Review Paper

Influence of Climatic Conditions on Chemical Configuration of Seeds in Safflower, Soybean, Linseed and Sesame.

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Abstract: The present review article is very helpful to understand the effect of environmental factors on minor oilseed crops. Environmental factors play a vital role during the growing stages of crops and eventually influence the chemical composition of seed. Temperature during growth stages, planting time, irrigation, rainfall, fertilizers, growing season and soil type affect chemical composition of different oilseed crops. Oil content and protein content are specially influenced by prevailing environmental conditions during maturity and post flowering period. Drought stress at flower blossoming and seed development stages reduces oil content and un-saturated fatty acids, while increases saturated fatty acids and protein in safflower. High temperature during seed development stage reduces oil percentage and increases protein content in safflower. Genotype and location has significant effect on protein content, oil percentage and unsaturated fatty acids, as linoleic acid, oleic acid and linolenic acid in soybean. Oil content and oleic acid increase while protein, linoleic and linolenic acids decrease in early sown soybean. Due to drought stress, protein content increases while oil content decreases in soybean. Pod position also affects protein, oil and iso-flavon contents of soybean. Temperature differences after flowering express immense impact on content and composition of the linseed oil. Late sowing decreases oil content in linseed while cool temperature, adequate moisture and long day length during and after flowering stage increase the grain yield, quality and quantity of oil content. Oil percentage and configuration in sesame is effected by soil type, genetic, climatic and agronomic factors as well as growth stages of plant.

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Introduction:

The minor oilseed crops contribute an important portion in the local oilseed production of Pakistan. During 2013-14, the total availability of edible oil in Pakistan was 3.20 million tonnes. Out of which 0.573 million tonnes of edible oil was locally produced while 2.627 million tonnes edible oil or oilseeds was imported from different countries. The total import bill during 2012-13 was Rs.246.895 billion (US$ 2.50 billion). *Economic Survey of Pakistan, 2014-15.*

Environmental conditions influence crop growth and development which are the most vital factors to reduce the crop productivity (Franklin *et al.,* 2010). Environmental factors during flowering stage and grain development period affect quality and productivity of oilseed crops (Ali *et al.,* 2009 and Monotti, 2003). Plants growth and development have key importance for the production of crops, depends upon Climatic conditions. Climatic conditions at the time of flowering and seed development effect seed weight and its chemical composition in different oilseed crops (Mustafa *et al.,* 2015). Genotypes behave differently under different climatic situations (Qadir *et al.,* 2006). Fatty acid profile of oil varies according to the climatic situations (Strecker *et al.,* 1997; Pritchard *et al.,* 2000; Roche *et al.,* 2006). Environmental conditions also effect the accumulation of saturated fatty acids (Roche *et al.,* 2006; Izquierdo and Aguirrezábal, 2008). The effect of heat on the fatty acid composition of the seed oil has been observed in various oilseed crops, including flax (Yermanos and Gooden, 1965; Green, 1986) and soybean (Martin *et al.,* 1986). Fatty acid composition is also effected by ecological factors other than heat, such as solar radiation (Santalla *et al.,* 1995), precipitation (Pritchard *et al.,* 2000), nitrogen concentration (Steer and Seiler, 1990), salt stress (Irving *et al.,* 1988) and plant vigor (Zimmer and Zimmerman, 1972). Post-flowering temperatures mainly effect the fatty acid profile of different oilseed crops (Pritchard *et al.,* 1999). The fatty acid configuration in different oilseed crops is effected by the temperature prevailing during seed maturation (Hilditchand Williams, 1964). Inconsistent ecological conditions may result in wide variation in oil quantity and composition in different oilseeds (Shafii *et al.,* 1992). Prevalence of lower temperature at the time of maturation resulted in an increase in polyunsaturated fatty acids in oilseed plants (Nykter *et al.,* 2006). Every rise of 1ºC in temperature leads to about 2% increase of oleic acid (Demurin *et al*., 2000).

Temperature is an important environmental factor affecting the fatty acid composition of different plant portions like seeds (Tremolieres *et al.,*1978), roots (Simolenka and Kuiper, 1977) and leaves (Wilson and Crawford, 1974). Temperature differential has strong influence on proportions of different fatty acids (Matsuzaki *et al.,* 1988) and molar proportion of oleic acid increased and that of linoleic and linolenic acid decreased as temperature increased. Tocopherol content in the oil of soybean (Izquierdo, 2007) depicted inverse relationship with the quantity of sun rays intercepted per plant during seed development stage.

Climatic conditions, water and nitrogen availability mainly during the seed-filling stage account for most of the variations than due to genotype differences in grain protein concentration (Cooper *et al.,* 2001). Oil and protein are two major components of seeds in oilseed crops and are affected significantly by environmental stresses (Dehnavi and Sanavy, 2008). Up to 17% decrease in yields of soybean for 1˚C rise in temperature above the optimum is reported in the United States during growing season (Lobell and Asner, 2003). Big quantity of oil is stored in embryonic tissues (cotyledons) and occupy the space between the integuments of the seed in most oilseed crops including soybean, linseed and safflower (Baud and Lepiniec, 2010).

Safflower

Seed filling pattern of Safflower (*Carthamus tinctorius* L.) affected by seasonal variations and relationship with other agronomic characters were studied by Koutroubas and Papakostab (2010). Plants grown-up under Mediterranean environment subjected to biotic and abiotic stresses throughout the seed development stage reduce their productivity. Seasonal distinction was pragmatic only for seed development period that was mostly resolute by the sink size, as it was particular by the number of seeds per head. Seed yield and seed oil yield were considerably connected with seed filling. Likewise, Alizadeh, (2005), studied Safflower germplasm by some agronomic characteristics. Results showed that number of seeds per head and plant height had recognizable correlation with grain yield, safflower seed-husk ratio decreased from outer to inner side in head. The positional allocation of linolenic acid in Triacylglycerol arranged from the immature seeds of safflower 2 days after flowering and from the leaves was unusual. Triacylglycerol was quickly accumulated (14–18 days after flowering). Diacylglycerols and compound lipids reached the highest rate of synthesis 15 days after flowering, and then a maximum incorporation into triacylglycerol occurred 18 days after flowering (Ichihara and Manjiro, 1980). Fatty acid composition of the oil from developing seeds of diverse varieties of safflower was studied by Gecgal *et al*., (2007).

Zinc and manganese foliar applications significantly increased percentage of palmitic and oleic acids whereas decreased for linoleic acid. Flowering stage is more sensitive to drought than vegetative or grain filling stages. Drought stress during flowering stage imposed the most damage to oil percent and yield and also decreased linoleic acid content and increased stearic and oleic acid content. Foliar application of zinc and manganese can compensate the negative effects of drought on safflower (Dehnavi and Sanavy, 2008). 60 to 70 percent of total oil in safflower seeds is produced at a 22-days period after flowering (Sharma *et al*., 1995). Drought stress at flowering stage resulted in decreasing the un-saturated fatty acids and increasing the saturated fatty acids, while drought stress at seed filling period had no significant effect on seed oil content in safflower. Palmitic acid content was increased and oleic acid content was decreased by drought stress while foliar spray of potassium increased the oleic acid content of oil (Dehnavi and Sanavy, 2008). Application of zinc sulfate increases seed oil and protein content in Indian mustard (Sultana *et al*., 2001).

Drought stress decreased the oil percentage, oleic acid and linoleic acid concentrations of the seeds while it increased the protein percentage, palmitic acid and stearic acid in safflower seeds (Mohsennia and Jalilian, 2012). Safflower oil contains the saturated fatty acids: palmitic (C16:0) and stearic acid (C18:0) and the unsaturated fatty acids: oleic (C18:1), linoleic (C18:2) and linolenic acid (C18:3) (Camas and Esendal, 2006). Safflower seed oil contains about 71–75% linoleic acid, 16–20% oleic acid, 6–8% palmitic acid, and 2–3% stearic acid (Velasco and Fernandez, 2001). There are 35-50% oil, 15-20% protein and 35-45% hull fraction present in safflower seed (Rahamatalla *et al.,* 2001). Oil contents of Safflower increase significantly with seed development, reach to maximum at 30 DAF and then decrease gradually (Rahmatalla *et al.,* 1998).

Sowing date and genotype showed significant effect on yield and oil content. Delayed sowing decreased yield (Mackinnon and Fettel, 2003). Thin crop density results in lower yield while thick crop and less weeds result in higher yield (Bilgili *et al.,* 2003; Lythoge *et al.,* 2001). Different sowing dates caused flowering and grain filling to occur at different temperature, radiation, and day length (Mirshekari *et* *al.,* 2013). Rise in temperature and water deficit condition during seed development stage was a major reason of reduction of oil content and thus increased protein content due to late sowing (Hocking and Stapper, 2001). Sowing date can affect oil percentage and fatty acid composition at the time of seed development (Samanci and O¨zkaynak, 2003). The ratio of oleic and linoleic acids in seed oil is mainly dependent on climatic conditions, especially humidity and temperature, during seed development stage (Gecgel *et al.,* 2007).

Water deficit stress generally results, reduction in plants size, less branches, reduce seed yield and oil percentage consequently leading to lower oil yield. Water deficiency during grain development stage in spring safflower genotypes significantly decreased seed and oil yields in arid and semi-arid regions (Pasban E. 2011). Gecgel *et al.* (2007) revealed that during flower initiation to seed maturity stage, oil percentage and the four major fatty acids in safflower grains were influenced by sowing dates, and the availability of water, resulted in high oil percentage. Ensiye and Khorshid (2010) reported that both oil percentage and the oil fatty acid configuration showed significant differences in relation to the water availability, sowing date and genotype. Sowing date has an expressing impact and determining of appropriate sowing date is one of the most perilous factors for high safflower productivity (Yau, 2007, Yarnia *et al.,* 2011).

Soybean

Soybean is important oil crop with 18-22%oil and 35-40% protein. It is known as the main source of plant oil and protein with highest acreage in the world (Maleki *et al*., 2013). About 90% of the world's soybean grows under rain fed areas characterized by high temperature and low or erratic rainfall (Thuzar *et al.,* 2010). Soybean 60% dry weight is composed of protein and oil, which rank it 1st for protein content and 2nd for oil content among other cereal and legume crops (Liu, 1997). Soybean oil consists of averages 12% palmitic acid (16:0), 4% stearic acid (18:0), 23% oleic acid (18:1), 53% linolenic acid (18:2), and 8% linolenic acid (18:3). The 16:0 and 18:0 fractions are saturated fatty acids and constitute 15% of the soybean oil. The remainder of the oil (about 85%) is made up of unsaturated fatty acids or 18:1, 18:2, and 18:3 (Lee *et al.,* 2007). Protein contents in seed are very important for both feed and food utilization of soybean (Vollmann *et al.,* 2000).

Growing season significantly influence protein content in soybean (Vollmann *et al.,* 2000). Genetic and environmental factors are major determinants of grain yield, protein and oil concentration of soybean (Wolf *et al.,* 1982, Maestri *et al.,* 1998). Intercepted radiation showed no impact on seed oil percentage in soybean (Andrade and Ferreiro, 1996). During the grain filling stage, average to high protein content was recorded with high temperature and moderate rates of rainfall whereas seed protein content was drastically reduced in seasons of insufficient nitrogen fixation or higher amounts of precipitation (Vollmann *et al.,* 2000). The proportion of small seeds predominated at the basal portion while large seeds was higher at the apical portion of the soybean stem axis. The contents of lipids, starch, soluble sugars and soluble proteins were higher in large seeds as compared to those in smaller ones. The percentage of membrane lipid components, on a 10-kernel basis, was higher in large seeds (Guleria *et al*., 2008).

Seed oil (16%) and oleic acid (22.8%) increase while protein (6.6%), linoleic (10.9%) and linolenic acids (27.7%) decrease in early sown soybean than late planting under irrigated conditions (Bellaloui *et al.,* 2011). Late sowing of soybean resulted in higher level of sucrose and raffinose while lower the stachyose as compared with early sowing (Bellaloui *et al.,* 2011). Sowing date and irrigation have a significant impact on grain protein, oil, unsaturated fatty acids and sugars (Bellaloui *et al.,* 2011). Oil percentage increased with early sowing (Pedersen and Lauer, 2004; Kane *et al.,* 1997; Helms *et al.,* 1990). Protein percentage increased and oil percentage decreased with late sowing (Kane *et al.,* 1997; Helms *et al.,* 1990). Palmitic and linolenic acids may decrease with late sowing date, but stearic acid may increase and this may be due to temperature changes during seed maturation at late sowing (Wilcox and Cavins, 1992). Oleic acid levels rose while the linoleic and linolenic acid decreased when soybeans were cultivated in hot environments (Carver *et al.,* 1986). Temperature may affect oleate and linoleate desaturases (Burton, 1991), decrease oleyl and linoleyl desaturase activities at 35°C (Cheesbrough, 1989), decrease ω-6 desaturase enzyme, encoded by the FAD2-1A gene, and desaturases degraded at high growth temperatures of 30°C (Tang *et al.,* 2005).

Seeds developed at the base part of soybean plant had large pod size and pod width than those developed at the top part of plants (Al-Tawaha, 2010). Environmental factors can affect the seed development and affect its composition (Cook, 2008). Adverse environmental conditions such as low temperature and high rainfall prevailing in northern regions of Europe reduce protein content (Vollmann*et al.,* 2000). Seed protein content in the Western and Eastern Corn Belt was clearly found lower than in southern regions of production over a number of seasons in USA (Hurburgh, 1994). Nian *et al.,* (1996) reported low protein content in the northern locations of north-east China and in northern sites of Europe, due to big seasonal changes (Schuster and Boehm

1981). Protein content showed significant negative ($P < 0.01$) while oil content ($P<0.05$) exhibited positive correlation with latitude (Kumar *et al.,* 2006). Vollman *et al.,* (2000) showed that during years of small rainfall and high temperature, protein synthesis was higher than oil synthesis in soybean grains. Soil moisture level affects protein while the timing with respect to maturity of irrigation controls oil content (Foroud *et al.,* 1993). High rainfall during the grain filling stage may increase the oil percentage in soybean (Vollman 2000). Sucrose and stachyose level were affected by the environment and content of both decreased with increasing temperature in soybeans, with sucrose showing the steepest level of decline per degree increase (Wolf *et al.,* 1982).

Protein and oil content of soybean is determined by genotype and environmental factors and the stage of maturity of the grain (Wolf *et al.,* 1982; Maestri *et al.,* 1998; Baydar and Sabri, 2005). Composition of soybean seed depends upon the climatic conditions prevailing during seed development stage when seed chemical components accumulation takes place (Wolf *et al.,* 1982; Wilson, 2004; Carrera *et al.,* 2009, 2011). The relationship of protein contents with temperature (Piper & Boote, 1999; Wilson, 2004) and water availability (Rose, 1988; Boydak *et al.,* 2002; Kumar *et al.,* 2006; Carrera *et al.,* 2009) has been studied. Higher temperature favors the accumulation of sulphur amino acids, methionine and cystine (Wolf *et al.,* 1982). Soybean from Northern zones of the United States are cooler than central and southern zones showed lower essential, nonessential and total amino acid content (Grieshop and Fahey 2001 and Karr-lilienthal *et al.,* 2005). Application of nitrogen fertilizers at different growth stages has no effect to increase the protein or oil percentage of soybean (Singh *et al.,* 2001; Schmitt *et al.,* 2001; Wesley *et al.,* 1998). Rainfall exhibited a negative correlation with protein content. Daily mean temperatures during seed filling showed a positive correlation with protein and a negative correlation with oil and linolenic acid. Genotypic, locational and genotypic-locational interactions were found to be significant for protein, oil and unsaturated fatty acids, namely oleic acid, linoleic acid and linolenic acid (Kumar *et al.,* 2006). Increasing water stress at reproductive stages resulted in an increment in protein content but oil percentage decreased. Seeds present at upper position of the canopies showed higher oil and protein content than those from middle and lower parts under all irrigation treatments (Ghassemi-Golezani and Lotfi, 2013). Water deficiency has little effect on seed protein content in soybean (Thompson 1978) while Hobbs and Muendel (1983) reported that drought stress increases protein content in soybean. At reproduction stage drought stress results in decreased grain size in soybean (Momen *et al.,* 1979; Kadhem *et al.,* 1985). Bravedan and Egli (2003) reported significant decrease (39%) in yield due to fewer and smaller grains if short period of water stress occurs during grain filling of soybean.

Seed position on mother plant is an important factor influencing grain quality (Ghassemi-Golezani and Lotfi, 2013). It may result in differences within-plant and account for part of the variation in physical (weight, shape) or physiological (germination and vigor) seed attributes (Illipronti 2000). Variation in protein content is reported among different nodes of same plant and protein content was lowest in the basal node grains and increases toward the apical nodes in soybean plants (Escalante and Wilcox 1993). Seed protein, oil quality and quantity of soybean showed significant variation with node position (Collins and Cartter, 1956; Escalante and Wilcox, 1993). Indeterminate cultivars depicted more oil content in seeds from lower nodes than seeds on the upper nodes, while in the case of determinate cultivars oil content was highest in seeds from terminal nodes (Collins and Cartter, 1956). Seed from the middle nodes on determinate cultivars had higher oil and lower protein than seeds from either the top or bottom of the plants (Collins and Cartter, 1956). Lowest nodes in both determinate and indeterminate types of soybean showed lowest seed protein concentration. Linear increase in protein concentration from 397 g kg^{-1} at the lowest node to 442 g kg^{-1} at the highest node in determinate and increased from the lowest (398 g kg^{-1}) and increased progressively through 14 in indeterminate, with no significant differences between nodes 12 and 16 (Escalante and Wilcox, 1993). Concentration of S in soybean leaves decreases during grain filling (Sweeney and Granade, 1993, Sexton *et al.,* 1998) as does N/S ratio (Sweeney and Granade, 1993).

The oleic acid concentration increased from 45.4 to 93% in the top node seed, while oil content and linolenic acid decreased from 14.4 to 26.8% and 5.7 to 34.4% respectively in the top node seed depending on the cultivar. The fully expanded leaves at R5-R6 growth stage showed higher protein and oleic acid concentration, higher nitrate reductase activity, chlorophyll concentration and nitrogen (N) and sulfur (S) percentages in the top node seeds. Seed protein, oil and fatty acids in nodes along the plant depended on the position of node on the main stem, cultivar differences, seed N and S status, and tissue N and S partitioning. Top nodes with higher nitrate reductase activity exhibit high protein and oleic acid (Bellaloui and Gillen, 2010).

Wilcox and Shibles (2001) reported that increase in protein caused decrease in oil and carbohydrates. Of the carbohydrates, sucrose decreased the most with an increase in protein. Temperature during the growing season has an effect on the composition of soybean seeds. Variation in temperature caused changes in soybean oil and carbohydrate contents in controlled growth chamber studies but protein was not affected by temperature changes. Starch and soluble sugar contents decreased with increased temperature and dramatic decreases occurred when the mean air temperature is greater than 20° C (Piper and Boote, 1999; Thomas *et al.,* 2003). Sucrose concentration decreased by 56% with a 15° C temperature increase and stachyose showed a slight reduction while other sugars remained unchanged. Oil content showed positive correlation with temperature (Wolf *et al.,* 1982). Oil content is enhanced with daily average temperature up to approximately 28 °C and decreases with higher temperature in soybean (Piper and Boote, 1999; Thomas *et al.,* 2003).

Water stress influence soybean seed composition by increasing the amount of protein and decreasing the amount of oil in the seed of the severely drought stressed plants (Dornbos and Mullen 1992). Foroud *et al.,* (1993) reported a decrease in protein content of soybean under moisture stress. All cultivars produced smaller seed size with lower protein and higher seed oil, free sugar and sucrose content compared with the same soybean grown in an average year (Poysa and Woodrow, 2002). Sucrose concentration was not affected by water stress in field or greenhouse trials (Egli and Bruening, 2004).

Soybean plant shifts from vegetative to reproductive stages due to changes in length of darkness. Flower initiation in soybean is influenced by temperature. High temperatures during the vegetative period can cause earlier flowering (Elmore and Flowerday, 1984). Late sowing results in reduction in grain yields (Anderson and Vasilas, 1985; Trostle and Bean, 2001). Planting date can influence the composition of soybean seeds. Planting date affects oil content in three Maturity Group II soybean cultivars as revealed by four-year study in Wisconsin conducted by Pedersen and Lauer (2003). Early sown crop showed higher oil content at one location while planting date does not affect oil content at other location. Soybean seed protein content is not influenced by sowing date of the crop (Kane *et al.,* 1997 and Helms *et al.,* 1990).

Planting location can affect the composition of soybean seeds especially protein and oil content (Helms *et al.,* 1998). Effect of location was not significant on sugar content of soybean seeds (Geater and Fehr, 2000) and Cober *et al.,* (1997); however, Geater *et al.,* (2000) reported significant effect of location on sugar content. Carrao-Panizzi *et al.*, (1999) reported that at high latitudes (cooler temperatures) growing soybean plants have highest isoflavone concentrations in seeds as compared to locations with low latitudes (warmer temperatures). Growth stage and pod position significantly affect the individual and total isoflavone contents (Al-Tawaha, 2010). Isoflavone concentration was lower in seeds collected from the top part of the plants and higher in seeds from the base parts (Bordignon*et al*., 2004). The maximum plants and total isoflavone contents were recorded in soybean seeds from the base parts of plants at brown pod stage (Al-Tawaha, 2010). Nakamura *et al*., (2001) reported that isoflavone concentration varied with the growth stages of soybean and was highest in mature bean seeds.

Both oil and protein content in soybean seed change due to positional effect (Collins and Cartter, 1956). Protein accumulation was highest in soybean seeds developing at the top parts of plants than the base region while seeds developing at the base parts of plants accumulate greater amount of oil than those from the top (Al-Tawaha, 2010). Incremental trend in protein content was observed in seeds from bottom to top nodes in both normal and high-protein breeding lines (Escalante and Wilcox, 1993a). The glycinin A3 polypeptide content gradually increased in successively lower nodes from the top of the plant while remaining seed storage protein components were not influenced by nodal position (Bennett *et al.,* 2003). Concentration of protein was higher in seeds appearing in the upper one-fourth of the plant while lower oil content than seeds from the lower one-fourth of the plant (Bennett *et al.,* 2003). Variation exists in protein content among the nodes of both determinate and indeterminate plants. Basal node seeds contain less protein and its concentration increased toward the apical nodes in both types of plants (Escalante and Wilcox, 1993b). Seeds developed on lower nodes showed higher oil in both determinate and indeterminate varieties (Collins and Cartter, 1956). Oil content varies among nodes but plants of the same variety showed a similar pattern of oil accumulation. Oleic (18:0) and linoleic (18:2) acids showed difference in accumulation at different nodes (Bennett *et al.,* 2003).

Linseed

Flaxseed is rich in numerous nutrients, such as polyunsaturated fatty acid, protein, and lignins (Wang *et al.,* 2007). Linseed contains 36-48 % oil which is the richest source of polyunsaturated fatty acids (PUFA) especially linolenic acid vital in the human food (Enser *et al.*, 2000; Kouba *et al.*, 2003; Kouba, 2006). Linseed oil is a rich source of unsaturated fatty acids like oleic (C18, 16–24 %), linoleic (C18, 18–24 %) and linolenic acid (C18, 36–50 %) (Flachowsky *et al.,* 1997) and it has a relatively low glucosinolates content (Schuster and Friedt, 1998). Nutritional value of linseed depends upon many factors like cultivar, locality, sowing date and year of production, with cultivar being the most important factor (Oomah *et al.*, 1992). Linseed contains 24.18% crude protein, 37.77% fat, 4.78% crude fiber, 3.50% ash and 25.86% nitrogen free extract, respectively (Khan *et al.,* 2009). The endosperm of linseed contains only 23% of the lipids and 16% of protein (Daun *et al.*, 2003; Oohma, 2003). Flax protein is relatively rich in arginine, aspartic acid and glutamic acid, and the limiting amino acids are lysine, methionine and cysteine (Chung *et al*., 2005). Protein content ranges from 18.8 percent to 24.4 percent (Daun and Pryzbylski, 2000).

Temperatures fluctuation before flowering has no effect on composition of the linseed oil. Temperature differential after flowering resulted in drastic change in the fatty-acid composition of the oil. Oil from Dakota variety showed highest linolenic and the lowest oleic acid content at 10^0C post-flowering treatment while 26.7^0C post-flowering temperature decreased linolenic acid from 57% to 41% and increased oleic acid from 18% to 34% (Yermanos and Goodin, 1965). Both the amount of oil per seed and oil content showed linear decline with daily average temperature between 13 and 25 °C in linseed (Green, 1986).

Rahimi *et al.,* (2011) reported that delayed sowing and increasing nitrogen fertilizer results in decreasing oil content in linseed. Cool temperature and long day length (photoperiod) during and after flowering increase seed yield and linolenic acid. Delayed sowing of linseed reduces number of capsule per plant, number of seeds per capsule, oil content, iodine value and linolenic acid (Ford and Zimmerman, 1964). Longer photoperiods increase oil content, iodine number and linolenic acid while shorter photoperiods result in delayed flowering and lower both, oil content and fatty acids (Sosulski and Gore, 1964). Higher temperatures along with intense radiations favor linseed seed production and oil accumulation. Higher temperature enhances the accumulation of saturated fatty acids while under the condition of low temperature with less intense radiations, plants retain their vegetative stage and yield more fiber of better quality (Rahimi *et al.,* 2011).

Under the warmer temperate climate conditions, linseed exists as a winter plant (Zajac *et al.,* 2012). Cool season and adequate moisture supply during the period from flowering to maturity favor both oil content and quality (Rubilar *et al.,* 2010). With progress in seed formation, level of palmitic and linoleic acid decreases but that of linolenic acid increases in percent while no clear trend has been observed for oleic acid. Environmental conditions required for large grain size also favor higher oil contents and iodine value (Comstock, 1960). Oil content showed linear relationship with polyunsaturated fatty acids namely linoleic and linolenic acids, negative correlation with saturated fatty acids like palmitic and stearic acid and weak correlation with monounsaturated fatty acids (oleic acid) (Adugna and Labuschange, 2003). Oil content and fatty acid composition showed considerable variation during maturation. Oil content is reported to be increased in first 30 days from flowering. Significant variability in fatty acid levels and total oil content was recorded during 10-20 days after flowering with 3.4% daily increase in oil content. Amount of polyunsaturated fatty acids especially linolenic acid increases while that of palmitic acid decreases during maturation (Bhatia and Sukhija, 1970). Cold weather and lower temperature prevailing during maturation reduce the concentration of palmitic, stearic and oleic acids whereas they enhance the level of linoleic and linolenic acids in 3 normal and 3 genetically modified linseed varieties (Green, 1986).

Day length during growing season showed immense impact on quality of linseed (Nykter *et al.,* 2006). Environmental conditions during the growing season of linseed are major determinant for dry matter accumulation (Marshall *et al.,* 1989; Diepenbrock *et al.,* 1995; Casa *et al.,* 1999; Froment *et al.,* 2000; Hassan *et al.,* 1999; Zajac *et al.,* 2002). Climatic conditions prevailing during two growth stages i.e. sowing and emergence as well as the plant maturation determine yield (Bravi and Sommovigo, 1997). Yield and its components are influenced by seeding rate of linseed (Zajac *et al.,* 2005). Increasing day temperature from 15 to 27°C and the night temperature from 10 to 22º C results in reduction in oil content to 40 g kg^{-1} (Berti *et al.,* 2010).

Oil/Fatty acid	Concentration (%) at 15°C	Concentration (%) at 30°C
Linolenic acid	49	31
Palmitic acid	7	37
Oleic acid	28	47
Linoleic acid	15	11
Oil content	38	31
Iodine value	176	140

(Dybing and Zimmerman, 1966)

Linseed can be sown at wide range of soil types and fertility levels (Townshend and Boleyn, 2013). Due to shallow root system and dry weather at harvest, linseed requires reasonable soil moisture during development stages (Claridge 1972). Linseed crop can be grown in a variety of environments mostly in temperate climates (Casa *et al.,* 1999; Adugna and Labuschagne, 2003). Temperature during plant development is single determinant influencing seed yield and seed yield components, plant height, time to maturity, oil percentage and oil configuration (Dybing *et al.,* 1988; D'Antuono and Rossini, 1995; Casa *et al.,* 1999; Adugna and Labuschagne, 2003; Cross *et al.,* 2003). Seed humidity at maturity may also effect the final seed oil percentage and the oil composition (Froment *et al.,* 1999; Adugna and Labuschagne, 2003).

Sowing year, location, variety, seeding date, nitrogen fertility and seeding rate are the factors with greatest influence on the final seed yield of linseed (Hassan *et al.,* 1999; Lafond 2001; Adugna and Labuschagne 2002). Nitrogen rate increased oil content and yield. Nitrogen, Phosphorus and Potassium rates or their interactions did not affect the oil composition. Seed yield, oil content, oil yield and oil composition were also not affected by P and K nutrients (Berti *et al.,* 2009). Late sown crop encounters higher temperature during reproductive growth resulting in lower seed quality (Greven *et al.,* 2004). Early sowing results in more plant height, number of primary branches, number of capsules/plant, seed/capsule, seed yield, oil % and yield, protein content, higher content of linolenic and linoleic acids (Mirshekari *et al.,* 2012).

Seed traits (Seeds per capsule, thousand seed weight and Seeds-husk ratio) and oil content were influenced by prevailing environmental conditions during maturity and post flowering period. No. of seeds per capsule, thousand seed weight, seed-husk ratio and oil content was maximum for lowest position and it decreased significantly towards top. Capsule position has significant effect on seed traits and oil contents of linseed that could be due to differential partitioning of photo-assimilate at different points of capsule (Mukhtar *et al.,* 2012). Linseed is a cool temperate annual herb with erect and cylindrical stems. Air temperatures below 10°C possibly inhibit growth rate subsequently delaying the flowering process (Gusta *et al.,* 1997). The growth of capsule or seed depends upon photosynthetic activities of leaves and inflorescences and translocation of photo-assimilate in the plant canopy before flowering (Dordas, 2009; Blum, 1998).

Seed formation and development takes place at different times, different positions (distance from main stem photo-synthates producing region) and at different temperatures, thus physical and chemical characteristics are affected differently. Progressive reduction in number of seeds/ capsule might be the effect of temperature variation. Dry matter accumulation and its partitioning into different plant parts are significantly affected by growing season. Differences in climatic conditions during seed development/maturation and uneven ripening of individual capsules might have caused variations in oil content (Mukhtar *et al.,* 2012). Application of manganese in flax also increased the oil percent and seed yield (Sawan *et al.,* 2001).

Sesame

A research on Sesame (*Sesamum indicum* L.) was done by Mosjidis and Yermanos, (1985), to study effect of capsule position on seed weight, oil percentage, and oil configuration. Three capsule positions-basal (nodes 16 to 20), middle (nodes 21 to 25), and apical (nodes 26 to 30) were tested. Seeds of middle capsules had more seed weight and their oil contained more palmitic and oleic acids than seeds from the upper and lower capsules. Though, middle capsules had seeds with less oil percentage than seeds from the side capsules. Seed weight and arachidic acid were found stable in seeds from capsules located at different nodes along the plant.

Lipid, protein, RNA and fatty acid composition changes in developing Sesame (*Sesamum indicum*) seeds were determined by Chung *et al*., (1995). They found that lipid increased from 15-day flowering and continual to 38 DAF (day after flowering) and protein content abruptly increased 12 DAF (day after flowering). RNA increased between 12 to 21 DAF (day after flowering) but after 21 DAF (day after flowering) slowly decreased. Oleic acid, palmitic acid, stearic acid, linoleic acid and linolenic acid consisted 98% of total lipid in growing seed. Oleic acid and linoleic acid are composed of about 80% of total fatty acids. However; Tashiro *et al*., (1991) found oil content and minor components in the oil of Sesame (*Sesamum indicum* L.) affected by capsule position; they found seed weight decreased with capsule position from bottom to the top of stem. Oil content was highest at top of main stem and lowest at bottom of main stem.

Sesame seed is a valuable soure of oil (44-58%), protein (18-25%), carbohydrate (~13.5%) and ash (~5%) (Borchani *et al.,* 2010). Sesame seed include 50 percent oil with 35% monounsaturated and 44% polyunsaturated fatty acids and 45 percent meal containing 20% protein (Ghandi, 2009; Hansen, 2011). The protein content of sesame seeds ranges from 20 to 30% and is high in tryptophan and methionine (IPGRI, 2004). This unique protein chemistry makes sesame an exceptional protein supplement as compared to soybean, peanuts and other protein sources that are deficient in enough methionine (RMRDC, 2004). Sesame oil is composed of oleic (35.9-47%), linoleic (35.6-47.6), palmitic (8.7-13.8%), stearic (2.1-6.4%), as well as arachidic acids (0.1-0.7%) (Elleuch *et al.,* 2007; Uzun *et al.,* 2002; Weiss, 1983). Sesame seeds include 50-60% oil and nearly 85% unsaturated fatty acids (Latif and Anwar, 2011).

Genetic, climatic and agronomic factors showed immense impact on oil content and composition of sesame. Oil content and composition differs considerably within varieties (Yoshida *et al.,* 2007). Fatty acid composition and oil content are subject to variation by various physiological, ecological and cultural factors (Uzun *et al.,* 2002). Sesame growth rate was negatively influenced by low temperature and less efficient photosynthesis rate (Nath *et al.,* 2003).

The composition of sesame oil depends upon the climatic conditions, soil type, maturity of plant and variety (El-Khier *et al.,* 2008). Proximate analysis showed significant variation among the different sesame genotypes which implies that genetic diversity exists among Nigerian sesame (Alege and Mustapha, 2013). Alege *et al.,* (2011) studied three species of sesame from Nigeria using morphological markers and reported significant genetic diversity. Akinoso *et al.,* (2006) described that the oil percentage varies with genetic and environmental influences.

Sesame, a warm-season crop is mostly grown to areas with long growing season and well-drained soil (Hansen, 2011). It requires long period of sunshine and is generally a short-day plant (Tunde-Akintunde *et al.,* 2012). Some varieties are not influenced by the day-length (Naturland 2002). Sesame requires a constant high temperature. Optimum range for growth, flowring and fruit ripeness is 26-30°C. The minimum 12°C temperature is required for germination and temperature below 18°C may have a negative effect during germination (Naturland 2002). Pollination and the formation of capsules are restricted at temperature above 40°C (Tunde-Akintunde *et al*., 2012). Sesame can germinate in stored soil moisture without precipitation and flooding, but heavy irrigation or extreme drought stress adversely affect sesame plants and cause in yield reduction (Anwar *et al.,* 2013).

Conclusion

This review concluded that in oilseed crops oil content in seed, protein and fatty acid composition of oil is severely affected by environmental factors. Availability of favourable temperature and adequate water are the major factors influencing the quality and quantity of oil. The extent of adverse effect depends upon crop type and its growth stage.

Chemical composition of safflower oil is considerably changed due to varying moisture level and temperature. Linoleic acid contents in oil decreases due to moisture stress during flowering, on the other hand stearic acid and oleic acid increases. During seed filling, concentration of palmitic acid increases and oleic acid decreases. Damaging effects of drought can be compensated by foliar application of Zn and Mn. In short, water deficiency decreases the unsaturated fatty acids and increases the saturated fatty acids. Late sowing of crop affect the growing stages of crop specially seed development and flowering stage due to rise in temperature. High temperature during seed development stage increases protein contents and alters the fatty acid composition.

Inadequate nitrogen fixation and higher amounts of precipitation during grain filling stage influence the chemical composition of soybean seeds as increase in oil content and protein content decreases. Temperature fluctuation and drought stress also effects the chemical composition of oil. Linoleic acid and linolenic acid are affected by warmer environments as their content decreases, while the oleic acid concentration increases. Temperature higher than 30^{o}C affects the activity of desaturase enzymes and decreases the sucrose level. Water deficiency causes significant decrease in oil content and increase in protein content. Seed quality is also influenced by pod position on plant. Basal node grains showed lowest level of protein content and high level of oil as compare to apical nodes. Chemical composition of soybean oil is also influenced by its planting location, crop grown at higher latitude has highest level of isoflavone in grains.

Fatty acid composition of linseed oil is adversely affected by temperature alterations after flowering. Rise in temperature upto 26.7^{o}C decreases the linolenic acid and oleic acid contents. High temperature increases the oil quantity in seed as well as unsaturated fatty acid of oil. Increasing nitrogen level enhances the oil contents but its composition remains unaffected. Oil content, iodine number and linolenic acid concentration are reduced in late sown linseed. Oil composition and concentration is also affected by photoperiod length; thereof longer photoperiod increases the linolenic acid content and vice versa.

In sesame, capsule position significantly affects the concentration and composition of oil. Seeds of middle capsules contain low level of oil contents and high level of palmitic acid and oleic acid in oil than apical and basal capsules. Sesame is long day plant and requires high temperature during all growth stages. Its germination is also significantly affected by temperature below 18^{o}C, while capsule formation and pollination is inhibited above 40^{o}C.

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