International Journal of PharmTech Research
CODEN (USA): IJPRIF, ISSN: 0974-4304, ISSN(Online): 2455-9563
Vol.9, No.10, pp 420-431, 2016

Influence of Selenium and Boron on Oil Production and Fatty Acids Composition of Canola (*Brassica napus* L.) Plant Irrigated with Saline Water

E. M. Badawy[1], Eman E. Aziz[2*], A. H. Hanafy Ahmed[3] and Hend Fouad[2]

[1]Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Egypt

[2]Medicinal and Aromatic Plants Research Department, National Research Centre (12622), Cairo, Egypt

[3]Agricultural Botany Department, Plant Physiology Section, Faculty of Agriculture, Cairo University, Egypt

Abstract : Salinity is a major factor that influences rapeseed production. Canola is now the third most important source of edible oil in the world and has many uses in modern medicine. Selenium and boron are required by plants in small quantities that involve several physiological and biochemical processes in plants. The aim of this investigation was to evaluate the effect of selenium (0, 2 and 4 mg l^{-1} as sodium selenate) and boron (0, 2, and 4 mg l^{-1} as boric acid) on oil production and fatty acids composition of *Brassica napus* plants irrigated with saline water (0, 2.5, 5 and 7.5 dS m^{-1}). Data revealed that salinity significantly decreased oil content of canola and the highest values (0.43 and 1.00 g $plant^{-1}$ in the 1st and 2nd seasons, respectively) were obtained from the lowest level of salinity (2.5 dS m^{-1}) while increasing salinity up to 7.5 dS m^{-1} resulted in the minimum values of oil content (0.25). Plants irrigated with the lowest level of salinity (2.5 dS m^{-1}) and sprayed with selenium at 4 mg l^{-1} and boron at 2 mg l^{-1} gave the highest oil content in the 2nd season (1.94 g $plant^{-1}$). Gas Chromatography / Mass Spectrometry analysis pointed out that canola oil was characterized by containing a high relative concentration of unsaturated fatty acids. The major monounsaturated fatty acids was Oleic acid (46.2 - 75.6 %), followed by cis-11-Eicosenoic acid (1.4 - 11.5 %) and Erucic acid (0.8 - 10.8 %). Linoleic acid (11.2 - 24.8 %) was the main component of polyunsaturated fatty acids. Whereas the main saturated fatty acids were Palmitic acid (1.0 - 5.0 %) and Stearic acid (1.4 - 3.0 %). The highest relative concentrations of Oleic acid (63.3 and 64.4 %) were recorded with salinity at 2.5 and 5 dS m^{-1}, respectively. While increasing salinity level up to 7.5 dS m^{-1} decreased Oleic acid (60.5%) and increased Linoleic acid (20.1%). Moreover, applying selenium at 2 mg l^{-1} and boron at 4 mg l^{-1} with plants irrigated with the lowest level of salinity 2.5 dS m^{-1} recorded the highest value of Oleic acid (75.6 %) and the lowest value of Linoleic acid (11.2 %), while increasing salinity up to 7.5 dS m^{-1} resulted in the maximum values of Linoleic acid (24.4%) and Palmitic acid (5.0%). The application of selenium at 4 mg l^{-1} and boron at 4 mg l^{-1} to plants irrigated with the lowest level of salinity (2.5 dS m^{-1}) increased refractive index, specific gravity, saponification number, ester number and iodine number and decreased acid number. Canola oil has high antioxidant activity which gave the greatest value (82.5 %) with plants irrigated with the lowest level of salinity (2.5 dS m^{-1}) and sprayed with selenium at 4 mg l^{-1} and boron at 2 mg l^{-1}.

Key words: Canola, salinity, selenium, boron, oil production, fatty acids, antioxidant activity.

Introduction

Brassica napus (*Brassicaceae*), is a medicinal food plant[1] providing 13% of the world's edible oil supply[2]. Canola seeds contain 40-45% fixed oil[3]. Its oil has a high proportion of unsaturated fats and a lower level of saturated fats[4]. Canola is used in treating cardiovascular disease[5], rheumatoid arthritis[6], lupus nephritis[7] and high blood pressure[8]. It has antithrombotic[9], antioxidant and anti-inflammatory effects because of the presence of omega-6 and omega-3 fatty acids[10]. Canola oil is also used in bio-diesel production[11].

Salinity is the main environmental factor accountable for decreasing crop productivity mainly in arid and semi-arid regions[12]. Approximately 33% of the cultivated land and most extensions of agricultural land in Egypt are already salinized[13]. Salinity is a major factor that influences rapeseed production[14].

Selenium is an essential trace element for both humans and animals[15], i.e. its adequate concentration in humans is about 60 µg day^{-1}. Selenium has efficacy for cancer prevention[16] as prostate cancer[17] and colon and mammary tumors[18]. It has a protective role in atherosclerosis, arthritis and immunity as well as improving fertility[19]. Deficiency of selenium in various animal species resulted in Se-responsive diseases such as muscular dystrophy, exudative diathesis and hepatosis dietetica.

Selenium is a beneficial element for higher plants and has a positive effect on plants growth[20]. It plays an important role in enhancing the resistance of the plants to certain abiotic stresses, e.g. salinity[21]. This protective role in most cases has been attributed to various defense mechanisms which can stimulate plant growth[22].

Boron is essential for plant growth, development and yield as well as the quality of harvested crops. It is required by plants in small quantities that involve several physiological and biochemical processes in the plants[23] including seed oleic fatty acid[24]. Boron application mitigated negative effects of salts and enhanced growth of canola[25]. Canola has a high demand for boron and is extremely sensitive to boron deficiency. Seed yield and oil quality of canola are often limited by the low availability of boron in soils[26]. The aim of this investigation was to determine the effect of selenium and boron on oil production and fatty acids composition of *Brassica napus* plants irrigated with saline water.

Materials and Methods

The experiments were carried out at the National Research Centre, Dokki, Cairo, Egypt during the two successive seasons of 2012/2013 and 2013/2014 to study the impact of selenium and boron on oil production and fatty acids composition of canola plants irrigated with saline water.

Canola "*Brassica napus* L. cv. Serw 4" seeds were obtained from the Ministry of Agriculture "Oil Crop Research Center", Giza, Egypt. On 5th November 2012 in the 1st season and 12th November 2013 in the 2nd season, the seeds were sown in plastic pots (30 cm height x 25 cm diameter) filled with 12kg of sandy soil. The pots were kept outdoor under natural environmental conditions. The seedlings were thinned twice, leaving two plants pot^{-1}.

The soil was prepared two weeks before sowing date. During soil preparation, all treatments were fertilized with compost at the rate of 15 ton fed^{-1}, 300 kg fed^{-1} calcium superphosphate (15.5% P_2O_5), 90 kg fed^{-1} potassium sulphate (48.5% K_2O) and 300 kg fed^{-1} agricultural sulphur (99.9%). Moreover, ammonium sulphate (20.5% N) was added at the rate of 150 kg fed^{-1} in three doses; during sowing date, one month later and at the end of vegetative growth stage.

A factorial experiment was imposed in three replication in a completely randomized design of all combination between four levels of saline water (0, 2.5, 5 and 7.5 dS m^{-1} as 2 NaCl : 2 $CaCl_2$: 1 $MgSO_4$), three selenium concentrations (0, 2 and 4 mg l^{-1} as sodium selenate Na_2SeO_4) and three boron concentrations (0, 2, and 4 mg l^{-1} as boric acid) as well as the interaction between selenium and boron under salinity treatments. The plants were sprayed with selenium and boron twice, after 40 and 70 days from sowing.

All pots were irrigated with 1.5 l pot^{-1} of tap water for 5 weeks and then with saline water. Every three times of saline water irrigation, the forth one was with 1.5 L pot^{-1} of tap water containing full-strength Hoagland's solution[27]. The plants were irrigated three times weekly in the summer and two times weekly in the winter. All the plants received natural agriculture practices whenever they needed.

The physical and chemical characteristics of the used sandy soil were determined according to Jackson[28] and are presented in Table (1).

Table (1): The physical and chemical properties of the experimental soil

Physical properties (particle size distribution %)									
		Sand		**Silt**		**Clay**		**Texture**	
		81.8		**7.0**		**11.2**		**Sandy**	
Chemical properties									
pH	**E.C.**	**(meq/l)**							
(1:2.5)	**(dSm^{-1})**	**Cations**				**Anions**			
	(1:5)	**Ca^{++}**	**Mg^{++}**	**Na^{+}**	**K^{+}**	**CO_3^{--}**	**HCO_3^{-}**	**Cl^{-}**	**SO_4^{--}**
7.8	0.3	1	0.5	1.5	0.4	-	0.4	2.5	0.5

Data recorded

The following data had been recorded

1. Percentage and yield of oil

Five grams of canola air-dried seeds were separately crushed and extracted with petroleum ether (40-60°C) using a Soxhlet apparatus[29]. Oil percentage (%) and content (g plant^{-1}) were calculated.

2. Esterification of fatty acids

The esterification was done using sodium methoxide-boron trifluoride method as described by Mota *et al*.[30] according to Christie[31] and Khan and Scheinmann[32].

3. Composition of fatty acids

The GC-MS analysis was carried out using gas chromatography-mass spectrometry instrument with the following specifications, Instrument: a TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a thermo mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer).The GC-MS system was equipped with a TG-5MS column (30 m x 0.25 mm i.d., 0.25 μm film thickness). Analyses were carried out using helium as carrier gas at a flow rate of 1.0 mL/min and a split ratio of 1:10 using the following temperature program: 80 ^{o}C for 1 min; rising at 4 ^{o}C/min to 300 ^{o}C and held for 5 min. The injector and detector were held at 240 ^{o}C. Diluted samples (1:10 hexane, v/v) of 0.3 μL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 35-500.

4. Physical and chemical properties of canola oil

a. Refractive index, specific gravity, acid number, saponification number and ester number were determined as stated by A.O.A.C.[33]

b. Iodine value

Iodine value of samples was calculated from fatty acids profile by using reacting ratios (calculated factors) between iodine and either the fatty acids bond[34].

5. Antioxidant activity

The antioxidant activity was measured in terms of hydrogen-donating or radical-scavenging ability, using the stable radical DPPH (2,20-Diphenyl-1-picrylhydrazyl)[35].

The data recorded were analyzed as completely randomized design by analysis of variance (ANOVA) using the General Linear Models procedure of CoStat[36]. Least significant difference (LSD) test was applied at 0.05 probability levels.

Results and Discussion

1. Oil percentage and content

Data presented in Table (2) indicate that, increasing salinity significantly decreased oil percentage (%) and content (ml plant^{-1}) in both seasons. It was obvious that, the lowest level of salinity (2.5 dS m^{-1}) resulted in the highest values of oil percentage and content (23.7 % and 0.43 g plant^{-1}, respectively) in the 1st season as well as (26 % and 1.00 g plant^{-1}, respectively) in the 2nd season. While the lowest values (20.3 % and 0.25 g plant^{-1}) and (21.7 % and 0.37 g plant^{-1}) in the 1st and 2nd season, respectively were recorded with the highest level of salinity (7.5 dS m^{-1}).

Table (2): Effect of selenium and boron on oil production of *Brassica napus* plants irrigated with saline water during 2012/2013 and 2013/2014 seasons

Foliar application (F) mg l^{-1}	2012/2013					2013/2014				
	Salinity (S) dS m^{-1}					Salinity (S) dS m^{-1}				
	0	2.5	5	7.5	Mean (F)	0	2.5	5	7.5	Mean (F)
	Percentage (%)									
Control	21.3	20.6	25.0	16.5	**20.8**	16.6	29.4	21.2	25.6	**23.2**
Se_1	22.0	19.6	22.2	21.4	**21.3**	27.6	24.9	23.0	20.0	**23.9**
Se_2	31.5	21.0	18.9	19.3	**22.7**	30.7	22.0	28.8	23.7	**26.3**
B_1	22.1	22.9	19.9	19.7	**21.2**	28.7	23.6	22.8	22.3	**24.4**
B_2	20.5	21.5	24.6	19.1	**21.5**	28.5	24.1	26.5	21.0	**25.0**
Se_1B_1	22.9	26.8	23.5	22.7	**24.0**	27.7	25.7	22.2	19.9	**23.9**
Se_1B_2	27.8	22.5	24.4	19.8	**23.6**	26.5	31.5	23.0	19.1	**25.0**
Se_2B_1	21.4	26.9	27.6	21.4	**24.3**	28.9	30.5	29.7	22.2	**27.8**
Se_2B_2	24.9	31.5	24.4	22.8	**25.9**	28.4	22.6	26.5	21.1	**24.6**
Mean (S)	**23.8**	**23.7**	**23.4**	**20.3**		**27.1**	**26.0**	**24.8**	**21.7**	
LSD at 5%	**S 0.60 F 0.91 SF 1.52**					**S 0.63 F 0.94 SF 1.57**				
	Content plant^{-1} (g)									
Control	0.41	0.36	0.37	0.17	**0.32**	0.45	0.97	0.41	0.46	**0.57**
Se_1	0.25	0.35	0.30	0.29	**0.30**	0.78	0.50	0.63	0.59	**0.62**
Se_2	0.63	0.45	0.30	0.31	**0.42**	0.91	0.76	0.92	0.30	**0.72**
B1	0.31	0.26	0.29	0.26	**0.28**	0.87	0.55	0.55	0.28	**0.56**
B_2	0.37	0.24	0.25	0.22	**0.27**	1.14	0.72	0.86	0.48	**0.80**
Se_1B_1	0.42	0.79	0.47	0.26	**0.48**	0.92	1.19	0.54	0.39	**0.76**
Se_1B_2	0.60	0.36	0.28	0.19	**0.36**	1.07	1.59	0.58	0.23	**0.87**
Se_2B_1	0.47	0.51	0.58	0.23	**0.45**	0.76	1.94	1.03	0.39	**1.03**
Se_2B_2	0.34	0.55	0.40	0.33	**0.40**	0.96	0.76	0.66	0.23	**0.65**
Mean (S)	**0.42**	**0.43**	**0.36**	**0.25**		**0.87**	**1.00**	**0.68**	**0.37**	
LSD at 5%	**S 0.009 F 0.013 SF 0.022**					**S 0.042 F 0.063 SF 0.105**				

Se_1 (Selenium 2 mg l^{-1}), Se_2 (Selenium 4 mg l^{-1}), B_1 (Boron 2 mg l^{-1}), B_2 (Boron 4 mg l^{-1})

The reduction in oil content may be attributed to the weakening of salinity to lipid complex or enzyme activities[37] which resulted in decreasing oil percentage in the produced seeds[38]. In addition, salinity limits vegetative and reproductive growth by inducing severe physiological dysfunctions and causing widespread direct and indirect harmful effects[39] including inhibition of enzymatic activity[40], photosynthesis[41], absorption of minerals[42], protein and nucleic metabolism[43], respiration[44] and stomatal behavior[45]. The adverse effect of salinity on canola oil content was reported previously by[46,47,48,49] who stated that oil content of canola was significantly decreased with increasing salinity levels.

In addition, the data show that spraying canola plants with selenium and boron had a positive effect on oil content and the favorable treatment was selenium at 4 mg l^{-1} with boron at 2 mg l^{-1} which achieved the maximum value (0.45 g $plant^{-1}$) in the 1st season as well as the highest percentage and content (27.8% and 27.1.03 g $plant^{-1}$, respectively) in the 2nd season. Whereas the highest value for oil content in the 1st season (25.9 %) was recorded for plants treated with selenium at 4 mg l^{-1} combined with boron at 4 mg l^{-1}. This effect may be attributed to that selenium and boron increase seed production of rapeseed[50, 51]. The positive effect of boron application on fixed oil was previously reported by[52,53] who found that oil content of soybean was significantly higher with boron application.

Moreover, the highest percentage and content of oil (30.5 % and 1.94 g $plant^{-1}$, respectively) were recorded with plant irrigated with the lowest concentration of salinity 2.5 dS m^{-1} and sprayed with 4 mg l^{-1} of selenium and 2 mg l^{-1} of boron.

2. Fatty acids composition

The results in Table (3) show that canola oil was characterized by containing a high relative concentration of unsaturated fatty acids. The major monounsaturated fatty acids was Oleic acid (46.2 - 75.6 %), followed by cis-11-Eicosenoic acid (1.4 - 11.5 %) and Erucic acid (0.8 - 10.8 %). Linoleic acid (11.2 - 24.8 %) was main component of polyunsaturated fatty acids. Whereas the main saturated fatty acids were Palmitic acid (1.0 - 5.0 %) and Stearic acid (1.4 - 3.0 %). This result agreed with that reported previously by[54] who found that the monounsaturated fatty acids were Oleic acid (18:1, ω-9), cis-11-Eicosenoic acid (20:1, ω-9) and Erucic acid (22:1, ω-9) as well as the polyunsaturated fatty acids; Linoleic acid (18:2, ω-6) and α-Linolenic acid (18:3, ω-3). Whereas the main saturated fatty acids were Palmitic acid (16:0), Stearic acid (18:0) and Arachidic acid (20:0).

The highest relative concentration of Oleic acid (63.3 and 64.4 %) were recorded with salinity at 2.5 and 5 dS m^{-1}, respectively as compared with control which gave 64.8%.While increasing salinity level up to 7.5 dSm^{-1} decreased Oleic acid to 60.5% and increased the polyunsaturated fatty acid Linoleic acid to 20.1% as well as cis-11-Eicosenoic acid to 7.0 % and Erucic acid to 4.9 %. The composition of fatty acids is strictly connected with a genetic factor[55]. Such changes in fatty acid composition were attributed to the activity of enzymes involved in lipid synthesis and conversion. The initial steps of fatty acid synthesis in oil seeds are localized in the plastids. Oleic acid is the main product of plastidal lipid synthesis, and is subsequently exported to the cytolsol. Cytololic desaturation of oleic acid to form PUFA (i.e. linoleic acid) is mediated by the enzyme oleate desaturase. The activity of this enzyme was put forward as an explanation for shifts in oleic acid / linoleic acid ratio in several crops under various types of stress, including salinity, drought, and heat[56,57,58]. The effect of salinity stress on fatty acids was previously reported by[59] who found that Linolenic acid percentage in canola oil was increased due to salt stress as well as[60] who demonstrated that fatty acids content of canola oil was increased due to increasing salinity.

On the other hand, the maximum value of Oleic acid and the minimum values of cis-11-Eicosenoic acid and Erucic acid were recorded with the combination of selenium at 2 mg l^{-1} with boron at 4 mg l^{-1}. The favorable effect of boron may be attributed to its involvement in several physiological and biochemical processes in the plants[23] including seed oleic fatty acid[61]. This result is in harmony with[52] who found that Oleic acid of soybean oil was increased and Linolenic acid was decreased with boron application.

Moreover, The maximum relative concentrations (75.6 %) of Oleic acid and the lowest concentration of Linoleic acid (11.2 %) were obtained from plants irrigated with the lowest level of salinity 2.5 dS m^{-1} and sprayed with selenium at 2 mg l^{-1} and boron at 4 mg l^{-1} while increasing salinity up to 7.5 dS m^{-1} combined with selenium at 2 mg l^{-1} resulted in the maximum values of Palmitic acid (5.0%) and Linoleic acid (24.8%) and the lowest value of Oleic acid (48.5 %).

Table (3): Effect of selenium and boron on fatty acids composition of *Brassica napus* plants irrigated with saline water during 2013/2014 season

Foliar Application (F) mg l^{-1}	Salinity (S) dS m^{-1}					Salinity (S) dS m^{-1}				
	0	2.5	5	7.5	Mean (F)	0	2.5	5	7.5	Mean (F)
	Palmitic acid					Linoleic acid				
Control	3.7	2.8	2.0	2.4	**2.7**	19.2	16.6	15.9	17.7	**17.4**
Se_1	2.5	3.4	3.1	5.0	**3.5**	18.0	17.9	19.3	24.8	**20.0**
Se_2	2.6	2.3	2.7	2.8	**2.6**	16.5	16.3	17.7	20.8	**17.8**
B_1	3.1	3.2	3.0	4.5	**3.4**	19.4	21.1	21.0	21.5	**20.7**
B_2	2.9	3.8	4.7	2.3	**3.4**	16.8	23.3	23.2	16.7	**20.0**
Se_1B_1	3.3	2.9	2.2	1.0	**2.4**	19.3	17.0	16.7	17.9	**17.7**
Se_1B_2	3.3	2.1	2.2	2.7	**2.6**	20.5	11.2	18.0	24.6	**18.6**
Se_2B_1	2.1	3.1	3.8	2.6	**2.9**	15.4	19.0	22.2	20.2	**19.2**
Se_2B_2	2.9	2.7	1.9	2.7	**2.5**	19.8	20.5	15.5	16.6	**18.1**
Mean (S)	**2.9**	**2.9**	**2.9**	**2.9**		**18.3**	**18.1**	**18.8**	**20.1**	
	Oleic acid					Stearic acid				
Control	64.2	54.4	73.7	67.7	**65.0**	2.4	2.3	1.5	1.9	**2.0**
Se_1	60.8	63.1	62.4	48.5	**58.7**	2.2	1.9	2.4	2.4	**2.2**
Se_2	62.0	62.1	60.1	60.2	**61.1**	2.0	2.0	2.1	2.5	**2.2**
B_1	62.2	58.2	69.7	46.2	**59.1**	2.5	2.6	1.4	2.4	**2.2**
B_2	67.3	60.4	56.0	68.6	**63.0**	1.9	2.7	3.0	1.7	**2.3**
Se_1B_1	59.3	68.0	61.6	70.1	**64.8**	2.1	1.9	2.0	1.6	**1.9**
Se_1B_2	70.1	**75.6**	65.1	63.0	**68.5**	1.5	1.8	1.8	1.7	**1.7**
Se_2B_1	70.2	61.3	64.8	56.1	**63.1**	2.0	2.1	2.8	1.8	**2.1**
Se_2B_2	67.4	66.6	65.9	64.6	**66.1**	1.9	1.5	1.7	2.1	**1.8**
Mean (S)	**64.8**	**63.3**	**64.4**	**60.5**		**2.0**	**2.1**	**2.1**	**2.0**	
	Cis-11-Eicosenoic acid					Erucic acid				
Control	4.0	**11.5**	3.8	5.2	**6.1**	2.6	**10.3**	1.8	3.7	**4.6**
Se_1	9.0	7.6	6.6	8.0	**7.8**	4.8	4.3	3.5	7.5	**5.0**
Se_2	8.6	9.4	8.5	6.9	**8.3**	6.2	6.3	6.7	3.4	**5.6**
B_1	5.4	8.2	1.5	10.8	**6.5**	3.8	3.6	0.9	10.8	**4.8**
B_2	5.3	3.7	6.5	5.7	**5.3**	3.7	2.1	2.9	3.6	**3.1**
Se_1B_1	7.8	5.4	10.9	4.6	**7.2**	5.5	2.6	5.1	2.2	**3.8**
Se_1B_2	1.4	5.6	7.2	3.5	**4.4**	0.8	2.7	4.2	1.7	**2.3**
Se_2B_1	5.0	7.2	2.3	10.4	**6.2**	3.7	4.7	0.7	7.4	**4.1**
Se_2B_2	3.7	3.3	6.6	8.2	**5.4**	2.0	3.6	6.6	4.1	**4.1**
Mean (S)	**5.6**	**6.9**	**6.0**	**7.0**		**3.7**	**4.5**	**3.6**	**4.9**	

Se_1 (Selenium 2 mg l^{-1}), Se_2 (Selenium 4 mg l^{-1}), B_1 (Boron 2 mg l^{-1}), B_2 (Boron 4 mg l^{-1})

3. Oil physical and chemical properties

Data illustrated in Table (4) reveal that salinity had no significant effect on refractive index, specific gravity, ester number or iodine number and significantly decreased saponification number and acid number.

Table (4): Effect of selenium and boron on physical and chemical properties of fixed oil of *Brassica napus* plants irrigated with saline water during 2013/2014 season.

Foliar application (F) mg l^{-1}	Salinity (S) dS m^{-1}					Salinity (S) dS m^{-1}				
	0	2.5	5	7.5	Mean (F)	0	2.5	5	7.5	Mean (F)
	Refractive index					Specific gravity				
Control	1.68	1.68	1.68	1.68	**1.68**	0.95	0.95	0.90	0.85	**0.91**
Se_1	1.68	1.68	1.68	1.68	**1.68**	0.93	0.93	0.88	0.93	**0.91**
Se_2	1.68	1.68	1.68	1.68	**1.68**	0.93	0.80	0.95	0.93	**0.90**
B_1	1.68	1.68	1.68	1.68	**1.68**	0.88	0.85	0.93	0.93	**0.90**
B_2	1.68	1.68	1.68	1.68	**1.68**	0.88	0.88	0.95	0.78	**0.87**
Se_1B_1	1.68	1.68	1.68	1.68	**1.68**	0.93	0.95	0.85	0.95	**0.92**
Se_1B_2	1.68	1.68	1.68	1.68	**1.68**	0.85	0.95	0.82	0.95	**0.89**
Se_2B_1	1.68	1.68	1.68	1.68	**1.68**	0.93	0.90	0.95	0.88	**0.91**
Se_2B_2	1.68	1.68	1.68	1.68	**1.68**	0.83	0.93	0.93	0.95	**0.91**
Mean (S)	**1.68**	**1.68**	**1.68**	**1.68**		**0.90**	**0.91**	**0.91**	**0.91**	
LSD at 5%	**S ns F ns SF ns**					**S ns F ns SF 0.097**				
	Saponification number					Acid number				
Control	174.5	187.6	199.4	189.6	**187.8**	0.94	0.55	0.99	0.60	**0.77**
Se_1	188.8	186.0	190.6	192.1	**189.4**	1.40	1.17	0.73	0.70	**1.00**
Se_2	213.9	196.3	176.9	193.0	**195.0**	0.70	0.85	0.57	0.79	**0.73**
B_1	189.2	177.4	179.5	202.0	**187.0**	0.98	0.66	0.78	0.68	**0.77**
B_2	188.9	205.1	191.3	188.8	**193.5**	0.68	0.65	0.46	0.65	**0.61**
Se_1B_1	216.3	203.3	202.9	203.5	**206.5**	0.55	0.89	0.62	0.63	**0.67**
Se_1B_2	186	185.6	208.0	189.4	**192.3**	0.65	0.76	0.64	0.66	**0.68**
Se_2B_1	218.9	194.9	205.4	189.8	**202.3**	0.82	0.57	0.52	0.60	**0.63**
Se_2B_2	218.1	216.9	188.8	186.2	**202.5**	0.92	0.66	0.70	0.67	**0.74**
Mean (S)	**199.4**	**194.8**	**193.6**	**192.7**		**0.85**	**0.75**	**0.67**	**0.66**	
LSD at 5%	**S 3.95 F 5.92 SF 9.91**					**S 0.066 F 0.100 SF 0.167**				
	Ester number					Iodine number				
Control	173.6	187.0	198.4	189.0	**187.0**	94.6	86.6	96.3	95.8	**93.3**
Se_1	187.4	184.8	189.9	194.7	**189.2**	90.9	92.4	93.7	94.1	**92.8**
Se_2	213.2	195.4	176.3	191.9	**194.2**	90.3	90.1	91.0	94.4	**91.5**
B_1	188.2	176.7	178.7	201.3	**186.3**	93.9	93.2	101.4	88.5	**94.3**
B_2	188.2	204.5	190.8	188.2	**192.9**	93.6	98.0	94.5	94.6	**95.2**
Se_1B_1	215.7	202.4	202.3	202.9	**205.8**	92.3	93.9	89.5	97.2	**93.2**
Se_1B_2	185.3	184.8	207.4	188.7	**191.6**	100.7	90.3	94.3	102.5	**97.0**
Se_2B_1	218.1	194.3	204.9	189.2	**201.6**	93.7	93.2	99.0	92.6	**94.6**
Se_2B_2	217.2	216.2	188.1	185.5	**201.8**	97.9	99.7	92.3	91.2	**95.3**
Mean (S)	**198.6**	**194.0**	**193.0**	**192.4**		**94.2**	**93.1**	**94.7**	**94.5**	
LSD at 5%	**S ns F 10.74 SF 17.96**					**S ns F ns SF ns**				

Se_1 (Selenium 2 mg l^{-1}), Se_2 (Selenium 4 mg l^{-1}), B_1 (Boron 2 mg l^{-1}), B_2 (Boron 4 mg l^{-1})

The application of selenium at 4 mg l^{-1} and boron at 4 mg l^{-1} on plants irrigated with the lowest concentration of salinity (2.5 dS m^{-1}) resulted in the highest values of refractive index, specific gravity, saponification number, ester number and iodine number and the lowest value of acid number.

The slight changes in oil properties may be due to that the oil properties are related to the oil quality genetics more than the environmental effects during plant growth in the field. The influences of boron on fixed oil properties may be attributed to that the oil quality of canola is often limited by the low availability of boron in soils[26].

4. Antioxidant activity of oil

Data in Table (5) point out that increasing salinity levels either alone or combined with foliar spray of selenium and/or boron decreased oil antioxidant activity. The greatest value of oil antioxidant activity (80.4 %) was achieved with the lowest level of salinity (2.5 dS m^{-1}).

At the same time, the foliar spray with selenium and boron significantly affected oil antioxidant activity. The highest value (80.9 %) was resulted from spraying selenium at 2 mg l^{-1} combined with boron at 2 mg l^{-1}.

In addition, the combination between salinity, selenium and boron significantly affected the antioxidant activity of oil. The oil recorded its highest antioxidant activity (84.1 %) in the plants irrigated with tap water (0 dS m-1) and sprayed with selenium alone at 4 mg l-1. It was observed that, there were no significant differences between the highest value of oil antioxidant activity and many values recorded with higher salinity concentrations up to 7.5 dS m-1 and sprayed with different levels of selenium and boron.

The antioxidant activity may be attributed to the presence of α-tocopherol, phenolic compounds, and unsaturated fatty acids. The lipid content may be changed due to oxidation of the oil which in turn affects the antioxidant potential of the oil[62]. Salt stress can also result in the accumulation of reactive oxygen species (ROS) in plants. The enhanced production of ROS can pose a threat to plants, but they are also believed to act as signals for the activation of the stress-response and defense pathways[63]. Either directly or indirectly *via* the regulation of antioxidants, selenium controls the production and quench of ROS[64]. In addition, its application at low concentrations enhanced antioxidative capacity of both mono- and dicotyledonous plants[65].

Table (5): Effect of selenium and boron on antioxidant activity (%) of fixed oil of *Brassica napus* plants irrigated with saline water during 2013/2014 season.

Foliar application (F) mg l^{-1}	Salinity (S) dS m^{-1}				
	0	2.5	5	7.5	Mean (F)
Control	78.2	82.1	79.2	79.0	**79.6**
Se_1	82.5	81.5	79.9	77.8	**80.4**
Se_2	84.1	82.6	79.2	77.4	**80.8**
B_1	82.5	80.3	78.8	79.7	**80.3**
B_2	70.2	77.8	79.0	78.0	**76.3**
Se_1B_1	83.7	81.3	77.5	81.0	**80.9**
Se_1B_2	81.8	78.9	79.6	75.9	**79.0**
Se_2B_1	68.9	82.5	79.8	80.2	**77.9**
Se_2B_2	82.2	76.9	78.8	79.2	**79.3**
Mean (S)	**79.3**	**80.4**	**79.1**	**78.7**	
LSD at 5%	**S 0.68 F 1.02 SF 1.70**				

Se_1 (Selenium 2 mg l^{-1}), Se_2 (Selenium 4 mg l^{-1}), B_1 (Boron 2 mg l^{-1}), B_2 (Boron 4 mg l^{-1})

The regulating role of Se on the uptake and redistribution of some essential elements (S, Zn, Mn, Cu and Fe) especially the latter, is an important mechanism to stimulate the antioxidant system, decrease the levels of reactive oxygen species, and enhance chlorophyll biosynthesis pathways, thereby improving plant tolerance to stress[64].

References

1. Saeidnia, S. and Gohari, A.R. (2012). Importance of *Brassica napus* as a medicinal food plant. Journal of Medicinal Plants Research, 6(14): 2700-2703.
2. Raymer, P.L. (2002). Canola: An emerging oilseed crop. In: Trends in new crops and new uses, Janik, J. and A. Whipkey (Eds.). ASHS Press, Alexandria, VA, pp: 122-126.
3. Amin, R. and Khalil , S.K. (2005). Effect of pre- and post emergence herbicides and row spacing on canola. Sarhad J. Agric., 21(2): 165-170.
4. Starner, E.D.; Bhardwaj, H.L.; Hamama A. and Rangappa M. (1996). Canola production in virginia. In: Progress in new crops, Janick, J. (Ed.). ASHS Press Alexandria, VA., ISBN: 0-9615027-3-8, pp. 287-290.
5. Grobas, S.; Mendez, J.; Lazaros, R.; Blas, C.D.; Mateos, G.G. and De, B.C. (2001). Influence of source of fat added to diet on performance and fatty acid composition of egg yolks of two strains of laying hens. Poult. Sci., 80: 1171-1179.
6. Kremer, J.M.; Jubiz, W.; Michalek, A.; Rynes, R.I.; Bartholomew, L.E.; Bigaouette, J.; Timchalk, M.; Beeler, D. and Lininger, L. (1987). Fish-oil fatty acid supplementation in active rheumatoid arthritis. A double-blinded, controlled, crossover study. Ann. Int. Med., 106(4): 497-503.
7. Clark, W. F. and Parbtani, A. (1996). Flaxseed in experimental and clinical lupus nephritis. Pages 17-24 in: Proceedings of the 56th Flax Institute of the United States. Flax Institute of the United States, Fargo, ND.
8. Pauletto, P.; Puato, M.; Angeli, M.T.; Pessina, A.C.; Munhambo, A.; Bittolo-Bon, G. and Galli, C. (1996). Blood pressure, serum lipids, and fatty acids in populations on a lake-fish diet or on a vegetarian diet in Tanzania. Lipids, 31: 309-312.
9. Herod, P.M. and Kinsella, J.E. (1986). Fish oil consumption and decreased risk of cardiovascular disease: A comparison of findings from animal and human feeding trials. Am. J. Clin. Nutr., 43: 566-598.
10. Ion, G.; Akinsete, J.A. and Hardman, W.E. (2010). Maternal consumption of canola oil suppressed mammary gland tumorigenesis in C3 (1) TAg mice offspring. BMC Cancer, 10(81): 1-12.
11. Mudeva, A. (2006). Food Industry calls for bio-diesel alternatives.–see, http://www.planetark.com/dailynewsstory.cfm?newsid=35885&newsda
12. Greenway, H. and Munns, R. (1980). Mechanisms of salt tolerance in nonhalophytes. Ann. Rev. Plant Physiol., 31: 149-190.
13. Amer, M.H.; El-Guindy, S. and Rafla, W. (1989). Economic justification of drainage projects in Egypt. In: Amer, M.H., Ridder, N.A., (Eds.), Land Drainage in Egypt. Drainage Research Institute, Cairo, pp 327-339.
14. Bahrani, A. (2013). Effect of salinity on growth, ions distribution and accumulation and chlorophyll concentrations in two canola (*Brassica napus* L.) cultivars. World Applied Sciences Journal, 27(8): 1057-1064.
15. Rellly, C. (1998). Selenium: a new entrant into the functional food arena, Trends Food Sci. Technol., 9: 114-118.
16. Ip, C. (1998). Lessons from basic research in selenium and cancer prevention, J. Nutr., 128: 1845-1854.
17. Duffield-Lillico, A.J.; Dalkin, B.L.; Reid, M.E.; Turnbull, B.W.; Slate, E. H.; Jacobs, E.T.; Marshall, J.R. and Clark, L.C. (2003). Selenium supplementation, baseline plasma selenium status and incidence of prostate cancer: an analysis of the complete treatment period of the Nutritional Prevention of Cancer Trial. BJU Int., 91: 608-612.

18. Finley, J.W.; Ip, C.; Lisk, D.J.; Davis, C.D.; Hintze, K.J. and Whanger, P.D. (2001). Cancer-protective properties of high-selenium broccoli. J. Agric. Food Chem., 49: 2679-2683.
19. Yang, G.Q. and Xia, Y.M. (1995). Studies on human dietary requirements and safe range of dietary intakes of selenium in China and their application in the prevention of related endemic diseases. Biomed. Environ. Sci., 8(3): 187-201.
20. Hajiboland, R. and Keivanfar, N. (2012). Selenium supplementation stimulates vegetative and reproductive growth in canola (*Brassica napus* L.) plants. Acta Agriculturae Slovenica, 99(1): 13-19.
21. Kong, L.; Wang, M. and Bi, D. (2005). Selenium modulates the activities of antioxidant enzymes, osmotic homeostasis and promotes the growth of sorrel seedlings under salt stress. Plant Growth Reg., 45: 155-163.
22. Ríos, J.J.; Blasco, B.; Cervilla, L.M.; Rosales, M.A.; Sanchez-Rodriguez, E.; Romero, L. and Ruiz, J.M. (2008). Production and detoxification of H_2O_2 in lettuce plants exposed to selenium. Ann. Appl. Biol., 154: 107-116.
23. Marschner, H. (1995). Mineral Nutrition of Higher Plants. 2nd Edition, Academic Press, San Diego, pp. 379-396.
24. Bellaloui, N.; Reddy, K.N.; Gillen, A.M. and Able, C.A. (2010). Nitrogen metabolism and seed composition as influenced by foliar B application in soybean. Plant and Soil, 336(1-2): 143-155.
25. Abid, M.; Khan, M.M.H.; Kanwal, M. and Sarfraz, M. (2014). Boron application mitigates salinity effects in canola (*Brassica napus*) under calcareous soil conditions. International Journal of Agriculture and Biology, 16(6): 1165-1170.
26. Didi, Z.; Hua, Z.; Lei, S. and FangSen, X. (2014). Physiological and genetic responses to boron deficiency in *Brassica napus*: a review. Soil Science and Plant Nutrition, 60(3): 304-313.
27. Hoagland, D.R. and Arnon, D.I. (1950). The water culture method for growing plants without soil. Circular 347. California Agricultural Experimental Station, Berkeley, CA. 142 p.
28. Jackson M.L. (1973). Soil Chemical Analysis. Prentice-Hall, Inc. Englewood Cliffs. N.J..
29. A.O.A.C. (1970). Official Methods of Analysis of Association of Official Analytical Chemists. 11th Ed. Washington, D.C.
30. Mota, A.S.; de Lima, A.B.; Albuquerque, Th.L.F.; Silveira, T.S.; do Nascimento, J.L.M.; da Silva, J.K.R.; Ribeiro, A.F.; Maia, J.G.S. and Bastos, G.N.T. (2015). Antinociceptive activity and toxicity evaluation of the fatty oil from *Plukenetia polyadenia* Mull. Arg. (*Euphorbiaceae*). Molecules, 20: 7925-7939.
31. Christie, W.W. (1993). Preparation of ester derivatives of fatty acids for chromatographic analysis. In Advances in Lipid Methodology; Christie, W.W., Ed.; Oil Press: Dundee, UK, pp. 69-111.
32. Khan, G.R. and Scheinmann, F. (1978). Some recent advances in physical methods for analysis and characterization of polyunsaturated fatty acids. Prog. Chem. Fats Lipids, 15: 343-367.
33. A.O.A.C. (2000). Official Methods of Analysis of Association of Official Analytical Chemists. physicochemical characteristics of some wild oilseed. Gaithersburg, MD, plants from Kivu region Eastern Democratic Republic Washington, USA.
34. Ham, B.; Shelton, R.; Butler, B. and Thionville, P. (1998). Calculating the iodine value for marine oils from fatty acid profiles. J. Am. Oil Chem. Soc., 75: 1445- 1446.
35. Brand-Williams, W.; Cuvelier, M.E. and Berset, C. (1995). Use of free radical method to evaluate antioxidant activity. LWT-Food Sci. Technol., 28: 25-30.
36. Snedecor, G.W. and W.G. Cochran (1967). Statistical Methods. Iowa State Univ. Press, 5th ed., Ames, Iowa, USA, pp. 593.
37. Sadak, M.Sh. and Mostafa, H.A.M. (2015). Physiological role of pre-sowing seed with proline on some growth, biochemical aspects, yield quantity and quality of two sunflower cultivars grown under seawater salinity stress. Sci. Agri., 9(1): 60-69.
38. Taffouo, V.D.; Kouamou, J.K.; Ngalangue, L.M.T.; Ndjeudji, B.A.N. and Akoa, A. (2009). Effects of salinity stress on growth, ion partitioning and yield of some cowpea (*Vigna unguiculata* L. Walp.) cultivars. Inter. J. of Botany, 5(2):135-143.

39. Shannon, M.C.; Grieve, C.M. and Francois, L.E. (1994). Whole-plant response to salinity. In: Plant- Environment Interactions, ed. R.E. Wilkinson, pp. 199-244. New York: Marcel Dekker.
40. Levitt, J. (1980). Responses of plants to environmental stresses. Vol.(1) Chilling, freezing and high temperatures stresses. New York, 426 p.
41. Downton, W.J.S. (1977). Photosynthesis in saltstressed grapevines. Aust. J. of Plant Physiol., 4: 183-192.
42. Dutt, S.K.; Bal, A.R. and Bandyopadhyay, A.K. (1991). Salinity induced chemical changes in *Casuarina equistifolia* Forst. Egyptian Journal of Soil Science, 31: 57-63.
43. Bar-Nun, N. and Poljakoff-Mayber, A. (1977). Salinity stress and the content of proline in roots of *Pisum sativum* and *Tamarix tetragyna*. Ann. Bot., 41: 173-179.
44. Kleinkopf, G.E. and Wallace, A. (1974). Physiological basis for salt tolerance in *Tamarix ramosissima*. Plant Sci. Lett., 3: 157-163.
45. Bekheta, M.A.; Abdelhamid, M.T. and El-Morsi, A.A. (2009). Physiological response of *Vicia faba* to prohexadione-calcium under saline conditions. Planta Daninha, 27(4): 769-779.
46. Khattab, E.A. and Afifi, M.H. (2009). Effect of Proline and Glycinebetain on canola plants grown under salinity stress condition. Modern Journals of Applied Biological Sciences, Crop Science, 3(2): 42-51.
47. Sakr, M.T. and Arafa, A.A. (2009). Effect of some antioxidants on canola plants grown under soil salt stress condition. Pakistan Journal of Biological Sciences, 12(7): 582-588.
48. Bybordi, A. (2011). Zinc, nitrogen and salinity interaction on agronomic traits and some qualitative characteristic of canola. African Journal of Biotechnology, 10(74): 16813-16825.
49. Al-Solaimani, S.G.; El-Nakhlawy, F.S. and Almarshadi, M.H. (2012). Response of canola (*Brassica napus* L.) seed yield and quality to high saline irrigation water under sulphur soil amendment. Journal of Food, Agriculture & Environment, 10(3/4): 434-436.
50. Lyons, G.H.; Genc, Y.; Soole, K.; Stangoulis, J.C.R.; Liu, F. and Graham, R.D. (2009). Selenium increases seed production in *Brassica*. Plant and Soil, 318(1-2): 73-80.
51. Ara, J.; Ryad, M.S.; Islam, M.M.; Shahriar, S.; Mehraj, H. and Uddin, A.F.M.J. (2015). Morphological characteristics and yield components of rapeseed in response to different nitrogen and boron levels. American-Eurasian J. Agric. and Environ. Sci., 15(3): 359-366.
52. Bellaloui, N. (2011). Effect of water stress and foliar boron application on seed protein, oil, fatty acids, and nitrogen metabolism in soybean. American Journal of Plant Sciences, 2: 692-701.
53. Hemantaranjan, A. and Trivedi, A.K. (2015). Influence of boron and zinc on nitrate and nitrite reductase activity in roots and leaves, and sulfur containing amino acids, protein and oil content in seeds of soybean [*Glycine max* (L.) Merr.]. International Journal of Scientific Research in Science and Technology, (1)3: 30-38.
54. Bybordi, A.; Tabatabaei, S.J. and Ahmedov, A. (2010). Effects of salinity on fatty acid composition of canola (*Brassica napus* L.). Journal of Food, Agriculture & Environment, 8(1): 113-115.
55. Zając, A.; Oleksy, A.; Klimek-Kopyra, A. and Kulig, B. (2012). Biological determinants of plant and crop productivity of flax (*Linum usitatissimum* L.). Acta Agrobot., 65(4): 3-14.
56. Flagella, Z.; Rotunno, T.; Tarantino, E.; Di Caterina, R. and De Caro, A. (2002). Changes in seed yield and oil fatty acid composition of high oleic sunflower (*Helianthus annuus* L.) hybrids in relation to the sowing date and the water regime. Eur. J. Agron., 17: 221-230.
57. Di Caterina, R.; Giuliani, M.M.; Rotunno, T.; De Caro, A. and Flagella, Z. (2007). Influence of salt stress on seed yield and oil quality of two sunflower hybrids. Ann. Appl. Biol., 151: 145-154.
58. Hernandez, M.L.; Padilla, M.N.; Mancha, M. and Martinez-Rivas, J.M. (2009). Expression analysis identifies FAD2-2 as the olive oleate desaturase gene mainly responsible for the linoleic acid content in virgin olive oil. J. Agric. Food Chem., 57: 6199-6206.
59. Bybordi, A. (2012, a). Effect of ascorbic acid and silicium on photosynthesis, antioxidant enzyme activity, and fatty acid contents in canola exposure to salt stress. Journal of Integrative Agriculture, 11(10): 1610-1620.
60. Bybordi, A. (2012, b). Effect of different ratios of nitrate and ammonium on photosynthesis, and fatty acid composition of canola under saline conditions. International Journal of Agriculture and Crop Sciences (IJACS), 4(10): 622-626.

61. Bellaloui, N.; Reddy, K.N.; Gillen, A.M. and Able, C.A. (2010). Nitrogen metabolism and seed composition as influenced by foliar B application in soybean. Plant and Soil, 336(1-2): 143-155.
62. Da Silva, A.C. and Jorge, N. (2014). Bioactive compounds of the lipid fractions of agro-industrial waste. Food Research International, 66: 493-500.
63. Mittler, R. (2002). Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci., 7(9): 405-410.
64. Feng, R.; Wei, C. and Tu, S. (2013). The roles of selenium in protecting plants against abiotic stresses. Environ. Exp. Bot., 87: 58-68.
65. Hasanuzzaman, M.; Hossain, A. and Fujita, M. (2010). Selenium in higher plants: physiological role, antioxidant metabolism and abiotic stress tolerance. J. Plant Sci., 5(4): 354-375.

*****