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Fatty Acids and Stress in Three Oil-Producing Plants: Canola (*Brassica napus* L.), Safflower (*Carthamus tinctorius* L.) and Sunflower (*Helianthus annus* L.)

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ABSTRACT

The effect of salinity- and drought-stressed soils collected from different sites in Egypt (Suez road; North Coastal area; El-Kantra East) on yield parameters of three oil plants canola (*Brassica napus* L.), safflower (*Carthamus tinctorius* L.) and sunflower (*Helianthus annus* L) was assessed. The plants were subjected to a pot experiment in which pots contained an equal amount of each soil-type either alone or supplemented with composted plant residue (wheat straw and *Eichhornia crassipes*) at three concentrations (0.25, 0.5, 1.0% v/v) as organic fertilizers and ammonium sulphate at three levels (5, 10, 15 g/pot) as inorganic fertilizer. All three soil types resulted in a decrease in all yield and yield attributes for all three plants when grown in these different soil types compared to the control garden soil although yield parameters improved when soils were supplemented with organic fertilizers rather than inorganic ones. Oil contents and the saturated and unsaturated fatty acid profile varied considerably among treatments.

Keywords: drought, organic and inorganic fertilizers, salinity

INTRODUCTION

Salinity and productivity: General perspectives

As the global population increases and resources become more limited, the continuing challenge to feed the world's population has become increasingly urgent. To cope with current and future food demand, governments in most countries of the world have encouraged agriculture since it represents the main source of food and plays a major role in economic development (Badawi 1997a).

In Egypt, considerable attention has been paid in the last few years to the subject of soil reclamation to increase agricultural production and subsequently overcome the deficiency in food requirements (El-Hamdi 1990).

Some regions of the world, such as parts of the Sahara Desert of North Africa, receive an average of 5 mm of rainfall or less per year. This extreme aridity is a typical of the arable land which is used for crops, as at El-Kantara and Suez sites in Egypt. Nevertheless, most of the world's agriculture is subjected to drought problems. Arid and semi-arid zones are defined as areas in which plant transpiration is about 50% or less than the transpiration that would normally occur in response to the limited water availability (El-Bassiouny and Shukry 2001; Qaderi *et al.* 2006).

In arid and semi-arid areas around the world, the main factors which reduce plant production are drought, salinity and soil nutrient deficiencies (McWilliam 1986; Shannon *et al*. 1994; Kurban *et al.* 1999; Heuer *et al*. 2002; Heuer and Ravina 2004; Heuer *et al*. 2005). Whenever drought is discussed, the problem of definition arises. There are many possible definitions of drought that range from a meteorological definition to those that include some aspects of plant performance (Kamel *et al.* 1995). The following are different definitions that exist. Drought is a multidimensional stress affecting plants at various levels of organization (Blum *et al.* 1990). True drought, resulting from inadequate rainfall and the strong matric forces holding water in soils, osmotic drought, results from the high soil salt concentration (Ibrahim 1999; Younis *et al*. 1999a; Nemat-Alla *et al.* 2002). Agricultural drought is the condition that exists when there is insufficient water available to a crop (Younis *et al*. 1999b). Physiological drought is said to exist when the plant suffers a water deficit (i.e. low tissue water potential) caused by salinity, low soil potential or other stress factors (El-Bastawisy 1999).

Salinity is preferably expressed in terms of the electrical conductivity of the saturation extract of the soil, a measure that takes the moisture retention properties as well as the soluble salt content of the soil into account. A detailed account of salinity as both a physiological and an agronomic problem can be found in several specific reviews and monographs, including those of Munns and Termatt (1986), Younis *et al*. (1993), Pessarakli (1994) and Naumann *et al*. (2007).

Plant water stress or water deficit refers to situations where cells and tissues are less than fully turgid. Water stress varies in degree and is caused either by excessive loss of water or inadequate absorption or a combination of the two (El-Shahaby *et al*. 1994; Younis *et al*. 1999a). It is well established that water stress impairs numerous physiological processes in plants.

Plant growth is often suppressed as a result of root zone stress such as salinity, drought and anaerobic conditions (Carimi 1993; ElKahoui *et al*. 2004). Water stress induced by water drought not only shows several physiological and biochemical disturbances associated with a general reduction in size but also results in characteristic modifications in structure, particularly of leaves.

The major inhibitory effect of soil salinity on plant growth and development has been attributed to osmotic inhibition of water availability, toxic effect of salt ions and nutritional imbalance caused by such ions. Under these conditions salinity has a great role in the definition of the absorption feature of plant roots which could be reflected on the behaviour of any particular crop with respect to physiological and metabolic activities. Pal *et al*. (1984) reported that under conditions of high salinity, stunted growth,

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nutrient imbalance and deep bluish-green foliage of plants followed by low crop production are common observation. Furthermore, different levels of salinity have resulted in a differential response, especially in terms of chemical constituents of the plant (Shinitzky 1984; Kuiper 1985; Morpurgo 1991; Tester and Darenport 2003; ElKahoui *et al*. 2004). Sekmen *et al*. (2007) also stated that high concentrations of salts in soils account for a large decrease in the yield of a wide variety of crops all over the world. The problem is huge; increased salinization of arable land is expected to have devasting global effects, resulting in 30% of land loss within the next 25 years and up to 50% by the middle of the 21st century (Wang *et al*. 2003).

Water stress may be alleviated by irrigation whenever possible (Boyer 1982) and by adding organic manures. Several groups reported that the application of organic manures to salt-affected sandy soil can ameliorate their salinity and improve their physical, chemical and biological properties and consequently increase plant growth and yield of crops (Abdel Magid *et al.* 1995; El-Fakhrani 1995; Sabrah *et al.* 1995; Abdel Magid *et al.* 1996; El-Fakhrani 1996). Moreover organic manures can improve the properties of soil exposed to drought by increasing the limited moisture holding capacity (Maynard 1994).

The negative impact of salinity on the growth of plants in irrigated and non-irrigated areas of the world's arid regions continues to be a major problem. Only in the Mediterranean basin, salinity affects more than 40% of soils. Draining saline soils or irrigating them with high quality water from remote sources is extremely costly. Therefore, selecting plants that can tolerate salinity is an alternative strategy for sustainable agriculture in those marginal lands (Zahran *et al*. 2007).

The total amount of nutrients in the soil and the content of their available forms as well as the rate of nutrients transformation from the unavailable state and *vice versa*, are the major factors determining the nutrient conditions of plants and their requirements for fertilizers. When the soil contains large amounts of available nutrients, plants need less fertilizers and *vice versa*. The total amount of available nutrients in various soils depends on their composition and properties, therefore the response of plants to fertilizers and their effectiveness in different soils are also different (Nason and Mc Elory 1963).

Egyptian crop systems

Incorporation of any new crop in Egyptian rotation is very difficult due to the limited cultivated area and due to the high competition from the main crops such as wheat and cotton. Hence, it is necessary to concentrate planting in newly reclaimed areas. Most of these areas have some stress problems, i.e. drought, salinity and unbalanced nutrient elements. Therefore, attempts are being made to increase crop productivity in new reclaimed soils by many ways such as through the application of organic manures (Keshta *et al*. 1999).

Oil plants in general appear to be one of the most promising plants since their gamut of products range from proteins to carbohydrates to fats. In Egypt, there is a big problem concerning edible oil production. The local production satisfies only 20% of the total requirements. Canola, safflower and sunflower have thus a bright future as sources of oil in Egypt.

Canola (*Brassica napus* L.) is one of the major oil crops in Asia and Europe (Qaderi *et al.* 2006). Recently, canola was introduced to Egypt to help contribute reduce the oil shortage. Canola is new winter oil seed crop containing more than 40% oil. Despite canola having only been considered as a new crop product (relative to other well established crops) it has the capacity to grow on reclaimed lands under wide soil variations as drought and salinity as revealed by some studies carried out under Egyptian conditions (Ibrahim *et al*. 1987; Keshta *et al*. 1999).

Safflower (*Carthamus tinctorius* L.) has been cultivated around the world since ancient times as an important oil crop. Seeds of safflower contain about 30-40% oil as well as 18-20% protein. In Egypt, many years ago safflower was cultivated for several purposes. Recently, more attention has been paid to increasing the productivity of safflower to face a shortage of vegetable oils. Safflower adapts to a wide range of climatic and soil conditions (Dordas and Sioulas 2007) and thus is recommended for cultivation in recently reclaimed soils.

Sunflower (*Helianthus annuus* L.) is an important oil crop around the world. It is one of the world's most important edible oil crops, along with soybean (FAO 2007). In Egypt, there is a bright future for sunflower as an oil crop to meet the deficiency of vegetable oils. Sunflower is adapted to a wide variety of soils and climatic conditions. It has been introduced as a new field crop, especially in the newly reclaimed lands. Ozer *et al*. (2003) stated that sunflower is well adapted to different climatic zones in Turkey in which it is an important oilseed crop whose production has greatly increased with the introduction of hybrids. Most of the production is in the Trakya region, with an estimated area of 320,000 ha. Mostly sunflower is grown without irrigation, but irrigation is sometimes used in sub-humid and semi-arid regions where precipitation is limited, as in the Trakya region. It is possible to increase production by well-scheduled irrigation programs Erdem *et al*. (2006).

Generally, plants require a number of mineral nutrients for proper growth and development, and in this connection nitrogen (N) fertilizers play a major role (Badawi 1997b). N is one of the macronutrients to which Egyptian soils respond since it was shown in many studies to be low in N (Abd El-Gawad and El-Kased 1993). Thus many researchers have paid much attention to the study of N as the principle fertilizer (Attallah and El-Karamity 1997).

The use of N in the form of mineral fertilizers is one of the most effective methods for overcoming the N deficiency of soil but the rising costs of such nitrogenous fertilizers together with the possible environmental problems limit their use (Attallah and El-Karamity 1997).

Recently, in line with clean agriculture and minimum pollution effects, the use of natural materials such as manures is recommended to substitute chemical fertilizers. Organic materials when added to soil undergo processes of mineralization during which many changes occur. Amendment of the soil with organic manure improves its physical, chemical and biological properties, the status of essential nutrients and soil fertility (Khalil *et al.* 2000). The effect of organic manuring on plant behaviour is not just a matter of nutrient supply, but organic materials also influence the physical, chemical and biological characteristics of soil which, in turn influence the development of plants (e.g., Di Benedetto 2007).

The productivity of oil plants as canola, safflower and sunflower depends on many factors, including N fertilization. Krogrman and Hobbes (1975) demonstrated the need for adequate N nutrition for high yielding rape seed when grown under irrigation. In accordance with the effect of N fertilizer on rapeseed productivity, many workers reported that increasing N levels significantly improved all growth characters such as plant height, number of branches/plant, seed yield/plant, straw, seed and oil yields but failed to attain significance in seed oil percentage (Garnayak *et al.* 2000).

Said and Keshta (1999) indicated that increasing N level from 30 to 60 kg N/Fed. (1 Feddan (Fed.) = 4200 m^2) significantly increased all studied characters such as plant height, number of branches/plant, seed yield/plant, straw, seed and oil yields/Fed. Also, Awad (2000) reported that a N level of 75 kg/Fed. resulted in a high significant increase in seed yield (kg/Fed.).

Chauhan *et al.* (1993) reported that seed and straw yields significantly increased with increasing level of N up to 60 kg/ha. Oil content showed an inverse relationship with N application but oil yield recorded an upward trend up to 60 kg N/ha caused by an increase in seed yield. Also, Stamer *et al.* (1996), Hocking *et al.* (1997) and Saini and Sidhu (1997) reported that canola showed the target seed yield responses to N fertilizer in the wet season.

Increasing N levels increased safflower plant height, number of leaves per plant, dry matter accumulation, number of heads per plant, number of seed per head, 100-seed weight, seed yield per plant and oil yield (Mane *et al.* 1990; Afifi 1991; Rajput *et al.* 1992; Whaba and Basilious 1993; Patel *et al.* 1994; Ashoub 1995; Badawi *et al.* 1996).

The effect of N fertilizer on the yield and its components of sunflower were studied by several researchers (Fleck and Silva 1987; Faizani *et al.* 1990; Hiremath *et al.* 1990; El-Naggar 1991) who reported that increasing N levels increased plant height, 1000-seed weight, head diameter and seed yield and decreased seed oil contents.

Saleh *et al.* (1984), Haron and Salah (1991), Anton *et al.* (1995) and Salama (1996) stated that the effect of N fertilizer significantly affected all studied characters in sunflower plants. Increasing N fertilizer rates from 30 through 60 kg N/Fed. markedly increased plant height, head diameter, seed yield (g/plant), seed yield/Fed., protein yield as well as stem diameter, seed protein percentage and oil yield/Fed.

Nowadays, incorporation of crop residues and organic manure into soil are the most common practices in fertility programs on many farms (Khamis 2000). Mulching rapeseed with wheat straw significantly increased the plant height primary branches/plant, siliqua/plant, seed weight/ plant and 1000-seed weight which resulted in significantly higher seed yield over no mulch treatment (control). Seed and stover yields increased significantly. Mulching did not affect seeds/siliqua and oil content, though (Singh *et al.* 1990).

Preceding winter crops (wheat (*Hordeum vulgare*) or faba bean (*Vicia faba*)) had a significant effect on plant height of sunflower, stem diameter, head diameter, weight of seeds/plant and 1000-seed weight. The values of these characteristics were higher when sunflower was sown after faba bean and were lower when sunflower was sown after wheat. Seed yield/Fed. was not significantly affected when the preceding crops was wheat (Seif El-Nasr *et al.* 1993; El-Hawary *et al.* 1994 and Metwally *et al.* 1994). On the other hand, Shaaban and Mobarak (2000) revealed that increasing the level of green material (*Eichhornia*) was highly positively correlated with yield and 100-seed weight (g) of *V. faba* plants. They also found that increasing the *Eichhornia* fertilizer rate from 100 to 150 and 200 kg/Fed. significantly increased the fresh weight, dry weight (g) and plant height (cm) of faba bean plants.

Haikel *et al.* (2000) reported that all the studied characters of maize were significantly affected by different sources of N. Either organic or mineral N form increased yield and its components of maize planting compared with the control treatment over two growing seasons. Hammad *et al.* (1998) concluded that the application of *Eichhornia* as an organic manure has a residual effect on increasing the yield of wheat plants and its nutrient content. *Eichhornia* fertilizer saves the cost of chemical fertilizers and protects the plant and soil environment from chemical pollution.

With respect to oil content and fatty acids, Garnayak *et al.* (2000) stated that the N and oil content in seeds are known to be inversely related. Application of N up to 40 kg/ ha slightly improved the oil content in canola seeds and thereafter decreased it progressively (Nepalia 1990; Sharma *et al.* 1997). However, Nitsgale (1989), Chauhan *et al.* (1993), Hocking *et al.* (1997) and Saini and Sidhu (1997) noted that the decrease in seed oil% by raising the N level was associated with an increase in oil yield/Fed. and this was mainly due to the increase in seed yield/Fed. caused by the increase in N levels.

Free fatty acids (responsible for the shelf-like of oil) in oil increased significantly with each successive doses of N because of a negative correlation between oil content and free fatty acids (Nepalia 1990; Sharma *et al.* 1997). Moreover, Tomar *et al.* (1997) reported that oil content and oil yield increased by fertilizations.

Despite its high capacity to take up N from the soil, winter oilseed rape (*Brassica napus*) is characterized by a very low N recovery in the reproductive tissues under field conditions. A significant part of the N taken up is lost to the soil in dead leaves during the growth cycle. An accurate description of N dynamics at the whole plant level in each compartment under field conditions should lead to a better understanding of N allocation in *B. napus* and improvements in the nitrogen harvest index (*Cheema et al.* 2001).

On the other hand, El-Gendy *et al.* (2001) showed that increasing organic manure (compost) levels significantly increased oil content in sweet basil plant. The mean of oil content per plant increased by increasing the fertilization level from 15 to 35 m^3/Fed. These results are in accordance with the findings obtained by Gupta *et al.* (1974) and Chattopadhyay *et al.* (1993) on *Mentha arvensis*; Ramteke *et al.* (1975) on *Mentha* spp. and El-Ghadban (1998) on *Mentha viridis* and *Origanum majorana*. Furthermore, Keshta *et al.* (1999) concluded that adding 25 m^3/Fed. of farmyard manure (FAM) and 30 kg P_2O_5/Fed. before sowing rapeseeds increased seed and oil yield/Fed. of rapeseed plants grown on saline soils at the North Delta, Egypt.

Strasil and Vorlicek (2002) found that N-fertilization affected the oil content of safflower plants non-significantly. With regards to the effect of N fertilizer levels on sunflower plant, it appears that the application of 20 kg N/Fed. resulted in the highest seed oil percentage, decreasing significantly by increasing or decreasing N fertilizer (as compared with 20 kg N/Fed. treatment; El-Zaher *et al.* 1999).

Zubriski and Zimmerman (1974), Blamey and Chapman (1981), Mishra *et al.* (1994), Bahl *et al.* (1997) and El-Zaher *et al.* (1999) stated that N-fertilizer reduced oil concentration and increased seed yield.

The experiments described here were designed to attempt to increase the total production of edible oils in order to minimizing the gap between oil production and consumption. The cultivated area with oil crops should be increased by expanding into newly reclaimed soils and/or planting high yielding cultivars and conducting good agricultural practices.

MATERIALS AND METHODS

Overview

This section is divided into three experiments, each of which includes a description of the conditions and the materials used followed by a description of changes in yield attributes and composition of fatty acids in the oil of canola (*Brassica napus* L.) and safflower (*Carthamus tinctorius* L.) during a winter season and sunflower (*Helianthus annus* L.) plants during a summer season under the effect of organic (wheat straw and *Eichhornia crassipes*) and inorganic fertilizers on three sites of soils (Suez, North Coast and El-Kantara). These sites suffered from either drought or salinity stress.

Plant material, experimental time course and location

The current investigation was carried out during winter season in 1998 using local varieties of canola (*Brassica napus* L.) and safflower (*Carthamus tinctorius* L.) and during the summer season of 1999 for sunflower (*Helianthus annuus* L.). All seeds were kindly supplied by the Faculty of Agriculture, Mansoura University.

Three sites were selected: the North Coastal area (i.e. 249 km north-west of Cairo); El-Kantara East (i.e. 180 km northeast of Cairo) and Suez road (i.e. 135 km northeast of Cairo). Soils were collected from these sites in order to study the possibility of cultivating in these desert areas.

Pot experiment

An experiment was carried out in pots (25 cm in diameter) containing equal amounts of soil (7 kg). Pots were divided into three groups, the first and second groups were supplied by composted plant residue (wheat straw and *Eichhornia crassipes*) as organic fertilizers at three concentration levels (0.25, 0.50, 1.0%) according to Guerif (1979) and El-Sirafy *et al*. (1989), respectively; the third group was supplied with ammonium sulphate (N = 20.5%) at three levels (5, 10 and 15 g/pot) as inorganic fertilizer (El-Sirafy *et al*. 1989). All fertilizers (wheat straw was collected from a field after the end of the wheat-growing season and prepared according to Guerif (1979) and *Eichhornia crassipes* was collected from the Nile River and prepared according to El-Sirafy *et al*. (1989)) were applied to the soil before sowing. Each group represented one type of soil besides the control (garden soil, sand-clay 2:1).

Culture conditions

Preliminary experiments to test the vitality of seeds was carried out prior to actual experiments. Seeds of all three plants were surface-sterilized with 0.001 M $HgCl_2$ solution for three minutes and then washed thoroughly with tap water.

Irrigation was carried out with tap water according to usual practices. Plants were exposed to natural daylength (daylength was 16 and 10 h in summer and winter, respectively) and illumination in a greenhouse at the Faculty of Science, Mansoura University. The chemical analysis of each experimental soil is shown in **Table 1** and the chemical properties of wheat straw and *E. crassipes* (organic fertilizers) are shown in **Table 2**. At the end of the experiment the percentage of oil and fatty acid contents were determined in the yielded seeds at the highest concentration (1.0% of wheat straw, 1.0% of *Eichhornia* and 15 g/pot of ammonium sulphate) as well as the yield attributes.

Table 1 Chemical and physical data for experimental soils.

	Control	Suez	North Coast	EL-Kantara
Chemical analysis				
Organic carbon %	0.80	0.12	0.48	0.30
$CaCO_3$ %	3.40	1.65	40.65	1.15
HCO_3 %	0.06	0.07	1.20	0.051
CO_3 %	-	-	-	-
Cl %	0.018	0.015	0.025	0.017
SO_4 (mg 100 g^{-1} D.wt.)	0.08	0.057	0.067	0.046
NO_3 (mg 100 g^{-1} D.wt.)	14.5	3.300	7.200	1.460
NH_4 (mg 100 g^{-1} D.wt.)	4.21	0.970	0.077	0.720
iP $x10^{-3}$ (mg 100 g^{-1} D.wt.)	0.55	0.120	1.470	5.600
Exchangeable cations				
$K^+ \times 10^{-4}$ mM g^{-1} D.wt.	19.2	15.9	15.6	14.6
$Na^+ \times 10^{-4}$ mM g^{-1} D.wt.	7.8	87.8	196.0	152.0
$Ca^{++} \times 10^{-4}$ mM g^{-1} D.wt.	336.5	136.5	429.0	151.0
Salinity (ppm)	121.6	102.0	177.9	108.2
pH	7.40	7.43	7.54	7.36
Physical analysis				
E.C. mmohs cm^{-1}	0.19	0.44	0.28	0.17
W.H.C. %	33.40	22.40	18.50	28.70
Mean moisture content	27.30	0.24	1.61	0.26

Table 2 Chemical data for experimental fertilizers.

	Eichhornia crassipes	**Wheat straw**
Carbohydrate content (mg glucose g^{-1} D.wt.)		
Total soluble sugar	9.884	6.353
Sucrose	3.081	0.598
Polysaccharides	19.688	13.904
Nitrogen content (mgNH_4-N g^{-1} D.wt.)		
Total soluble nitrogen	9.348	4.726
Protein	24.024	11.162
Ionic content (mM g^{-1} D.wt.)		
Potassium	0.363	0.254
Sodium	0.098	0.169
Calcium	1.014	0.401
Hormonal content (μg g^{-1} D.wt.)		
IAA	750.6	645.2
GA_3	397.4	240.1
ABA	398.6	363.6
Cytokinins	224.0	199.0

Determination of yield and yield attributes

At the harvest date, as described by Hassanein (1987), ten plants were taken at random to assess the data of yield components, which includes the following: Crop weight/plant; number of grains or seeds/plant (g); grain or seed weight/plant (g); weight of 100 seeds or grains (g); straw weight/plant (g); harvest index × 100 (according to Zelitch 1975); mobilization index (according to Ray and Choudhuri 1980); crop index.

Determination of oil content

The method adopted for the extraction of oil from oleaginous material was that described by Meara (1955) who pointed out that careful preparation of the samples for oil content estimation must be followed since oil-rich seeds will yield some oil even under moderate pressure.

At the time of fruiting (150 days for canola, 140 days for safflower, 150 days for sunflower) sample of the seeds was weighed, ground in a mortar and then transferred to a fat-free extraction thimble. The mortar was washed several times with light petroleum ether (b.p. 40-60°C) and the washings were added to the extraction thimble. Extraction with petroleum ether in a Soxhlet apparatus continued for 18 hours, which was found to be satisfactory for the complete extraction of oils. The extract was then quantitatively transferred to a pre-weighed flask, and the solvent was evaporated using an electric fan. The last traces of the solvent and moisture were removed by heating the flask at 100°C under reduced pressure. The flask was then allowed to cool in a desicator and reweighed to the nearest mg, and the increase in weight was considered equivalent to the weight of oil in the sample.

Identification, fractionation and quantification of different fatty acids

It is well known that natural fats are the glycerol esters of fatty acids. When they are saponified, both a soap and glycerol are obtained. Acidification with sulphuric acid of soap results in the liberation of fatty acids which are used in the different physical as well as chemical determinations (Sink *et al*. 1964).

Methylation of fatty acids for gas-liquid chromatography analysis

The method used in this investigation was essentially that adopted by Sink *et al*. (1964). The fatty acids were converted to methyl esters by refluxing for 2 hours in a conical flask containing 0.5 g of oil (lipid extract), 25 ml methyl alcohol and 0.5 ml concentrated H_2SO_4. The mixture was cooled and extracted with diethyl ether three times using a separating funnel. The combined ether extract was thoroughly washed three times with distilled water until the washing gave no acidic reaction with litmus paper and became free of any traces of sulphuric acid. Fatty acid extracts were dried using anhydrous sodium sulphate, filtered with a Whatman filter paper No. 1 and the ether was removed by distillation on a warm water bath (37°C) under vacuum in a CO_2 gas atmosphere until the last traces of solvent were removed. The sample was cooled in a desiccator and fatty acid methyl ester was used for GLC analyses.

Gas liquid chromatography (GLC)

One μl of fatty acid methyl ester was injected into a Hewellet-Packard (model No. 3700 GLC).

GLC conditions were: Variation type 3700 GLC; Detector F.I.D.; Temperature of detector 300°C; column 20% diethylene glycol succinate (DEGS) on chromosorb 60-80 mesh; temperature of column 195ºC; length of column 6 feet, internal diameter 1/8 inch; chart speed/cm/minute; carrier gas: nitrogen.

Quantification of fatty acids

The response of each fatty acid separated on the chromatogram was determined as the peak area per unit weight of sample.

Peak area = height × peak width (at the peak height). The area so obtained is 0.94 times the true area. This method is widely used

Table 3 Effect of different soil types and treatments on yield attributes of *Brassica napus* L. plants. Each value is the mean of 3-5 samples.

Soil type	Treatment	Crop weight/ plant	№ seeds/ plant	Straw weight/ plant	Seed weight/ plant	Weight of 100 seeds	Harvest index	Mobilization index	Crop index	Weight of oil/ 100 seeds
Suez	Control	0.190	223.33	0.870	0.0383	0.0515	4.402	0.218	0.042	0.0472
soil	WS 0.25%	0.206*	268.75*	1.179	0.0686*	0.0766	5.821*	0.175	0.055*	
	0.50%	0.397	316.40	1.653	0.1064	0.1009	6.437	0.240*	0.060	
	1.00%	0.787	427.13	2.115	0.2666	0.1873	12.605	0.372	0.112	0.0708
	Eich. 0.25%	0.689	325.00	1.253	0.1771	0.1635	14.134	0.550	0.124	
	0.50%	1.597	457.33	1.881	0.3576	0.2346	19.015	0.849	0.160	
	1.00%	2.480	640.00	2.900	0.7571	0.3549	26.105	0.855	0.207	0.0832
	AS 5 g/pot	0.681	494.00	2.648	0.2979	0.1809	11.247	0.257*	0.101	
	10 g/pot	1.022	651.67	3.612	0.6705	0.3086	18.564	0.283	0.157	
	15 g/pot	1.877	767.56	4.114	1.1519	0.4502	28.000	0.456	0.219	0.1774
	LSD at 5%	0.108	48.309	0.237	0.043	0.023	1.577	0.045	0.013	0.0095
North	Control	0.096	153.00	0.406	0.0216	0.0424	5.327	0.237	0.051	0.0421
Coast	WS 0.25%	0.134*	185.00*	0.485*	0.0303*	0.0491*	6.237*	0.276	0.059*	
soil	0.50%	0.161	236.50	0.557	0.0430	0.0545*	7.707	0.289	0.072	
	1.00%	0.202	272.00	0.631	0.0978	0.1078	15.491	0.320	0.134	0.0581
	Eich. 0.25%	0.174	240.00	0.598	0.1000	0.1250	16.722	0.291	0.143	
	0.50%	0.347	308.00	1.171	0.1597	0.1555	13.642	0.296	0.120	
	1.00%	0.715	456.00	1.827	0.3019	0.1986	16.528	0.391	0.142	0.1648
	AS 5 g/pot	0.282	300.00	1.577	0.1288	0.1288	8.170	0.179	0.076	
	10 g/pot	0.700	507.11	2.845	0.3388	0.2004	11.910	0.246*	0.106	
	15 g/pot	0.828	600.00	3.339	0.5206	0.2603	15.591	0.248*	0.135	0.1418
	LSD at 5%	0.039	34.496	0.145	0.019	0.014	1.244	0.028	0.011	0.0102
El-	Control	0.155	190.00	0.712	0.0324	0.0512	4.554	0.218	0.044	0.0620
Kantara	WS 0.25%	0.165*	220.00*	0.795*	0.0407*	0.0555*	5.119*	0.208	0.049*	
soil	0.50%	0.177*	284.00	1.148	0.0599*	0.0632*	5.216*	0.154	0.050*	
	1.00%	0.265	383.50	2.005	0.1700	0.1330	8.477	0.132	0.078	0.0882
	Eich. 0.25%	0.305	471.50	0.921*	0.2079	0.1323	22.572	0.331	0.184	
	0.50%	0.752	564.67	1.793	0.3337	0.1773	18.605	0.419	0.157	
	1.00%	0.991	933.33	2.299	0.6572	0.2112	28.588	0.431	0.222	0.2191
	AS 5 g/pot	0.409	442.00	2.677	0.3013	0.2045	11.256	0.153	0.101	
	10 g/pot	0.701	520.00	3.791	0.5398	0.3114	14.242	0.185	0.125	
	15 g/pot	1.100	710.67	4.691	0.8890	0.3753	18.951	0.234*	0.159	0.1732
	LSD at 5%	0.054	50.330	0.224	0.036	0.018	1.478	0.025	0.012	0.0159
Garden soil		1.360	1002.00	3.996	0.9278	0.2778	23.218	0.340	0.188	0.1037

* Non significant LSD at the 5% level.
WS = wheat straw; Eich. = *Eichhornia*; AS = Ammonium sulphate

as it is highly reproducible (Sink *et al.* 1964). True area = peak area/0.94.

Experimental design and statistics

For yield and yield attributes, ten determinations were made for each character. Oil was analyzed in triplicate while fatty acids were only analyzed once. The data of different treatments were statistically analyzed and the comparison among means was carried out by calculating the least significant difference (LSD) at the 5% level (Snedecor and Cochran 1973).

RESULTS AND DISCUSSION

There is a general agreement that water stress, at certain critical stages of plant growth, causes more injury than at other stages. As stated by Maas and Grieve (1990), Hyung-Baek *et al.* (1992) and Turner (1993) the sensitive critical periods coincide with the time of development of reproductive organs, i.e. at flowering and pollination as well as fertilization and pod developing stages. The total amount of nutrients in the soil and content of their available forms are the major factors determining the nutrient conditions of plant and their requirements for fertilizers Nason and McElory (1963), El-Samahy (2000) and Heuer *et al*. (2005).

Therefore, in the present study we investigated differential stress response of either salinity or drought on yield and fatty acids of three oily plants (canola, safflower, sunflower) grown in soil from three sites in Egypt (Suez, North Coast and El-Kantara) and the effect of soil application with different levels of organic fertilizers (wheat straw and *Eichhornia crassipes*) and inorganic fertilizer (ammonium sulphate).

Changes in the yield and yield attributes of canola

The effect of different fertilizers and different soil types on the yield parameters of canola plants is presented in **Table 3**.

In the case of Suez soil, it is apparent that the treatment with both organic (wheat straw and *Eichhornia*) and inorganic fertilizers (ammonium sulphate) at the three concentrations used markedly increased all the yield parameters compared with the respective control values except for the lowest concentration of wheat straw (0.25%) which non-significantly affected the crop weight/plant (g), number of seeds/ plant, seeds weight/plant (g), harvest index and crop index and significantly decreased the mobilization index. Meanwhile, 0.5% of wheat straw and 5 g/pot of ammonium sulphate did not significantly affect the mobilization index.

In the North Coast soil, the pattern of change in the yield parameters was similar to a great extent with that of Suez soil. Since, the treatment with wheat straw at its lowest concentration showed a non-significant change in all yield parameters while that with wheat straw at 0.5% and 1.0% exhibited a marked increase compared with the control levels. Treatments with *Eichhornia* at 0.25, 0.5 and 1.0% ammonium sulphate at 5, 10 and 15 g/pot significantly increased all yield parameters except for the mobilization index which markedly decreased with 5 g/pot ammonium sulphate and changed non-significantly with 10 and 15 g/pot.

On the other hand, supplementation of El-Kantara soil with wheat straw significantly decreased the mobilization index at all concentrations used and non-significantly changed the crop weight/plant (g), seeds weight/plant (g), weight of 100 seeds, harvest index and crop index at lower concentrations (0.25 and 0.5%) as well as the number of seeds/plant and straw weight/plant at 0.25%. In contrast

Table 4 Effect of different soil types and treatments on yield attributes of *Carthamus tinctorius* L. plants. Each value is the mean of 3-5 samples.

Soil type	Treatment	Crop weight/ plant	№ seeds/ plant	Straw weight/ plant	Seed weight/ plant	Weight of 100 seeds	Harvest index	Mobilization index	Crop index	Weight of oil/100 seeds
Suez soil	Control	1.033	11.0	1.422	0.482	3.158	33.889	0.726	0.253	0.4075
	WS 0.25%	1.430	11.0*	1.523*	0.578	3.508*	37.923	0.750*	0.275	
	0.50%	1.483	17.0	1.941	0.676	3.791	34.836*	0.764*	0.258*	
	1.00%	1.612	19.8	2.018	0.692	4.111	34.283*	0.799	0.255*	0.7145
	Eich. 0.25%	2.304	22.4	2.721	0.862	3.552	31.692	0.847	0.241	
	0.50%	3.018	25.0	3.517	1.170	4.040	33.279	0.858	0.250	
	1.00%	4.179	36.5	4.183	1.439	4.639	34.411*	0.999	0.256*	0.7621
	AS 5 g/pot	2.135	25.0	2.972	0.778	3.961	26.179	0.719*	0.207	
	10 g/pot	3.286	27.6	4.311	1.237	4.186	28.679	0.762*	0.223	
	15 g/pot	3.868	33.0	4.631	1.646	4.450	35.546*	0.835	0.262*	0.8944
	LSD at 5%	0.230	3.2	0.27	0.093	0.356	3.883	0.070	0.021	0.053
North Coast soil	Control	0.401	7.0	0.755	0.246	2.233	32.532	0.531	0.245	0.3632
	WS 0.25%	0.474*	8.7*	0.822*	0.295*	2.302*	35.886*	0.577*	0.264*	
	0.50%	0.549	10.0	0.890*	0.334	2.531	37.596	0.617	0.273	
	1.00%	0.753	11.3	1.126	0.429	2.553	38.100	0.669	0.276	0.5466
	Eich. 0.25%	1.770	17.0	2.037	0.511	3.760	25.068	0.869	0.200	
	0.50%	1.927	19.0	3.099	0.868	3.847	25.323	0.622	0.233	
	1.00%	2.149	22.5	4.197	1.003	3.936	70.651	0.577*	0.273	0.6736
	AS 5 g/pot	1.047	12.7	1.420	0.363	2.837	25.551	0.738	0.204	
	10 g/pot	1.303	16.3	1.467	0.613	3.020	41.780	0.888	0.295	
	15 g/pot	1.547	20.7	1.472	0.816	3.568	55.394	1.051	0.356	0.7647
	LSD at 5%	0.138	2.7	0.197	0.069	0.243	3.374	0.074	0.026	0.042
El-Kantara soil	Control	0.628	8.3	1.015	0.410	2.871	40.350	0.619	0.287	0.4087
	WS 0.25%	0.994	14.0	1.438	0.446*	2.953*	36.873*	0.692	0.269	
	0.50%	1.229	16.0	1.764	0.572	3.071*	32.426	0.696	0.245	
	1.00%	1.961	17.0	2.108	0.614	3.830	29.122	0.930	0.226	0.6802
	Eich. 0.25%	0.781	14.3	1.692	0.469*	3.274	26.997	0.495	0.213	
	0.50%	1.080	18.0	2.183	0.704	3.530	36.902*	0.380	0.180	
	1.00%	2.368	22.4	3.399	1.193	4.750	26.042	0.517	0.207	0.9592
	AS 5 g/pot	1.226	12.6	1.715	0.549	3.449	27.675	0.617	0.217	
	10 g/pot	2.083	13.5	2.536	0.861	3.646	33.952	0.742	0.253	
	15 g/pot	2.384	16.8	2.805	1.016	4.267	36.231	0.784	0.266	0.9952
	LSD at 5%	0.146	2.1	0.210	0.079	0.361	3.84	0.065	0.020	0.060
Garden soil		1.81	19.0	2.536	0.561	4.000	18.464	0.466	0.165	0.8714

* Non significant LSD at the 5% level.
WS = wheat straw; Eich. = *Eichhornia*; AS = Ammonium sulphate

supplementation with both *Eichhornia* and ammonium sulphate fertilizers exhibited a marked increase in all yield parameters excluding the straw weight/plant which changed non-significantly in the 0.25% *Eichhornia* treatment as well as the mobilization index, which decreased significantly at lower concentrations of ammonium sulphate and changed non-significantly with the highest concentration of ammonium sulphate. These results provide good support for the data in **Tables 1** and **2**.

Changes in the yield and yield attributes of safflower

Except for the lowest concentration (0.25%) of wheat straw treatment which induced a non-significant effect on the number of seeds/plant, straw weight/plant and weight of 100 seeds in Suez soil and on the crop weight/plant, number of seeds/plant, straw weight/plant, seed weight/plant and weight of 100 seeds in the North Coast soil as well as on the seed weight/plant and weight of 100 seeds in El-Kantara soil, all treatments (wheat straw, *Eichhornia*, ammonium sulphate) showed, in general, a significant increase in the yield parameters (crop weight/plant, number of seeds/plant, straw weight/plant, seeds weight/plant and weight of 100 seeds) above the respective control values (**Table 4**). Wheat straw at 0.5% concentration induced a non-significant change in straw weight and weight of 100 seeds in North Coast and El-Kantara soils, respectively.

Concerning the harvest index in Suez soil, the treatment with wheat straw at 0.5 and 1.0% concentrations with *Eichhornia* at 1.0% as well as ammonium sulphate at 15 g/pot caused a non-significant increase while the treatment with *Eichhornia* and ammonium sulphate at lower concentrations showed a marked reduction effect in relation to the control levels. Moreover in the North Coast soil, there was a significant increase (compared to controls) when the soil was supplemented with wheat straw at 0.5 and 1.0%, *Eichhornia* at 1.0% and ammonium sulphate at 10 and 15 g/pot. In contrast, there was a significant decrease (compared to controls) in response to the treatment with *Eichhornia* at lower concentrations and with ammonium sulphate at 5 g/pot, the treatment with 0.25% of wheat straw non-significantly affected the harvest index. In El-Kantara soil, all treatments (wheat straw, *Eichhornia*, ammonium sulphate) significantly decreased the harvest index below the control value.

With respect to the mobilization index, in Suez soil all treatments (wheat straw, *Eichhornia*, ammonium sulphate) exhibited a significant increase above the control level except for the treatment with lower concentrations (0.25% and 0.5) of wheat straw and 10 g/pot of ammonium sulphate, which non-significantly affected this parameter. Five g/pot of ammonium sulphate reduced the mobilization index. On the other hand, in the North Coast soil, the lowest concentration (0.25%) of wheat straw and the highest concentration of *Eichhornia* non-significantly changed this parameter while the other treatments significantly increased it. Moreover, in El-Kantara soil the treatment with wheat straw at all concentrations used and ammonium sulphate at higher concentrations (15 g/pot) produced a significant increase compared to the control level while the treatment with *Eichhornia* at all concentrations used (0.25, 0.5, 1.0%) and ammonium sulphate at 5 g/pot showed a marked decrease.

For crop index, lower concentrations of both *Eichhornia* (0.25, 0.5%) and ammonium sulphate (5, 10 g/pot) showed a significant decrease compared with the control

Table 5 Effect of different soil types and treatments on yield attributes of *Helianthus annus* L. plants. Each value is the mean of 3-5 samples.

Soil type	Treatment	Crop weight/ plant	№ seeds/ plant	Straw weight/ plant	Seed weight/ plant	Weight of 100 seeds	Harvest index	Mobilization index	Crop index	Weight of oil/100 seeds
Suez	Control	1.741	18.0	1.948	0.299	1.625	15.331	0.894	0.1329	0.6255
soil	WS 0.25%	2.865	18.0*	2.117*	0.329*	1.706*	15.558*	1.353	0.1346	
	0.50%	3.283	28.7	3.332	0.640	2.096	19.213	0.985*	0.1612	
	1.00%	4.272	33.5	4.923	0.948	2.240	19.263	0.868*	0.1615	0.7236
	Eich. 0.25%	5.816	28.0	5.781	0.901	2.178	15.586*	1.006*	0.1348*	
	0.50%	8.490	48.0	8.215	1.285	2.801	15.641*	1.033	0.1353*	
	1.00%	11.463	68.0	10.218	3.474	5.247	33.995	1.122	0.2537	2.5440
	AS 5 g/pot	7.022	31.0	3.734	0.619	2.111	16.580*	1.880	0.1422*	
	10 g/pot	8.669	44.0	4.368	1.175	2.430	26.910	1.985	0.2120	
	15 g/pot	12.867	91.0	5.543	2.358	2.674	42.536	2.322	0.2984	1.0608
	LSD at 5%	0.719	4.335	0.536	0.130	0.261	2.251	0.137	0.018	0.093
North	Control	1.991	16.0	3.233	0.254	1.357	7.842	0.616	0.0727	0.5186
Coast	WS 0.25%	4.411	21.0*	3.325*	0.301*	1.496*	9.044*	1.326	0.0829*	
soil	0.50%	4.623	23.3	4.153	0.527	1.796	12.691	1.113	0.1126	
	1.00%	5.039	38.0	4.622	0.916	2.135	19.825	1.090	0.1654	0.6956
	Eich. 0.25%	8.960	43.3	4.947	0.832	1.984	16.820	1.811	0.1440	
	0.50%	12.452	68.2	7.244	1.336	2.163	18.439	1.719	0.1557	
	1.00%	15.885	72.7	9.868	1.870	2.396	18.949	1.610	0.1593	0.8004
	AS 5 g/pot	9.508	60.0	7.232	1.251	1.902	17.301	1.315	0.1475	
	10 g/pot	13.523	84.3	9.603	2.142	2.193	22.303	1.408	0.1824	
	15 g/pot	21.362	100.0	9.778	3.027	2.653	30.952	2.185	0.2364	0.9168
	LSD at 5%	1.064	5.676	0.675	0.136	0.208	1.848	0.151	0.015	0.122
El-	Control	2.062	18.3	1.363	0.332	1.695	24.367	1.513	0.1297	0.6752
Kantara	WS 0.25%	2.622*	19.0*	1.598*	0.397*	1.993	24.839*	1.641*	0.2255	
soil	0.50%	3.913	27.0	2.230	0.605	2.015	27.121*	1.755	0.2745	
	1.00%	5.433	38.5	2.392	0.968	2.690	40.489	2.272	0.2882	0.7930
	Eich. 0.25%	6.279	60.0	3.421	1.379	2.102	40.313	1.835	0.2873	
	0.50%	9.164	72.3	4.976	2.145	2.826	43.099	1.842	0.3012	
	1.00%	11.451	86.5	6.179	2.823	3.132	45.690	1.853	0.3136	1.0605
	AS 5 g/pot	6.734	75.7	3.445	1.904	2.517	55.286	1.955	0.3560	
	10 g/pot	9.838	92.0	6.087	2.919	2.807	47.964	1.616*	0.3242	
	15 g/pot	13.075	117.0	8.109	3.713	3.397	45.782	1.612*	0.3140	1.9029
	LSD at 5%	0.693	6.533	0.427	0.187	0.261	4.118	0.182	0.030	0.177
Garden soil			37.0	6.042	1.155	3.214	19.112	1.768	0.1605	0.8928

value while the other treatments (all concentrations of wheat straw and the highest concentration of *Eichhornia* and ammonium sulphate) induced a non-significant change in the crop index of Suez soil. In the North Coast soil except for the treatment with wheat straw at the lowest concentration (0.25%) which induced a non-significant change in crop index as well as the treatment with lower concentrations of *Eichhornia* and 5 g/pot of ammonium sulphate, which significantly decreased this parameter, the other treatments induced a significant increase. In El-Kantara soil all treatments (wheat straw, *Eichhornia*, ammonium sulphate) induced a significant decrease in the crop index below the control value.

Changes in the yield and yield attributes of sunflower

It can be seen from **Table 5** that the lowest concentration of wheat straw (0.25%) did not significantly affect the number of seeds/plant, straw weight/plant, seeds weight/plant and weight of 100 seeds of plants grown in the three soils used (Suez, North Coast, El-Kantara), while the remaining organic and inorganic treatments (*Eichhornia*, ammonium sulphate) at their different tested concentrations (0.25, 0.5, 1.0% and 5, 10, 15 g/pot, respectively) markedly increased these yield parameters compared with the untreated controls. The crop weight/plant significantly increased more than the control values with all treatments (wheat straw, *Eichhornia*, ammonium sulphate) in all soils used.

Supplementation with wheat straw at 0.25%, *Eichhornia* at 0.25 and 0.5% as well as ammonium sulphate at 5 g/pot non-significantly changed harvest index in Suez soil. Also, supplementation with wheat straw at 0.25% in North Coast soil as well as 0.25 and 0.5% in El-Kantara soil give the same response (effect), while the other treatments significantly increased the harvest index above the control values.

The mobilization index non-significantly changed following treatment with 0.50 and 1.0% wheat straw as well as 0.25% *Eichhornia* in Suez soil. The same effect was observed in the El-Kantara site soil when the soil treated with 0.25% wheat straw as well as 10 and 15 g/pot ammonium sulphate. An inverse situation was observed in the case of North Coast soil as well as the other treatments of Suez and El-Kantara soils, since there were marked increases above the untreated ones. Regarding the crop index, there were non-significant changes as a result of treatment with 0.25 and 0.5% *Eichhornia*, 5g/pot ammonium sulphate in Suez soil as well as the treatment with 0.25% wheat straw in North Coast soil.

Comparing yield components of the variously treated plants, we observed a decrease in all yield and yield attributes (crop weight/plant, number of seeds/plant, straw weight/plant, seeds weight/plant, weight of 100 seeds, harvest index, mobilization index and crop index) of canola, safflower and sunflower plants grown in the three tested Egyptian soils compared with the garden soil (**Tables 3-5**). This is in agreement with the results in **Table 1**. In this connection Younis *et al*. (1999a, 1999b) using bushbean, kidneybean and soybean plants found that salinity and drought induced a reduction in yield of these plants below the control value. These are in conformity with those obtained by El-Kahoui *et al*. (2004) in *Catharanthus roseus*.

Data in **Tables 3-5** indicate that supplementation of Suez, North coast and El-Kantara soils by wheat straw, *Eichhornia* and ammonium sulphate fertilizers induced a variable change in yield depending on their concentration and soil type, parallel to data in **Table 2**. Casa *et al*. (1999) and El-Shakweer *et al*. (1998) stated that the addition of different organic conditions to four soils in the El-Fayom area, Egypt, improved the physical (saturation percentage, field capacity, bulk density, total porosity and hydraulic conductivity) and chemical (pH, E.C., organic matter, total nitrogen and available N, P and K) properties of soils. At cropping, dry matter and grain yield of wheat increased. Also, Shukry *et al.* (1999) found that wheat straw changed the chemical composition of the tested soil, where total soluble salts and inorganic nitrogen in the form of ammonia-N were higher than in untreated soil (Kitou and Yashida 1994). On the other hand, green manure had a more effective response than wheat straw (**Tables 3-5**). These results are in agreement with those obtained by El-Hawary *et al.* (1994) and Metwally *et al.* (1994).

Regarding ammonium sulphate as a nitrogen fertilizer, it is clear (**Tables 3-5**) that the yield and yield attributes of canola, safflower and sunflower were significantly increased above the control value in the three tested soils. In this respect, Porter (1993) and Yusuf and Bullock (1993) reported that high rates of N fertilizer are usually applied to oilseed rape in order to obtain maximum seed yields. Also, Singh *et al.* (1992), Nimje and Gandhi (1993), Ashoub (1995) and Badawi (1997b) found that increasing nitrogen fertilizer increased the weight of 100 seed, seed yield/plant, number of heads/plant and number of seeds/head of safflower. In addition, Salama (1991) and Abd El-Wahed (1996) found that increasing nitrogen level led to significant increase in seed yield/Fed. of sunflower. Manoharan *et al.* (1991), Tsvetanova *et al.* (1992), El-Nakhlawy (1993), Taema and Mahmoud (1994) and Reddy and Giri (1997) found that an increase in nitrogen fertilizer levels significantly increased head diameter, seed weight/plant and weight of 1000 seeds of sunflower. Moreover, Agegnehu and Honermeier (1997) stated that yield and yield components increased with increasing N rate of flax plants. In this respect, Dubey (1997) and Singh and Verma (1997) stated that seeds/capsule of linseed were significantly increased due to fertility level.

Changes in oil percentage and fatty acid composition of canola seeds

The results represented in **Table 3** show that the application of both organic (wheat straw, *Eichhornia*) and inorganic (ammonium sulphate) fertilizers at the highest concentration showed a significant increase in the oil percentage of the seeds yielded by canola plants in the three soils used (Suez, North Coast, El-Kantara) compared with untreated plants.

The results in **Table 6** revealed the following main changes in the fatty acid composition of the various canola seeds yielded by these treatments.

The predominant fatty acids of the oil produced from the canola seeds grown in the garden soil were: nonanoic (9:1), 10-octadecenoic (18:3), 6-octadecenoic (18:1), hexadecanoic (16:0), 9, 12-octadecadienoic (18:7), nonanedioic (9:2), octadecanoic (18:0) and eicosenoic (20:0).

For Suez soil (**Table 6**), the predominant fatty acids in

Table 6 Effect of different soil types and treatments on percentage of fatty acids in the oil of seeds yielded from *Brassica napus* L. plants.

Fatty acid	Suez soil				North Coast soil				El-Kantara soil				Garden soil
	A	B	C	D	A	B	C	D	A	B	C	D	
Octanedioic acid (8:0)	1.308												
Nonanoic acid, 4-oxo (9:0)	5.615												
Nonanoic acid, 9-oxo (9:1)	1.614		7.139				9.005						30.014
Nonanedioic acid (9:2)	6.861				5.470					9.207			5.885
γ-Decalactone acid (9:3)					8.306								
Cyclopropaneoctanoic acid (11:0)										5.929			
Tridecanedioic acid (13:0)	3.156												
Cyclopropanedecanoic acid (13:1)								1.62					
Tetradecanoic acid (14:0)									3.019				
Hexadecanoic acid (16: 0)	14.917	12.911	8.329	6.034	15.043	9.013	20.179	6.096		11.035	9.469	8.750	14.965
9-Hexadecenoic acid (16:1)											1.225		
7,10,13-Hexadecatrienoic acid (16:2)				32.769									
Heptadecanoic acid (17:0)									8.856				
10-Heptadecenoic acid (17:1)									7.607				
Octadecanoic acid (18:0)	6.506				3.890	2.692	5.165	3.219	1.942	2.695	4.241	2.847	4.447
6-Octadecenoic acid (18:1)		5.434											16.142
9-Octadecenoic acid (18:2)	8.589		18.115	61.198		23.126		42.147			13.925		
10-Octadecenoic acid (18:3)		66.359			32.593					22.591			17.865
11-Octadecenoic acid (18:4)					21.485						37.229		
13-Octadecenoic acid (18:5)							64.635						
16-Octadecenoic acid (18:6)	17.048											42.919	
9,12-Octadecadienoic acid (18:7)		9.567				18.52			11.050	5.605			7.062
9,15-Octadecadienoic acid (18:8)			20.186										
Eicosanoic acid (20:0)	3.293				2.516			1.660			3.297	2.535	3.619
11-Eicosenoic acid (20:1)	8.921	5.728	4.997		8.712	7.828		12.532				9.576	
11,14-Eicosadienoic acid (20:2)									45.313				
Docosanoic acid (22:0)	2.042						1.016	1.329			0.418	1.514	
13-Docosenoic acid (22:1)	20.128		41.234			38.82		31.395		42.937	30.197	31.859	
13,16-Docosadienoic acid (22:2)									5.343				
Saturated fatty acids (relative %)	45.312	12.911	15.468	6.034	35.225	11.705	35.365	13.924	30.687	28.866	17.425	15.646	62.549
Unsaturated fatty acids (relative %)	54.686	87.088	84.532	93.967	64.775	88.294	64.635	86.074	69.313	71.133	82.576	84.354	37.450
Unsaturated/saturated fatty acid ratio	1.2068	6.7452	5.4649	15.5729	1.8389	7.5432	1.8276	6.181	2.2587	2.4642	4.7389	5.3914	0.5987

A = control; B = wheat straw (1%); C = *Eichhornia* (1%); D = ammonium sulphate (15 g/pot).

the oil of the control (untreated soil) were: 13-docosenoic (22:1); 16-octadecenoic (18:6); hexadecanoic (16:0); 11-eicosenoic (20:1); 9-octadecenoic (18:2); nonanedioic (9:2); octadecanoic (18:0); nonanoic (9:0); eicosanoic (20:0); tridecanedioic (13:0); docosanoic (22:0); nonanoic (9:1) and octanedioic (8:0).

The supplementation of Suez soil with wheat straw at the highest concentration (1.0%) revealed that there were a decrease in the value of hexadecanoic (16:0) and 11-eicosenoic (20:1) compared with the control value and a disappearance of the other predominant fatty acids. Besides that, newly synthesized fatty acids appeared; 10-octadecenoic (18:3); 9,12-octadecadienoic (18:7) and 6-octadecenoic (18:1).

Meanwhile, the addition of *Eichhornia* at the highest concentration (1.0%) led to an increase in the value of 13-docosenoic (22:1); 9-octadecenoic (18:2) and nonanoic (9:1) above the control value as well as a decrease in the value of hexadecanoic (16:0) and 11-eicosenoic (20:1). In addition, the other fatty acids disappeared while a new fatty acid appeared, namely 9-15 octadecadienoic (18:8) (**Table 6**).

However, application of ammonium sulphate at 15 g/pot induced changes in the predominant fatty acids, since there were an increase in the value of 9-octadecenoic (18:2) and a decrease in the value of hexadecanoic (16:0). The only new synthesized fatty acid was 7,10,13-hexadecatrienoic (16:2), but the other predominant fatty acids disappeared (**Table 6**). The treatment with either organic (wheat straw, *Eichhornia*) or inorganic (ammonium sulphate) fertilizers at the highest concentration were more favourable for unsaturated fatty acids and less for saturated ones. So, the ratio of unsaturated/saturated ratio increased above the untreated soil (control).

In the North Coast soil, the predominant fatty acids in the control (untreated soil) were 10-octadecenoic (18:3), 11-octadecenoic (18:4), hexadecanoic (16:0), 11-eicosenoic (20:1), decalactone (9:3), nonanedioic (9:2), octadecanoic (18:0) and eicosanoic (20:0).

The treatment of North Coast soil with 1.0% wheat straw changed the fatty acid composition of the oil since it induced a decrease the content of hexadecanoic (16:0), 11-eicosenoic (20:1) and octadecanoic (18:0) fatty acids. The 13-docosenoic (22:1), 9-octadecenoic (18:2) and 9, 12-octadecadienoic (18:7) fatty acids were newly synthesized (**Table 6**).

Compared to the control, the treatment of North Coast soil by 1.0% *Eichhornia* elicited an increase in hexadecanoic (16:0) and octadecanoic (18:0) fatty acids while the other predominant fatty acids disappeared (**Table 6**). There were new synthesized fatty acids: 13-octadecenoic (18:5), nonanioic (9:1) and docosenoic (22:0).

In the case of ammonium sulphate (15 g/pot) there was a decrease in the value of hexadecanoic (16:0) and eicosenoic (20:0) fatty acids, no change in the value of octadecanoic (18:0) as well as an increase in the value of 11-eicosenoic (20:1), compared with the control value (**Table 6**). Also, 9-octadecenoic (18:2), 13-docosenoic (22:1); cyclopropanedecanoic (13:1) and docosanoic (22:0) fatty acids were newly synthesized.

There was a decrease in the saturated fatty acids when the North Coast soil was treated with wheat straw (1.0%) and ammonium sulphate (15 g/pot). An inverse situation occurred in the *Eichhornia* treatment (1.0%). So the unsaturated/saturated ratio was higher than the control value in the case of wheat straw and ammonium sulphate treatments but lower for *Eichhornia* when compared to the control.

Furthermore, the predominant fatty acids in the oil of plants grown in the untreated soil of El-Kantara site were: 11, 14-eicosadienoic (20:2); 9, 12-octadecadienoic (18:7); heptadecanoic (17:0); 10-heptadecenoic (17:1); 13, 16-docosadienoic (22:2); tetradecanoic (14:0) and octadecanoic (18:1).

Treatment of El-Kantara soil with wheat straw at 1.0% resulted in a change in the fatty acid composition of the oil, an increase in the value of octadecanoic (18:1) and a decrease in the value of 9,12-octadecadienoic (18:7). The remaining fatty acids of this sample were newly synthesized (**Table 6**).

Supplementation of El-Kantara soil with 1% *Eichhornia* resulted in an increase in the value of octadecanoic (18:0). The other predominant fatty acids disappeared while new fatty acids (13-docosenoic (22:1); 11-octadecenoic (18:4); 9-octadecenoic (18:2); hexadecanoic (16:0); eicosanoic (20:0) and 9-hexadecenoic (16:1)) were synthesized.

Meanwhile, the supplementation of El-Kantara soil with ammonium sulphate at 15 g/pot induced a different fatty acid profile of the seed oil. All the fatty acids were newly synthesized except for octadecanoic (18:0), which was higher than the control value (**Table 6**).

An increase in the saturated fatty acids when organic fertilizers (wheat straw and *Eichhornia*) were used is absolutely clear but, where inorganic fertilizer was applied, no change was observed. So the ratio of unsaturated/saturated decreased in wheat straw and *Eichhornia* treatments compared to the control but did not change in the ammonium sulphate treatment in soil from the El-Kantara site.

Changes in oil percentage and fatty acids composition of safflower seeds

The results represented in **Table 7** show the following main changes in the fatty acid composition of variously yielded seeds of safflower.

With respect to the fatty acid composition of oil, the predominant ones found in safflower seeds derived from plants grown in the garden soil were: 9,12-octadecadienoic (18:6), octadecanoic (18:0), nonanoic (9:1); nonanedioic (9:2), 9-octadecenoic (18:1), 10-octadecenoic (18:2), octanoic (8:0) and hexadecanoic (16:0).

The growth of safflower plants in the untreated Suez soil (control) resulted in a change in the pattern of fatty acids, becoming hexadecanoic (16:0), 9-octadecenoic (18:1), 9,12-octadecadienoic (18:6), nonanoic (9:1), nonanedioic (9:2) and nonanoic (9:1).

The supplementation of Suez soil with wheat straw at the highest concentration (1.0%) produced the following fatty acid oil profile: 9,15-octadecadienoic (18:7), hexadecanoic (16:0), octadecanoic (18:0). There was a decrease in the amount of hexadecanoic (16:0) relative to the control, and new fatty acids appeared: 9,15-octadecadienoic (18:7), octadecanoic (18:0). The other predominant fatty acids disappeared.

Furthermore, the application of *Eichhornia* at the highest concentration (1.0%) induce a different composition of the oil in which there was an increase in the percentage of 9-octadecenoic (18:1) and nonanoic (9:1) above the control value and a decrease in the percentage of hexadecanoic (16:0) and nonanoic (9:1). In addition, all other fatty acids disappeared while new fatty acids appeared: (8:0), octadecanoic (18:0), tetradecanoic (14:0), 8,11-octadecenoic (18:5) and decanoic (10:0).

The treatment with ammonium sulphate at 15 g/pot caused an increase in the value of nonanoic (9:1) and a decrease in hexadecanoic (16:0) and 9-octadecenoic (18:1). The only new synthesized fatty acid was octadecanoic (18:0) but the other predominant fatty acids disappeared.

Wheat straw at 1.0% and ammonium sulphate at 15 g/pot increased the unsaturated fatty acids and decreased the saturated ones (**Table 7**). So, the ratio of unsaturated/saturated fatty acids increased more than the untreated soil (control). However, the application of *Eichhornia* at the highest concentration (1.0%) did not change the unsaturated and saturated fatty acids and as a result the ratio was equal to that of the control.

Concerning the North Coast soil, the predominant fatty acids in the untreated soil sample were tetradecanoic (14:0), heptadecanoic (17:0), 6,9,12-octadecatrienoic (18:8), tricosanoic (23:0), 11,14,17-eicosatrienoic (20:3), 10-heptadecenoic (17:1), 9,12-octadecadienoic (18:6), 11,14-eicosatrienoic (20:2), 13,16-docosadienoic (22:1), 13-docosenoic

Table 7 Effect of different soil types and treatments on percentage of fatty acids in the oil of seeds yielded from *Carthamus tinctorius* L. plants.

Fatty acid	Suez soil				North Coast soil				El-Kantara soil				Garden soil
	A	B	C	D	A	B	C	D	A	B	C	D	
Octanoic acid (8:0)			9.853										6.394
Nonanoic acid, 4-oxo (9:0)	10.208		1.155										
Nonanoic acid, 9-oxo (9:1)	13.649		19.126	15.181		17.954	8.074		11.295				13.427
Nonanedioic acid (9:2)	10.956							6.271		22.653		20.684	11.765
Decanoic acid, 9-oxo (10:0)			0.845										
9-Methyl undecanoic acid (12:0)							1.599						
Tridecanedioic acid (13:0)					1.413								
Cyclopropanedecanoic acid (13:1)							1.877						
Tetradecanoic acid (14:0)			1.522		24.218								
Hexadecanoic acid (16: 0)	29.043	8.528	21.350	20.884		21.060	12.796	19.841	35.552	36.244	91.089	27.521	2.566
Heptadecanoic acid (17:0)					22.413								
10-Heptadecenoic acid (17:1)					6.836								
Octadecanoic acid (18:0)		2.676	4.776	3.951		8.549	4.570	7.578		13.354	5.909		21.821
9-Octadecenoic acid (18:1)	18.179		39.554	9.031		18.524		64.338				6.514	8.769
10-Octadecenoic acid (18:2)							36.579		32.061				6.556
11-Octadecenoic acid (18:3)										27.749			
12-Octadecenoic acid (18:4)												19.022	
8,11-Octadecadienoic acid (18:5)			1.819										
9,12-Octadecadienoic acid (18:6)	17.965			50.954	4.796	33.913					3.001	26.259	28.702
9,15-Octadecadienoic acid (18:7)		88.796											
6,9,12-Octadecadienoic acid (18:8)					13.036								
Eicosanoic acid (20:0)							2.056	1.971	21.092				
11-Eicosenoic acid (20:1)							7.943						
11,14-Eicosadienoic acid (20:2)					4.333								
11,14,17-Eicosatrienoic acid (20:3)					7.515								
11,14-Eicosadienoic acid (20:2)					1.745		24.506						
13-Docosenoic acid (22:1)					2.294								
13,16-Docosadienoic acid (22:2)					10.362								
Tetracosanoic acid (23:1)					1.406								
Saturated fatty acids (relative %)	63.856	11.204	58.627	40.016	59.813	47.563	30.972	35.661	67.939	72.251	96.998	48.205	55.973
Unsaturated fatty acids (relative %)	36.144	88.796	42.895	59.985	40.187	52.437	69.028	64.338	32.061	27.749	3.001	51.795	44.027
Unsaturated/saturated fatty acid ratio	0.5660	7.9254	0.7316	1.4990	0.6718	1.1024	2.2287	1.8041	0.4719	0.3840	0.0309	1.0745	0.7866

A = control; B = wheat straw (1%); C = *Eichhornia* (1%); D = ammonium sulphate (15 g/pot).

(22:0), tridecanoic (13:0) and tetracosanoic (23:1).

Application of wheat straw at 1.0% to the North Coast soil induced an increase in the value of 9,12-octadecadienoic (18:6) as well as the synthesis of new fatty acids, namely hexadecanoic (16:0); 9-octadecenoic (18:1); nonanoic (9:1) and octadecanoic (18:0).The wheat straw treatment led to the disappearance of the other fatty acids.

In the case of *Eichhornia* supplementation (1.0%), except for the value of 13-docosenoic (22:0), which increased compared to the control, the remaining fatty acids of this treatment were newly synthesized. The other fatty acids disappeared.

On the other hand, the treatment with ammonium sulphate (15 g/pot) showed a characteristic pattern of fatty acid composition since all the fatty acids of this treatment were newly synthesized.

As shown clearly in **Table 7**, there was an increase in the unsaturated fatty acids with all treatments of North Coast soil (1.0% wheat straw, 1.0% *Eichhornia* and 15 g/pot ammonium sulphate). An inverse situation occurred in the saturated fatty acids. So the unsaturated/saturated ratio increased more than the control value in all treatments.

With regards to the growth of safflower plants in El-Kantara soil the fatty acids were: hexadecanoic (16:0), 10-octadecenoic (18:2), eicosanoic (20:0) and nonanioic (9:1). In the treatment of El-Kantara soil with wheat straw at 1.0% there was no change in the value of hexadecanoic (16:0), while the remaining fatty acids were newly synthesized. Where *Eichhornia* was applied at 1.0% there was an increase in the percentage of hexadecanoic (16:0). The other predominant fatty acids disappeared while octadecanoic (18:0) and 9,12-octadecadienoic (18:8) were newly synthesized. Supplementation of El-Kantara soil by ammonium sulphate (15 g/pot) induce a decreased in the value of hexadecanoic (16:0) compared with the control. All the remaining fatty acids produced were newly synthesized.

It is clear that there was an increase in the saturated fatty acids when using organic fertilizers (wheat straw, *Eichhornia*), but there was an inverse situation when inorganic fertilizers were used. So the ratio of unsaturated/saturated fatty acids decreased in wheat straw and *Eichhornia* treatments compared with the control but increased in the ammonium sulphate treatment of soil from the El-Kantara site.

Changes in the oil and fatty acids composition of sunflower seed

The results represented in **Table 8** revealed the following

Table 8 Effect of different soil types and treatments on percentage of fatty acids in the oil yielded by seeds of *Helianthus annus* L. plants.

Fatty acid	Suez soil				North Coast soil				El-Kantara soil				Garden soil
	A	B	C	D	A	B	C	D	A	B	C	D	
Heptanoic acid (7:0)			2.442										
Octanoic acid (8:0)			11.339	0.947							5.979		
Octanedioic acid (8:1)	3.107					2.292							
Heptan-1,1-dimethoxy acid (9:0)				1.468									
Nonanoic a.,4-oxo acid (9:1)	6.889			2.175									
Nonanoic a.,9-oxo acid (9:2)	1.407		27.038	3.100		2.941				2.943	15.371		
Nonanedioic acid (9:3)	17.731			3.100		15.589	5.934	2.976	6.514	6.972			32.221
Decanoic acid (10:0)	1.714		1.989										
Decanedioic acid (10:1)	1.655												
10-Undecenoic acid (11:0)											2.622		
Tetradecanoic acid (14:0)			1.183									8.0996	
Pentadecanoic acid (15:0)		4.518											
Hexadecanoic acid (16:0)	23.425	19.293	17.749	13.038	36.656	19.768	24.674	12.222		24.158	23.599		34.745
9-Hexadecenoic acid (16:1)			1.512										
Trans-10-phenyldecalin acid (16:2)	5.166												
Heptadecanoic acid (17:0)												12.586	
10-Heptadecenoic acid (17:1)												1.677	
Octadecanoic acid (18:0)	6.484	7.327		7.505	9.164	7.563	7.429	4.889	8.769	9.044	5.636		5.349
8-Octadecenoic acid (18:1)	32.422												
9-Octadecenoic acid (18:2)		22.467	34.888	71.082	54.180	50.002	61.963		63.263		44.833		16.423
10-Octadecenoic acid (18:3)								79.913					
13-Octadecenoic acid (18:4)										56.883			
9,12-Octadecadienoic acid (18:5)		3.853	1.861									13.365	11.262
9,15-Octadecadienoic acid (18:6)						1.845							
Eicosanoic acid (20:0)									21.453		1.959		
11-Eicosenoic acid (20:1)		7.806											
11,14-Eicosadienoic acid (20:2)												49.000	
11,14,17-Eicosatrienoic acid (20:3)												3.044	
13-Docosenoic acid (22:0)		5.674											
13,16-Docosadienoic acid (22:1)		2.557										12.295	
Tricosanoic acid (23:0)		11.175											
Tetracosanoic acid (24:0)		4.634											
15-Tetracosenoic acid (24:1)		10.698											
Saturated fatty acids (relative %)	62.412	46.947	61.740	28.918	45.820	48.153	38.037	20.087	36.736	43.117	52.544	20.686	72.315
Unsaturated fatty acids (relative %)	37.588	53.055	38.261	71.082	54.180	51.847	61.963	79.913	63.263	56.883	47.455	79.314	27.685
Unsaturated/saturated fatty acid ratio	0.6023	0.8849	0.6197	2.4581	1.1825	1.0767	1.6290	3.9783	1.7221	1.3193	0.9032	3.8344	0.38284

A = control; B = wheat straw (1%); C = *Eichhornia* (1%); D = ammonium sulphate (15 g/pot).

main changes in the fatty acid composition of the variously yielded seeds of sunflower.

The predominant fatty acids of sunflower seed from the oil of plants grown in garden soil were: hexadecanoic (16:0); nonanedioic (9:3); 9-octadecenoic (18:2); 9,12-octadecadienoic (18:5) and octadecanoic (18:0).

For Suez soil, the predominant fatty acids in the oil of the control (untreated soil) were: 8-octadecenoic (18:1), hexadecanoic (16:0), nonanedioic (9:3), nonanoic (9:1), octadecanoic (18:0), *trans*-10-phenyldecalin (16:2), octanedioic (8:1), decanoic (10:0), decanedioic (10:1), and nonanoic (9:2).

The addition of wheat straw at the highest concentration (1.0%) resulted in a decrease in the value of hexadecanoic (16:0) and octadecanoic (18:0) compared with the control value. New fatty acids appeared: 9-octadecenoic (18:2), tricosanoic (23:0), 15-tetracosenoic (24:1), 11-eicosenoic (20:1), 13-docosenoic (22:0), tetracosanoic (24:0), pentadecanoic (15:0), 9,12-octadecadienoic (18:5) and 13,16-docosadienoic (22:1). The other predominant fatty acids disappeared. Supplementation of the soil with *Eichhornia* at 1.0% resulted is an increase in the value of nonanoic (9:2) above the control value, no change in the value of decanoic (10:0) and a decrease in the value of hexadecanoic (16:0). In addition, the other fatty acids disappeared while new fatty acids appeared viz. 9-octadecenoic (18:2), octanoic (8:0), heptan-1,1-dimethoxy (9:0), 9,12-octadecadienoic (18:5), 9-hexadecenoic (16:1) and tetradecanoic (14:0). However ammonium sulphate application at 15 g/pot induced changes in the predominant fatty acids since there was an increase in the value of nonanoic (9:2) and a decrease in the amount of nonanoic (9:1), nonanedioic (9:3), hexadecanoic (16:0) and octadecanoic (18:0). The newly synthesized fatty acids were 9-octadecenoic (18:2), octanoic (8:0) and heptan-1,1-dimethoxy (9:0) but the other predominant fatty acids disappeared.

As shown in **Table 8** wheat straw at 1.0% and ammonium sulphate at 15 g/pot were more favourable for unsaturated fatty acid production and less favourable for saturated ones. So, the ratio of unsaturated/saturated fatty acids was higher than the untreated soil (control). However, the application of *Eichhornia* at the highest concentration (1.0%) did not change the unsaturated and saturated fatty acids; as a result the ratio is equal to that of the control.

Concerning the growth of sunflower plants in the North Coast soil (untreated soil), the profile of fatty acids was: 9-octadecenoic (18:2), hexadecanoic (16:0) and octadecanoic (18:0). The addition of wheat straw at 1.0% to the North Coast soil changed the fatty acid composition of oil in which the percentage of 9-octadecenoic (18:2), hexadecanoic (16:0) and octadecanoic (18:0) decreased while nonanedioic (9:3), nonanoic (9:2), octanedioic (8:1) and 9,15-octadecadienoic (18:6) were newly synthesized. Compared to the control, treatment with *Eichhornia* at 1.0% produced a decrease in hexadecanoic (16:0) and octadecanoic (18:0) as well as an increase in 9-octadecenoic (18:2). There was only one new fatty acid, nonanedioic (9:3). In the case of ammonium sulphate (15 g/pot) a decrease in the value of hexadecanoic (16:0) and octadecanoic (18:0) was recorded compared with the control value, also, 10-octadecenoic (18:3) and nonanedioic (9:3) were newly synthesized fatty acids. An increase in the saturated fatty acids with the treatment of North Coast soil by wheat straw at 1.0% as well as a decrease with *Eichhornia* at concentration 1.0% and ammonium sulphate at 15 g/pot were clearly observed. An inverse situation was observed in the unsaturated fatty acids. So the unsaturated/saturated ratio was higher than the control value in the case of *Eichhornia* and ammonium sulphate treatments.

With regard to El-Kantara soil, the untreated predominant fatty acids in sunflower seed oil were 9-octadecenoic (18:2), eicosanoic (20:0), octadecanoic (18:0) and nonanedioic (9:3). On the other hand, the treatment of El-Kantara soil with wheat straw elicited no change in the percentage of octadecanoic (18:0) and nonanedioic (9:3) as well as synthesis of new fatty acids namly 13-octadecenoic (18:4), hexadecanoic (16:0) and nonanoic (9:2). It is clear that for *Eichhornia* at 1.0% there was a decrease in the value of 9-octadecenoic (18:2), octadecanoic (18:0) and eicosanoic (20:0). The other predominant fatty acids disappeared while others were newly synthesized: hexadecanoic (16:0), nonanoic (9:2), octanoic (8:0) and 10-undecenoic (11:0). Supplementation of El-Kantara soil by ammonium sulphate at 15 g/pot produced a whole group of newly synthesized fatty acids 11,14-eicosadienoic (20:2), 9,12-octadecadienoic (18:5), heptadecanoic (17:0), 13,16-docosadienoic (22:1), tetradecanoic (14:0), 11,14-eicosadienoic (20:2) and 10-heptadecenoic (17:1).

From the data in **Table 8**, it is clear that there was an increase in the saturated fatty acids when using organic fertilizers (wheat straw, *Eichhornia*) but in the case of inorganic fertilizer there was an inverse situation. So the ratio of unsaturated/saturated fatty acids was lower in wheat straw and *Eichhornia* treatments and higher in the ammonium sulphate treatment than the control in soil from the El-Kantara site.

Applicability of results

The changes observed in the fatty acid composition of sunflower oil of plants grown in Suez soil and treated with ammonium sulphate, in North Coast soil treated with both *Eichhornia* and ammonium sulphate as well as in El-Kantara soil treated with ammonium sulphate indicate this oil to be a good source for essential fatty acids (for using as edible oils). The other resulting oils can be used for several other purposes other than foods.

The observed decrease in the total unsaturated fatty acids at the expense of saturated ones in response to moderate and high levels of salinity led us to believe that the resulting oil can be characterized by high stability through the inhibitory action of salinity on desaturase enzymes in seeds. According to the FAO (Food Agriculture Organization), the high contents of saturated fatty acids of the oil of these plants evaluate this oil to be an unsuitable source for essential fatty acids. Ramadan (1992), using soybean, found that by increasing temperature and drought conditions the unsaturated fatty acids decreased whereas the saturated ones increased. Agegnehu and Honermeier (1997) stated that the compositional changes in fatty acid of oil and proportion of saturated to unsaturated varied according to soil fertility. Also, Salvador *et al.* (1988) using safflower found that the contents of palmitic and stearic acids were not affected by soil moisture though the oleic acid content increased; moreover, linoleic acid content decreased with increasing soil moisture.

From my results I can conclude that canola gave the best quality fatty acids when cultivated in Suez soil supplemented with ammonium sulphate, when cultivated in North Coast soil supplemented with wheat straw and when cultivated in El-Kantara soil supplemented with ammonium sulphate. For safflower, the best quality fatty acids were obtained when cultivated in Suez soil supplemented with wheat straw, when cultivated in North Coast soil supplemented with *Eichhornia* fertilizer and when cultivated in El-Kantara soil supplemented with ammonium sulphate. For sunflower, the best quality fatty acids resulted when cultivated in North Coast soil supplemented with ammonium sulphate, when cultivated in El-Kantara soil supplemented with ammonium sulphate fertilizer and when cultivated in Suez soil supplemented with ammonium sulphate.

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