Fatty acid composition of canola cultivars as affected by different sowing dates

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Abstract

To investigate the effect of sowing date on yield and qualitative traits of canola cultivars to cope with late-season drought stress, an experiment was carried out during two planting years in Karaj, Iran. Sowing dates at six levels including three fall and three winter dates were considered as the main factor, and five canola cultivars (RGS003, Dalgan, Zabol10, Hyola 401, and Hyola 4815) were considered as the sub-factors. Results showed that except for palmitic acid, the simple effect of sowing date on all the studied traits was significant in winter. The simple effect of cultivar on all traits in fall was significant, and in winter it was only significant on the seed yield and seed oil yield. The interaction between sowing date and cultivar in fall is the reason for significant effect of seed oil yield, linoleic acid, linolenic acid, erucic acid, and glucosinolate. The same reason holds for the significant difference in seed yield, oil content, oil yield, and erucic acid of the plants sown in winter. Dalgan cultivar had the highest seed yield and oil yield on sowing date of October 7, also with the highest levels of oleic, linoleic, and palmitic fatty acids. Based on the results of this study, Dalhgan cultivar with low and standard erucic acid and glucosinolate is recommended for cultivation in the area.

Keywords: *Brasica napus* L., fatty acid composition, late-season drought stress, new cultivation status, sowing date

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Introduction

Canola (*Brassica napus* L.) is one of the most important oily seed species in the world because of the high quality of oil and its press cake, having the potential as a renewable source of biofuels. With 40 to 44 percent oil, canola is a new oil plant cultivated in most agricultural systems of the world. It is a suitable plant for rotation with cereals and crop production in arid and semi-arid areas and is the third most important source of edible oil after soybeans and palm oil (Scarth and Tang, 2006). The optimal sowing date of canola is one of

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the first factors to be regarded when introducing a plant into the cultivation pattern of each region. Sowing date is a significant factor affecting the length of vegetative and reproductive growth as well as the balance between them (Bashir, 2010). An appropriate sowing date significantly increases the seed yield through providing the necessary growth rate for canola plants besides decreasing their vulnerability to late-season drought stress (Bashir, 2010). Investigation of the reaction of canola genotypes to delayed cultivation and selection of genotypes with higher yield stability in these conditions greatly affect the development of canola cultivation, especially in areas where spring crops harvesting is carried out late. The area under cultivation of canola may be developed through development of canola sowing by identifying the suitable cultivars for delayed cultivation, and the severity of damage caused by environmental degradation factors will be decreased by selecting the appropriate cultivar and the proper sowing time in each area (Ul-Hassan et al., 2005). Moreover, Robertson and Holland (2004) reported that delayed planting of fall canola resulted in a decreased flowering period because of an increased ambient temperature. Consequently, the contiguity of late-season heat with the seed-filling period reduced the seed yield and canola seed oil yield. An appropriate sowing date significantly increases the seed yield by providing the necessary growth rate of canola plants and reducing their vulnerability to frost (Pasban Eslam, 2011). Different research results indicate that applying early or late sowing dates and unfavorable temperature regimes during the growth period decrease the yield and yield components, and the highest seed yield is achieved by the appropriate sowing date (Daneshian et al., 2008; Safavi Fard et al., 2018).

Planting date is a crucial factor influencing seed yield, seed oil content, and the combination of fatty acids (Koutroubas and Papadoska, 2005). The seed oil content is affected by drought stress (Tohidi-Moqadam et al., 2011) and temperature (Aslam et al., 2009) during the seed-filling period. The combination of canola oil fatty acids contains 7% saturated fatty acids, 66% mono-unsaturated fatty acids and 27% multi-unsaturated fatty acids, and canola cultivars are significantly different in the composition of oil seed fatty acids (Kadivar et al., 2010). The quality of canola oil is mainly determined by the amount of oleic, linoleic, and erucic fatty acids and is highly affected by the environmental conditions (Enjalbert et al., 2013), cultivar type (Nasr et al., 2006; Javidfar et al., 2007) as well as the length of the phonological stages (Pritchard et al., 2000). Davoudi et al. (2016) during a study concluded that the delayed planting from October 5 to October 25, reduced the amount of linoleic (ω6) and oleic (ω9) fatty acids, which play an important role in increasing the quality of canola seed oil. Safavi-Fard et al. (2018) reported that delayed planting of canola reduces the ratio of unsaturated fatty acids to saturated fatty acids.

Investigation of the responses of canola cultivars to sowing dates and selection of cultivars and hybrids with a higher yield stability in these conditions will significantly affect the development of canola crop, in particular in areas where spring crops are harvested late (Ul-Hassan et al., 2005). Furthermore, introduction of appropriate cultivars for relatively delayed and delayed cultivations may be very effective in development of the canola's cultivated area in areas where the last irrigation of spring crops interacts with the early irrigation of timely cultivation of canola in fall. The present research was aimed at investigating the delayed cultivation and late-season drought stress on yield and qualitative traits of canola genotypes.

Materials and Methods

To investigate the effect of sowing date on new canola cultivars and hybrids and to cope with late-season drought stress, a split plot experiment was carried out in a randomized complete block design with three replications for two planting years (2014 - 2015) and (2015 - 2016) in Karaj, Iran, (35° 59′ N, 50° 75′ E, with an altitude of 1313 m). According to the average meteorological data of 30 years, the average annual rainfall in the Karaj region is 243 mm, and precipitation mainly occurs in late fall and early spring. The meteorological statistics of the experiment site during the two planting years is presented in Fig. (I). The soil texture of the experiment farm is clay loam, and the soil specification of the site is presented in

Table 1
Physicochemical properties of soil collected from site study

Depth (cm)	EC (dS m^{-1})	pH	Organic Carbon (%)	N (%)	P (ppm)	K (ppm)	Texture
0-30	1.42	7.8	0.90	0.08	13.7	190	Clay loam
30-60	1.25	7.2	0.97	0.06	15.7	153	Clay loam

Table 1.

In the present research, sowing dates at six levels including three fall sowing dates (October 7), (October 17), and (November 1) and three winter sowing dates (February 9), (February 19), and (February 29) were considered as the main factor and the canola (early-season) cultivars including RGS003, Dalgan, Zabol10, Hyola 401, and Hyola 4815 were the sub-factors. Each experimental plot consisted of six lines with a length of 6 meters and spacing lines of 30 cm, and the two marginal lines were considered as margins. Plant spacing on the cultivation lines was 5 cm. Fertilizers were applied based on soil test including (1) 150 kg ha^{-1} of ammonium phosphate and 150 kg ha^{-1} of potassium sulfate as the basis for preparing the seedbed, (2) 350 kg ha^{-1} of urea (100 kg at three-leaf stage, 150 kg fat stem elongation stage, and 100 kg at budding stage). The cultivation of seeds for each experimental plot was mechanically performed by a seeding machine. Irrigation was done immediately after planting, and weeds were manually removed at 4-8-leaf stage.

To determine the seed yield, the plants in the 4.8 m^2 of each plot were separately harvested and accurately weighed with a precise balance. To determine the seed oil percentage, a sample of 5 g of seeds was selected from each plot and its percentage was determined by NMR (Nuclear Magnetic Resonance) (International Standard ISO 5511, 1992). After determining the seed oil percentage, seed oil yield was calculated in kg ha^{-1} as the product of seed oil percentage times seed yield. GC-FID analyses were performed with an Agilent 6850 series gas chromatograph (GC) equipped with a flame ionization detector (FID) using a DB-225 capillary column to measure and determine fatty acids in the seed oil. Oil samples were extracted in triplicate from canola seed (100 g) according to the method described by Azadmard-Damirchi et al. (2005). The fatty acids' Methyl Esters contents (FAMEs) were analyzed by GC according to the method described by Azadmard-Damirchi and Dutta (2006). The GC instrument was equipped with a flame ionization detector and a split/splitless injector. The injector and detector temperatures were 230 and 250 C, respectively. Oven conditions were 158 ℃

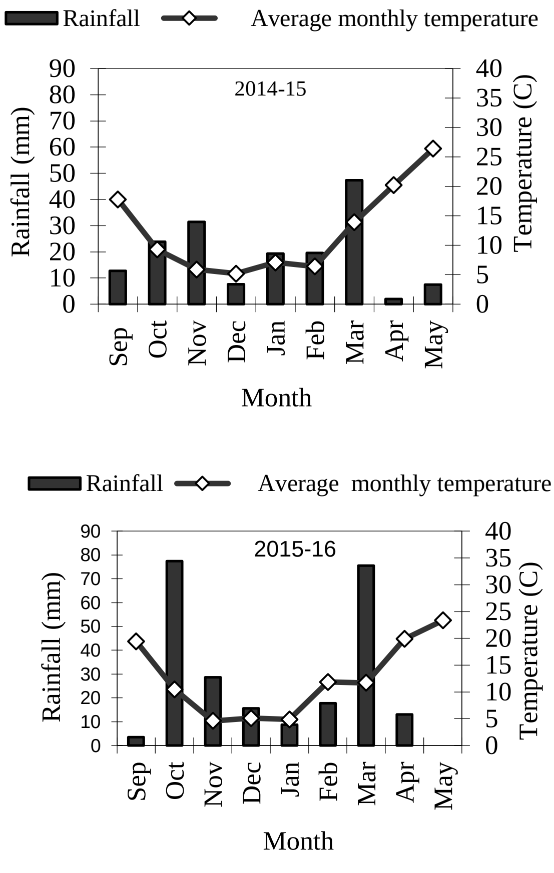

Fig. I. Variations of temperature and rainfall in Karaj meteorology station during 2014 - 2016 growing seasons

increased to 220 ℃ at a rate of 2 ℃ min^{-1} and maintained for 5 min. Helium was used as the carrier gas and nitrogen as the make-up gas at a flow rate of 30 ml min^{-1}. FAMEs were identified by comparison of their retention times with standard

FAMEs and the peak areas reported as a percentage of the total fatty acids. The amount of seed glucosinolate was measured by a spectrophotometer (Harinder et al., 2007).

Table 2
Mean comparisons of simple effects of year, sowing date, and cultivar on canola characteristics in fall

		Palmitic acid (%)	Oleic acid (%)	Seed yield (Kg ha^{-1})	Oil content (%)
Year	Y1	4.48b±0.66	64.22b±2.02	4077a±673.39	41.76a±1.62
	Y2	4.85a±0.69	66.00a±1.86	4582a±784.16	42.82a±1.58
Sowing Date	Oct. 7	5.29a±0.38	66.88a±1.38	5032a±611.50	43.74a±0.94
	Oct. 17	4.79a±0.50	65.18b±1.59	4301b±490.19	42.39b±0.85
	Nov. 1	3.92b±0.33	63.28c±1.67	3656c±472.07	40.75c±1.55
Cultivar	RGS003	4.82a±0.55	65.40b±2.13	4318b±594.85	42.85ab±1.17
	Dalgan	4.87a±0.69	65.79a±2.29	4681a±846.56	43.16a±1.32
	Zabol10	4.59b±0.76	65.23b±1.72	4144c±673.94	42.01bc±1.60
	Hyola401	4.58bc±0.73	64.43c±2.15	4134c±865.36	41.68c±1.97
	Hyola4815	4.49c±0.72	64.70bc±2.26	4371b±786.84	41.77c±1.83

Any two means sharing a common letter do not differ significantly from each other at 5% probability.

Table 3
Mean comparisons of interaction effect of sowing date and cultivar on canola characteristics in winter

Sowing date	Cultivar	Seed yield (Kg ha^{-1})	Oil content (%)	Oil yield (Kg ha^{-1})	Erucic acid (%)
Feb. 9	RGS003	3295a±303.58	42.25a±0.89	1392a±134.21	0.23h±0.03
	Dalgan	3443a±210.21	42.19a±1.02	1454a±118.22	0.22h±0.02
	Zabol10	2723bc±390.75	40.98bc±0.67	1116bc±169.29	0.25g±0.01
	Hyola401	2670c±318.70	40.45c±1.63	`1082c±157.04	0.24gh±0.03
	Hyola4815	2849bc±187.27	41.89ab±1.40	1192b±73.10	0.23h±0.05
Feb. 19	RGS003	2915b±239.64	40.21ce±1.18	1173bc±112.41	0.28f±0.02
	Dalgan	2833bc±399.29	40.36cd±0.86	1145bc±178.28	0.29f±0.03
	Zabol10	2304d±236.20	39.01fh±1.52	900d±112.27	0.33e±0.02
	Hyola401	2200d±206.03	39.13eg±1.71	862d±99.84	0.33e±0.03
	Hyola4815	2337d±443.41	39.29df±1.67	921d±203.81	0.36cd±0.06
Feb. 29	RGS003	1485g±196.55	37.20i±1.25	553g±81.88	0.39ab±0.03
	Dalgan	2349d±138.11	37.67i±1.32	886d±74.69	0.38bc±0.02
	Zabol10	1674fg±152.22	37.99hi±1.43	636fg±63.48	0.40a±0.02
	Hyola401	1778ef±115.79	38.17fi±1.59	678ef±48.99	0.37bc±0.03
	Hyola4815	1983e±153.12	38.11gi±1.75	757e±85.16	0.34de±0.05

Any two means sharing a common letter do not differ significantly from each other at 5% probability.

Finally, after assuring the experimental assumptions, combined analysis of variance was performed using SAS software (version 9.1) after employing the Bartlett test and confirming the homogeneity of the test variances in each year. Means were compared by the least significant difference (LSD) test. The mean comparison of interaction effects was compared using the cutting procedure. Excel software was used to draw diagrams.

Results

Table 4
Mean comparisons of interaction effect of sowing date and cultivar on canola characteristics in fall

Sowing date	Cultivar	Oil yield (Kg ha^{-1})	Linoleic acid (%)	Linolenic acid (%)	Erucic acid (%)	Glucosinolate (µmole g^{-1})
Oct. 7	RGS003	2097bc±183.19	19.00c±1.51	4.62i±0.27	0.23i±0.02	11.22h±0.89
	Dalgan	2488a±272.30	20.20a±1.52	3.83l±0.20	0.14l±0.03	8.61k±1.05
	Zabol10	2088bc±276.88	19.18bc±1.50	4.56i±0.55	0.22ij±0.02	10.83i±0.80
	Hyola401	2159b±321.84	19.44b±1.44	4.34k±0.23	0.20k±0.02	10.32j±0.56
	Hyola4815	2179b±202.00	19.32bc±1.52	4.43j±0.28	0.21jk±0.02	10.53j±0.76
Oct. 17	RGS003	1879cd±284.87	18.41d±1.00	4.94h±0.24	0.26h±0.05	12.26g±0.64
	Dalgan	1916 c±246.37	18.09 e±0.90	5.11g±0.44	0.28g±0.04	12.81f±0.99
	Zabol10	1693de±158.07	17.57f±0.75	5.46f±0.31	0.31f±0.04	13.91e±0.97
	Hyola401	1705de±164.52	17.43fg±0.77	5.56e±0.31	0.32f±0.05	14.23d±1.47
	Hyola4815	1927c±160.23	17.24g±0.99	5.63e±0.32	0.33e±0.04	14.46d±0.73
Nov. 1	RGS003	1587ef±101.84	16.78h±0.61	6.01d±0.34	0.38d±0.03	15.66c±0.70
	Dalgan	1680de±190.37	16.62h±0.64	6.07d±0.39	0.40c±0.03	16.03b±1.07
	Zabol10	1463fg±199.42	16.03i±0.48	6.51c±0.34	0.45b±0.04	17.15a±1.24
	Hyola401	1331g±175.80	15.95i±0.41	6.58b±0.50	0.453ab±0.01	17.26a±1.04
	Hyola4815	1404fg±280.01	15.82i±0.41	6.70a±0.41	0.46a±0.01	17.38a±1.12

Any two means sharing a common letter do not differ significantly from each other at 5% probability.

Table 5
Mean comparisons of simple effects of year and sowing date on canola fatty acids in winter

		Palmitic acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Erucic acid (%)	Glucosinolate (µmole g^{-1})
Year	Y1	4.95b±0.60	61.47b±1.79	18.42b±2.16	6.02a±1.24	0.31a±0.06	12.59a±2.83
	Y2	5.45a±0.73	62.76a±2.32	19.31a±1.98	5.70a±1.07	0.30a±0.07	11.79a±3.07
Sowing date	Feb. 9	5.81a±0.57	63.80a±1.52	20.77a±1.52	4.64c±0.52	0.23c±0.03	9.07c±1.61
	Feb. 19	5.22a±0.49	62.26ab±1.68	18.50b±1.56	5.87b±0.66	0.31b±0.04	12.48b±1.62
	Feb. 29	4.57a±0.43	60.30b±1.69	17.32c±1.61	7.07a±0.65	0.38a±0.04	15.02a±1.80

Any two means sharing a common letter do not differ significantly from each other at 5% probability.

Results of the analysis of the obtained data are shown in Tables (1-5). The results of ANOVA test showed that except for seed yield and oil content in fall, and erucic acid and glucosinolate in winter, the simple effect of the year on all tested traits was significant. Also, except for palmitic acid in winter, the simple effect of sowing date on all characteristics was significant (Tables 2). Moreover, the simple effect of cultivar in all traits was significant in fall, and in winter, it was significant only on seed yield and seed oil yield. The interaction between sowing date and cultivar in fall resulted in significant oil yield, linoleic acid, linolenic acid, erucic acid, and glucosinolate. (Tables 3-5). On the other hand, in winter, the interaction between sowing date and cultivar led to significant seed yield, oil content, oil yield, and erucic acid (Table 3).

Discussion

Seed yield

Comparing the mean of year's effect revealed that the seed yield in the second year was higher than that in the first year. The increase was due to climatic change and favorable rainfall in the second year (Table 2). The tested cultivars showed a significant difference in the seed yield on different sowing dates. The sowing date of October 7 had the highest seed yield (5032 kg ha^{-1}). Delayed sowing from October 7 to October 17 was associated with a reduced seed yield by 14.5%. A further delay in the sowing (November 1) was associated with a further decline in this trait (17.3%). Among the tested cultivars, Dalgan with an average of 4681 kg ha^{-1} had the highest seed yield while Hayola 401 with an average of 4134 kg ha^{-1} had the lowest seed yield in fall.

Comparing the average interaction of cultivar and sowing date in winter revealed that on different sowing dates, the tested cultivars were significantly different in terms of seed yield (Table 3). On the sowing date of February 9, the highest seed yield in Dalgan and RGS003 cultivars was respectively observed with an average of 3443 and 3295 kg ha^{-1}. In sowing date of February 19, the RGS003 and Dalgan cultivars with averages of 2915 and 2833 kg ha^{-1}, respectively, and in sowing date of February 29, with the average of 2349 kg ha^{-1}, Dalgan cultivar had the highest seed yield. The delayed cultivation of canola caused the plant's vegetation period to be exposed to high temperatures, increasing the respiration rates of the pods, followed by reduced photosynthetic materials, reduced seed weight, and eventually reduced seed yield (Rafiei et al., 2011; Gan et al., 2004). The late fall canola planting seems to lead the plant start winter with weak rosette, which results in the plant damage due to the cold weather. Therefore, after the winter when the weather gets warm, the plants cannot use the environmental conditions appropriately for photosynthesis and producing enough phloem sap. Also, the seed filling takes place when the temperature is high, and the high temperature prevents seed filling and the amount of metabolic substances reduces as the respiration is resonated (Ozer, 2003).

Oil content

The mean seed oil content was significantly different in fall sowing dates (Table 2). The highest seed oil content (43.74%) was obtained on the sowing date of October 7. The sowing date of October 17 led to a 3% decrease in seed oil and the sowing date of November 1 resulted in a reduction by 6.8% in the seed oil percentage compared to the sowing date of October 7. With the means of 16.43% and 42.85%, respectively, Dalgan and RGS003 cultivars had the highest seed oil content in fall.

Comparison of the mean interaction effect of cultivar and sowing date in winter revealed that at different levels of sowing date, the cultivars under study had significantly different seed oil contents (Table 3). On sowing date of February 9, the highest seed oil content was seen in RGS003 and Dalgan cultivars with the means of 42.25% and 42.19%, respectively. On the sowing date of February 19, with the means of 40.36% and 40.21%, respectively, Dalgan and RGS003 cultivars had the highest seed oil contents, and Hyola 401 cultivar with the mean of 38.71%, had the highest seed oil contents on the sowing date of February 29. It seems that in the winter sowing date, due to the reduced duration of growth, there was a limited period to increase the percentage of seed oil content. Hence, the seed oil percentage in winter sowing was lower than that in fall sowing dates

In general, genetic factors are the main parameters determining the percentage of canola seed oil and the impact of environmental factors on seed oil content is very low (Robertson and Holland, 2004). Late-season drought stress reduces the percentage of seed oil (Sinaki et al., 2007). The oil content in the late planting dates of canola can be reduced because of the change in temperature at the seed filling stage and the reduction of pure photosynthesis. In this case, a lower percentage of the material is made and carbohydrates are converted into oil. Whenever the duration of flowering period until ripening is longer, there is more time to synthesize the oil, and therefore, its percentage increases (Gecgel et al., 2007).

Gilbertson et al. (2007) found similar results in investigating the effect of planting dates on the oil content. They reported that different planting dates would expose the plant to different environmental conditions, and thus the yield of the plants would be different at different times.

When the ambient temperature changes during seed formation and filling stage, the amount of oil synthesis will be affected and the percentage of seed oil will be reduced (Adamsen and coffelt, 2005).

Oil yield

Comparison of the mean interaction effects between sowing date and cultivar revealed that the cultivars under study were significantly different in oil yield (Tables 3 and 4) at different levels of sowing date. On the sowing dates of October 7 and November 1, Dalgan had the highest oil yields with the means of 2488 kg ha^{-1} and 1680 kg ha^{-1}, respectively. Also in the sowing date of October 17, the Hyola 401 and Dalgan cultivars, respectively with the means of 1927 and 1916 kg ha^{-1} had the highest seed oil yield. In winter and on the sowing dates of February 9 and February 19, Dalgan cultivar had the highest oil yield, with the means of 3443 and 2349 kg ha^{-1}, respectively. The RGS003 cultivar with the mean of 2915 kg ha^{-1} produced the highest oil yield on sowing date of October 17.

The seed oil yield decreases in late sowing dates (delayed) due to the increased risk of exposure to summer heat and drought stress, reducing the photosynthesis rate and increasing respiration in seed adjustment or seed-filling stages (Daneshian et al., 2008). Adamsen and Coffelt (2005) and Miri and Bagheri (2013) also reported the decreased seed oil yield due to delayed sowing.

Oleic acid

The mean oleic acid percentage in different sowing dates in fall and winter was significantly different (Tables 2 and 5). Sowing dates of October 17 and November 1, respectively indicated a decrease by 2.5% and 5.4% in oleic acid compared to the sowing date of October 7. Also in winter, the sowing date of February 9 had an increase by 2.5% in oleic acid in comparison with the sowing date of February 19 and an increase by 5.5% compared to the sowing date of February 29. The cultivars under study did not show any significant difference in winter sowing dates; however, in the fall, the highest oleic acid percentage was related to Dalgan cultivar. Given that oleic acid forms the main component of canola oil fatty acids and plays a significant role in increasing the canola oil quality, with the mean of 62.47%, Dalgan genotype had the highest amount of oleic acid (ω9). Flagella et al. (2002) also emphasized the impact of different environmental conditions on the oleic acid content in different regions. The seed oil quality is mainly determined by the amount of oleic and linoleic fatty acids (Ul-Hassan et al., 2005).

Linoleic acid

The amount of linoleic fatty acid was significantly different in different winter sowing dates (Table 5). The sowing date of February 9 showed a 2.5% increase in linoleic acid in comparison with the sowing date of February 19 and a 5.9% increase compared to the sowing date of February 29.

Comparison of the mean interaction of cultivar and sowing date in fall revealed that the tested cultivars were significantly different in linoleic acid in different levels of sowing date (Table 4). On the sowing date of October 7, Dalgan cultivar had the highest linoleic acid content with the mean of 20.20%. On the sowing dates of October 17 and November 1, RGS003 cultivar had the highest linoleic acid content with the means of 18.41% and 16.78%, respectively.

Delayed sowing resulted in a decrease in this fatty acid. In the study by Safavi fard et al. (2018), canola delayed sowing (Feb. 4) led to a significant reduction of linoleic acid in canola cultivars as compared to the optimal sowing date (Oct. 7). Furthermore, Shahsavari et al. (2014) and Tohidi Moghadam et al. (2011) reported a decrease in the linoleic acid rate in canola cultivars due to late-season drought stress and decreased carbohydrates for oil synthesis. Since linoleic acid is considered as an important and essential fatty acid for the photosynthetic activity of the plant (Hugly et al., 1989) and the development of canola pollen (Mc-Conn and Browse, 1996), it seems that its percentage increases under delayed planting conditions to achieve maximum seed yield.

Linolenic acid

The content of linolenic fatty acid was significantly different at different winter sowing dates (Table 5). The sowing date of February 9 had a reduction by 1.26% in linolenic acid compared to the sowing date of February 19 as well as a reduction of 2.41% compared with the sowing date of February 29.

Comparing the mean interaction of cultivar and sowing date in fall revealed that in different levels of sowing date, the tested cultivars were significantly different in linolenic acid contents (Table 4). In sowing date of October 7, Dalgan cultivar with a mean of 3.83% had the lowest linoleic acid content. Also, RGS003 cultivar on the sowing dates of October 17 and November 1 with the mean of 4.94% and 6.01% had the lowest linolenic acid contents, respectively. Unlike linoleic and oleic acids, delayed sowing date increased the percentage of linolenic fatty acid. Since linolenic acid is an essential and significant fatty acid for photosynthetic activity of the plant (Hugly et al., 1989) and pollen grain development (Mc-Conn and Browse, 1996), it seems that increasing its percentage in terms of delayed sowing is attributed to achieving the maximum seed yield. Gallardo et al. (2014) reported that decreased linolenic acid could be attributed to the fact that its accumulation stops at 30 ℃. An increase by 1.7 to 2% of unsaturated fatty acids like linolenic acid, associated with a 3.8% decrease in oleic acid in canola seed oil, has been reported due to the drought stress in Mediterranean climate conditions (Aslam et al., 2009). Shahsavari et al. (2014) also reported a 35% increase in linolenic acid content in canola under late-season drought stress conditions.

Palmitic acid

Canola cultivars in this study indicated a significant difference in palmitic acid content in different sowing dates (Table 2). The sowing date of October 7 had the highest palmitic acid content (5.29%). Delayed sowing from October 7 to October 17 resulted in a 10.5% decrease in palmitic acid content. A further delay in sowing date (November 1) was associated with a further decline (35%) in the content of this fatty acid. Among the tested cultivars, Dalgan and RGS003 with the means of 4.87% and 4.82%, respectively had the highest levels of palmitic acid content in fall. Different studies have revealed that climatic conditions, in particular temperatures, change the composition of fatty acids over the growing season and the seed filling stages (Badri et al., 2011). Stefanoudaki et al. (2001) also reported that moisture stress decreases the saturated fatty acids, especially palmitic acid. In his study, Garsid (2004) suggested that the palmitic and oleic fatty acid contents decreased due to the coincidence of the synthesis of oil with hot summer weather.

Erucic acid

Comparison of the mean interaction of sowing date and cultivar revealed that the canola cultivars in this study were significantly different in terms of erucic acid content on different sowing date treatments (Tables 3 and 4). With a means of 0.14 and 0.28%, Dalgan cultivar had the highest erucic acid content in the planting dates of October 7 and October 17, respectively. Also, RGS003 cultivar produced the lowest amount of this fatty acid with a mean of 0.38% on the sowing date of November 1.

In the winter and the sowing dates of February 9 and February 19, Dalgan and RGS003 cultivars had the least erucic acid contents. In addition, the Hyola 4815 cultivar, with the mean of 0.34%, produced the least amount of erucic acid content on the sowing date of February 29. The erucic acid content is an important indicator for canola and its edible consumptions (Gecgel et al., 2007), and the rate of this harmful fatty acid in the present study was at standard level (less than 2%).

Glucosinolate

In different winter dsowing dates, the level of glucosinolate was significantly different (Table 5). The sowing date of February 29 had an increase by 17% in glucosinolate content compared to the sowing date of February 19. It also showed an increase by 39.5% compared to the plants sown on February 9.

Comparison of mean interactions between cultivars and sowing dates in fall revealed a significant difference in glucosinolate content in cultivars sown on different dates (Table 4). In the sowing date of October 7, Dalgan cultivar with a mean 6.61 µmole g^{-1}, had the lowest glucosinolate content. In the sowing dates of October 17 and November 1, the RGS003 cultivar had the lowest glucosinolate contents with the means of 12.26 and 15.66 µmole g^{-1}, respectively. Thus, in the canola cultivars under study that were sown on different dates, the glucosinolate level was standard and less than 30 µmole g^{-1} of dry weight of the press cake. To describe the quality of winter canola, two factors of oil and protein contents of seeds are used, which are applied for human or industrial use depending on the composition of fatty acids, (Rathke et al., 2005). Increased glucosinolate declines the quality and nutritional value of canola press cake (Sulisbury et al., 1987), which is affected by hereditary and environmental factors (Fieldsend et al., 1991).

Conclusions

The results of the two-years study on canola cultivars revealed that the characteristics under study were influenced by sowing dates. An appropriate sowing date results in a significant increase in the seed yield and seed oil quality through providing the required growth rate of canola plants as well as reducing their vulnerability to late-season drought stress. In this study, delayed sowing date and late-season drought stress dramatically reduced the seed yield, oil yield, and qualitative characteristics of canola cultivars. Among the studied cultivars, Dalgan had the highest seed and oil yields on the sowing date of October 7, and had the highest oleic, linoleic, and palmitic fatty acid contents. Therefore, with low and standard erucic acid and glucosinolate content, this cultivar is recommended for cultivation under the climatic conditions similar to that of the present study.

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