunflower head is scarce. The present study was designed to document how seed position affects oil and fatty acid accumulation in different circles of sunflower head.

2. Materials and methods

2.1. Field experimentation and soil status

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, during 2007 and 2008. The soil of the experimental site was loam-type in texture with class typic camborthids having sand 43%, silt 46% and clay 11%, pH 7.4 and EC 0.66 m S cm^{-1}. Available NPK concentrations in the soil before sowing were 300, 5.00 and 140 mg kg^{-1}, respectively.

2.2. Soil preparation and sowing methodology

Prior to sowing, the particular site was fallow during the winter and was prepared for sowing by giving one soil-inverting plough and, thereafter, ploughed thrice with a tractor-mounted cultivator and planked with the last ploughing. The recommended dose of fertiliser 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. Crop was sown on 18th March, 2007, and 20th March, 2008. Sowing was done with a dibbler, by putting two seeds at each pre-marked spot. Plant to plant distance was maintained 25 cm, and row to row 75 cm, in a net plot size of 5×3 m^2. The sunflower hybrid S-278 was sown by using seed at 5 k/ha. After complete emergence, one plant was maintained per hill. Weeds were kept under control by hand-weeding throughout crop life cycle.

2.3. Data recording and treatments

Ten randomly selected heads from central rows in each plot and three replications were harvested on the 8th of July, 2007 and the 11th of July, 2008 and sun-dried for five days. Heads were equally divided (Fig. 1) into three circles Outer (O), middle (M) and central (C). The two years (2007 and 2008) were considered as factor A and three equal circles (outer, middle and central), thus making three treatments, as factor B. Meteorological data during the course of the experiment were also recorded (Table 1).

2.4. Oil extraction and fatty acid determination

Achenes from each circle were separated by hand. Achenes from each circle were separately analysed for oil content by NMR, Model MQA-7005, Oxford Institute, USA, by standardising the equipment with six different oil contents (samples previously analysed). Thus oil contents in each circle were recorded (Warnsely, 1998). The fatty acids in oil were analysed 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). Oil samples (50 μl) were methylated

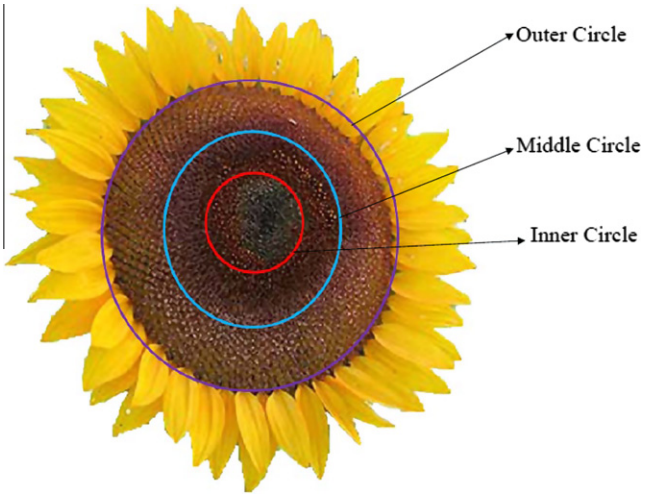

Fig. 1. Circles of sunflower head.

in 4 ml of 1 M KOH for one hour at room temperature. The resultant fatty acid methyl esters (FAME) were extracted with high performance liquid chromatography-grade hexane and analysed by GC using a fused capillary column (WCOT fused silica 30 m × 0.25 mm coating CPWAX 52 CBDF = 0.25 μM, CP8713), a flame ionisation detector (FID) and nitrogen gas as carrier (3.5 ml/min). FAMEs were injected manually. Fatty acids were detected by chromatographic retention time and by comparison with authentic standards (Paquot, 1988).

2.5. Statistical analysis

The collected data were subjected to statistical analysis by using analysis of variance with the help of MSTATC, separately for both the years (Freed & Eisensmith, 1986). Least significant difference (at 5% probability) was used to compare the means (Montgomery, 2001). Multiple regression analysis was performed by using STATGRAPHICS software while Box-and-Whisker plots were generated by using original recorded data (StatPoint Technologies Inc., 2009).

3. Results

3.1. Oil content

Oil content consistently decreased from outer to central circle during both the years. Statistical differences for oil content were recorded among circles for both the years, 2007 and 2008 (Table 2). The maximum oil content (48.87%) was obtained from the outer circle which was statistically ($p < 0.05$) similar to the middle circle (47.55%) but statistically ($p < 0.05$) different from the central circle (45.19%). Comparison of the years showed statistically non-significant differences for oil content. Interactions of years × circles were statistically significant. The outer circle accumulated the maximum (48.85%, 47.70%) oil contents during both years of experimentation, respectively, while the central circle gave the minimum (44.26%, 46.12%) values during the two years, respectively. Similarly, the output of the multiple linear regression model to describe the relationship between oil contents and two independent variables, i.e. years (Y) and sunflower head circles (C), depicted a negative relationship (Oil content = $50.285 - 0.13 \times Y - 1.5425 \times C$). Since the p-value was less than 0.05, a statistically significant relationship existed between the variables. The R-Squared and adjusted R-squared statistics indicated 51.08% and 44.56% variability in oil content, respectively, with standard error