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Fatty acid composition of oilseed rapeseed genotypes as affected by vermicompost application and different thermal regimes

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Abstract. Vegetable oils with a high relative amount of unsaturated fatty acids are of great significance for human health. Hence, in a 2-year factorial split plot experiment, the effects of different sowing date (optimum (October 17) and late (October 27)), vermicompost (0 and 20 ton ha^{-1}) and genotypes (BAL104, DIE710.08, BAL102, FJL330, FJL290 and Okapi) on the fatty acid composition of rapeseed were evaluated. Rapeseed genotypes and the combination of sowing date and vermicompost application were randomized to sub and main-plots, respectively. The present results revealed that yield, oil percentage and fatty acids composition is affected by sowing dates along with genotypes. However, the unsaturated fatty acid, eicosanoic acid was not affected by interaction sowing date and genotype. Vermicomposting increased the yield, oil percentage, oleic, linoleic and linolenic acids and decrease erucic unsaturated fatty acid. The FJL290 and BAL102 genotypes produced the highest values of grain yield (5,853 and 5,763 kg ha^{-1}, respectively), oil percentage (43.98% and 43.85%, respectively), linoleic % acid (20.51 and 20.37% respectively), oleic % acid (65.23 and 64.93% respectively) and linolenic % acid (7.20 and 7.09% respectively) in comparison to the other genotypes, when they were sown at the optimum sowing date. The FJL290 and BAL102 also accelerated their growth period at the late sowing date. Consequently, oleic, linoleic and linolenic acids had the highest direct and indirect effect influence on grain oil percentage indicating their importance as selection criteria to improve yield and oil quality of rapeseed. Concluding the combination of sowing date, vermicompost and FJL290 and BAL102 lines may be the most favourable cropping strategy for rapeseed production in Iran.

Key words: Fatty acids, Oil percentage, Rapeseed, Sowing date, Vermicompost.

INTRODUCTION

Oil crops have great deal of importance for world agriculture and associated industries. Rapeseed (*Brassica napus* L.) belongs to (Brassicaceae) family which becomes one of the most important sources of the vegetable oil in the world (Baghdadi et al., 2013). It is a valuable oil-seed attracting the attention of many people during the recent years. The production and usage of brassica seed oils has a making it rank third among the oilseed crops after soybean and oil palm in production of vegetable oils, while fifth in the production of oilseed proteins (Armin & Golparvar, 2013).

Canola is a specific type of rapeseed associated with high quality oil and meal. It has less than 2% erucic acid and its meal has less than 30 µg of glucosinolates (El-Nakhlawy & Bakhashwain, 2009). Moreover it contains 40–45% oil and 39% protein, and rapeseed oil contains a desirable profile of saturated fatty acids (~7%) and high level of unsaturated fatty oleic acids about 61% and medium level of linoleic 21% and 11% linoleic acids (Molazem et al., 2013); therefore it represents a healthy edible oil. Over 13.2% of the world's edible oil supply now comes from the oil seed Brassica (Eskandari & Kazemi, 2012). On the other hand, oil obtained from conventional rapeseed is not considered as regular cooking oil because of its low quality due to the presence of high erucic acid (more than 40%) and glucosinolates (more than 100 µm g^{-1} of dry meal) and low level of oleic and linoleic acid (Abdul Sattar et al., 2013). That is the reason for using rapeseed oil potentially in the bio-diesel market (El-Nakhlawy & Bakhashwain, 2009). Romanian investigation with 50 rapeseed cultivars showed significant differences in the grain yields (Gheorghe et al., 2013). Fink et al. (2006) stated that sowing time is one of the most important production decisions. Appropriate sowing date of rapeseed has proven as a key point to maximize yield potential. With the delay in sowing date, all the investigated traits declined (Baghdadi et al., 2013). Winter-type rapeseed cultivars respond to temperature in different mechanisms. Therefore, sowing date in temperate and cold regions should be considered. Seedling growth and establishment are enhanced on optimum sowing dates compared with those on late sowing dates (Pasban Eslam, 2008). Rafiei et al. (2011) observed that yield and yield compounds decrease. Oil yield decreases on late sowing dates because of an increase in the risk of late season heat and drought stress, which decrease the photosynthetic rate and increase the respiratory rate in seed setting or seed filling stages (Daneshian et al., 2008).

Bio-fertilizers as a highly potent alternative are the increase of oleic acid and linoleic acid, and the reduction of linolenic acid content to chemical fertilizers because of important environmental issues. In this regard, composting as a waste management technique is used to treat various organic wastes for organic fertilizers. Vermicompost is a product of composting in which earthworms are used to create a heterogeneous mixture of decomposing organic wastes. Thus, it Increase fertility and quality of soil, improve its water retention capacity and enhance plant growth and development. Previous studies showed the influence of vermicompost and inorganic fertilizers on yield and protein of crops (Manivannan et al., 2009). Applications of vermicompost alone or in combination with other fertilizers have been proved to be effective to enhance growth and yield of various plants (Javed & Panwar, 2013). Kumar & Sood (2011) reported that rapeseed vegetative growth and oil yield and components are increased by vermicompost compared with cattle manure or other bio-fertilizers. Therefore the aim of this study was to evaluate the oil content and fatty acid composition of rapeseed from different genotypes. Moreover due to the significance of rapeseed as a crop with high nutritional values, it is very important to suggest the most suitable sowing date and vermicompost fertilizer level for canola production, with regard to the climatic conditions.

MATERIALS AND METHODS

The experiment were carried out at the Seed and Plant Improvement Institute, Karaj, Iran (35° 49′ N, 51° 06′ E, 1,321 m asl) in 2015 and 2016 growing seasons. A factorial split plot experiment was performed on the basis of the randomized complete block design with three replications. The factorial combination of two sowing dates (October 17 and 27 as optimum and late sowing dates, respectively) and two vermicompost amounts (0 and 20 ton ha^{-1}) were allocated to the main plots, and six rapeseed genotypes (BAL104, DIE710.08, BAL102, FJL330, FJL290, and Okapi; Table 1) were randomized in sub-plots.

Table 1. Growth type and origin of studied rapeseed genotypes

Name	Origin	Growth type	Hybrids	Cultivars	Lines	Lines pedigree
BALl104	Iran	Winter			*	RNX-3621 Selfing
DIE710.08	Germany	Winter	*			-
BAL102	Iran	Winter			*	Bristol Selfing
FJL330	Iran	Winter			*	Sunday× Geronimo
FJL290	Iran	Winter			*	Sunday× Geronimo
Okapi	France	Winter		*		-

The 6 rows in each sub plot were 6 m long, with 60 cm interspacing. The plots were 3 m apart and seeds planted at a 5 cm distance on the rows (70,000 plants ha^{-1}). Weeds were controlled using Galant Super and Lontrel (1 L ha^{-1}) from 4-leaf stage to 8-leaf stage.

Table 2. Climate data experimental from Karaj between in 2015–2016 years

Month	October		November		December		January		February	
Year	2014	2015	2014	2015	2014	2015	2015	2016	2015	2016
Rainfall (mm)	13.4	3.5	13.7	77.4	31.6	28.6	6	15.6	47.8	8.7
Average Temp (°C)	18.1	19.4	18.2	10.5	6.3	4.6	5.2	5.1	7.3	4.9
Month	March		April		May		June		July	
Year	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Rainfall (mm)	21.3	17.8	45.4	75.5	2.2	13	6.6	-	-	-
Average Temp (°C)	6.7	11.8	13.8	11.7	20	19.9	26.4	24.2	30.9	28.9

Climate data, including temperature and precipitation for the whole year are presented in Table 2. The results of soil analysis samples were obtained at depths of 0–30 cm before sowing presented in Table 3. Fertilization was performed according to the soil testing analyses. A total of 150 kg ha^{-1} ammonium phosphate and 150 kg ha^{-1} potassium sulphate were applied to the soil before grain sowing. In addition, 350 kg ha^{-1} urea was applied at three separate times: 100 kg ha^{-1} in the sowing time, 150 kg ha^{-1} in the stem elongation, and 100 kg ha^{-1} in the flowering stage. Then before seed was sown, vermicompost (20 ton ha^{-1}) was spread onto the soil surface and incorporated into the soil at a depth of 30 cm. Vermicompost fertilizer characteristics are presented in Table 4.

Table 3. Result of chemical and physical analysis of experimental soil

Year	Depth, cm	Ec, ds m^{-1}	pH	Organic matter, %	Nitrogen, kg ha^{-1}	Posphorus P_2O_5, kg ha^{-1}	Potassium K_2SO_4, kg ha^{-1}	Soil Texture
2014–15	0–30	1.45	7.9	0.91	0.09	14.7	197	Clay loam
2015–16	0–30	1.33	7.8	0.83	0.08	14.2	165	Clay loam

Table 4. Vermicompost nutritional parameters

Sample	N-total, %	P, %	K, %	C/N	OC, %	EC, ds m^{-1}	pH
Vermicompost	1.5	0.81	0.75	19.2	15.2	7.2	6.5–8.5

Plants were harvested, when 40–50% of the seeds in the main pods and primary branches turned brown. After harvesting, the oil content and the fatty acid composition were determined. Oil content was determined by NMR (Mq20, Bruker, Germany) at the Seed and Plant Improvement Institute (ISO 10565, 1988). Fatty acid composition, including saturated (sum of palmitic (C16:0), stearic acid (C18:0) and arachidic acid (C20:0)) and unsaturated (sum of oleic (C18:1), linoleic (C18:2) and linolenic (C18:3), palmitoleic (C16:1), ecosanoeic (C20:1) and erucic acid (C22:1)) acids, was analysed using gas chromatography of methyl esters (Metcalf et al., 1966; Lee et al., 1988) by the following procedure.

Fifty milligram of extracted oil was saponified with 5 mL of methanolic NaOH (2%) solution by refluxing for 10 min at 90 °C. After addition of 2.2 mL BF3-methanolic, the sample was boiled for 5 min. The FAMEs were extracted from a salt-saturated mixture with hexane. The FAMEs were then analyzed using a gas chromatograph (UNICAM model 4600, UK) coupled with a FID detector. The column used for fatty acid separation was a fused silica BPX70 column, 30 m×0.22 mm i.d.×25 μm film thickness (from SGE, UK). The oven temperature was held at 180 °C during separation; the injector and detector temperatures were 240 and 280 °C, respectively. The carrier gas (helium) flow ratio was 1 mL min^{-1}. One microliter of methyl esters of free fatty acids was injected into the split injector. The split ratio was adjusted to 1:10. The compounds were identified by comparison of their retention times with authentic compounds. The internal standard C15:1 was used in the quantitative analysis of the separated fatty acid. Each fatty acid was expressed as a percent of the total fatty acids. Also, glucosinolate content was identified through HPLC (Thies, 1974).

Statistical analysis

Bartlett test was performed to evaluate homoscedasticity at a significance level of 0.05. In the presence of homoscedasticity in all of the traits except harvest index, combined ANOVA was conducted at a significance level of 0.05 on both sides and at a significance level of 0.01. LSD test was carried out to compare the means within ANOVA at a significance level of 0.05. Data were analyzed in SAS 9.0.

RESULT AND DISCUSSION

The monthly rainfall and average temperature data for 2015 and 2016 presented in Table 2. The average rainfall for 2016 (240.1 mm) was higher than observed (188 mm) in 2015.

According to The Tables 5, 6, 7 and 8, the growth season, sowing date, vermicompost, genotype and interaction effect of sowing date and genotype significantly affected the amount of saturated and unsaturated fatty acids. However, the unsaturated fatty acid, eicosanoic acid was not affected by interaction sowing date and genotype. In addition to the interaction effects of sowing date, vermicompost and genotype on the amount of palmitoleic unsaturated fatty acid was significant.

The highest values of grain yield (4,515 kg ha^{-1}), oil yield (1,929 kg ha^{-1}), oil percentage (42.31%), oleic, linolenic and linoleic acids (64.55, 5.89 and 19.05%) were obtained during the second growing season (Table 5 and 7). These enhancement at the second growth season may be due to improvement of the agronomic practices and particulary favourable weather conditions.

The highest values of grain yield (5,853 and 5,763 kg ha^{-1}), oil yield (2,576 and 2,528 kg ha^{-1}) and oil percentage (43.98 and 43.85%) were obtained by FJL290 and BAL102 lines sown at the optimum sowing date, while the lowest values were recorded from DIE710.08 hybrid sown at the late sowing date (Table 6), and the same trend was found by Siadat & Hemayati (2009) that explained the optimum sowing produced higher grain yield and this may be due to the variation in temperature, or attributed to more light, water and mineral absorption by plant canopies thus, increasing photosynthetic capacity. These results are in agreement with Shamsi (2012), reporting that sowing time had significant effect on oil content, the reduction in oil content with delayed after 15th Oct may be due to the increase of temperature during the grain filling stage. An increase in temperature above 16 °C after flowering stage causes (1.2–1.5) decrease in oil content for each 1 °C increase in temperature (Pritchard et al., 1999). This finding was in conformity with Soleymani & Shahrajabian (2013) that stated that oil yield is significantly affected by the interaction between sowing date and genotype.

The highest values of grain yield (4,394 kg ha^{-1}), oil yield (1,879 kg ha^{-1}) and oil percentage (42.35%) were obtained when vermicompost was applied (Table 5). Application of vermicompost is a sustainable technology capable that improve plants growth and yield of them (Castillo et al., 2010). Vermicompost is effective as organic fertilizer and bio-control agents that have organic nutrition role and increase plant growth (Arancon, 2005; Simsek, 2011). Oil yield and content can be increased by 10 ton ha^{-1} vermicompost (Mohammadi et al., 2012). Karimi et al. (2011) reported that application of vermicompost significantly increased corn yield compared with control treatment. Furthermore, Amin Ghafuri et al. (2010) demonstrated that castor bean grain yield is more effectively increased by vermicompost than by other organic fertilizers. Sesame oil yield also increases because of vermicomposting (Sajadi Nik et al., 2011).

Table 5. Analysis of variance and means of some quality traits of rapeseed genotypes under variouse sowing dates and vermicompost treatments

Parameters	Mean Squares[1] and Mean Values					
	Grain yield, kg ha^{-1}	Grain oil yield, kg ha^{-1}	Oil percentage, %	Glucosinolate content, mg gr^{-1}dw	C18:1, %	C18:2, %
Growth season (df=1)	**17,768,332****	**3,532,520****	**6.11****	**10.01***	**243.12****	**86.95****
First	3,812b	1,616b	41.90b	1,292a	61.95b	17.50b
Second	4,515a	1,929a	42.31a	1,239b	64.55a	19.05a
LSD 0.05	138.25	58.55	0.10	0.21	0.18	0.19
Sowing date (Sd) (df=1)	**223,868,925****	**48,476,406****	**254.16****	**1,526.39****	**293.12****	**400.20****
Optimum sowing date	5,410a	2,352a	43.43b	9.41b	64.68a	19.94a
Late sowing date	2,916 b	1,192b	40.78a	15.92a	61.83b	16.61b
LSD 0.05	192.65	85.87	0.13	0.39	0.40	0.39
Vermicompost (V) (df=1)	**7,660,440****	**1,658,514****	**8.73****	**25.07****	**28.72****	**5.55****
Non application	3,933b	1,665b	41.86b	13.08a	62.81b	18.08b
Application	4,394a	1,879a	42.35a	12.25b	63.70a	18.47a
LSD 0.05	192.65	85.87	0.13	0.39	0.40	0.39
Genotype (G) (df=5)	**18,206,990****	**404,103****	**2.70****	**11.44****	**2.55****	**2.69****
BAL104	3,980bc	1,689bc	41.87c	13.08a	63.05cd	18.07cd
DIE710.08	3,886c	1,645c	41.76c	13.30a	62.87d	17.95d
BAL102	4,446a	1,907a	42.42a	11.95c	63.50ab	18.61ab
FJL330	4,201b	1,781b	42.17b	12.65b	63.35bc	18.30bc
FJL290	4,531a	1,949a	42.57a	11.70c	63.73a	18.74a
Okapi	3,935c	1,664c	41.84c	13.28a	63.03d	17.99cd
LSD 0.05	239.46	101.41	0.81	0.37	0.31	0.34
Gs×Sd (df=1)	**225,662**	**68,994**	**0.33**	**5.34****	**14.49****	**29.62****
Gs×V (df=1)	**283,112**	**57,760**	**0.05**	**0.12**	**0.27**	**0.21**
Sd×V (df=1)	**23,180**	**336**	**0.06**	**0.24**	**0.08**	**0.07**
Gs×Sd×V (df=1)	**60,639**	**11,990**	**0.15**	**0.07**	**0.03**	**0.01**
Error (df=12)	**281,457**	**55,916**	**0.13**	**1.16**	**1.24**	**1.16**
Gs×G (df=5)	**722**	**349**	**0.01**	**0.07**	**0.09**	**0.11**
Sd×G (df=5)	**993,630****	**214,860****	**1.25****	**6.41****	**1****	**1.45****
Gs×Sd×G (df=5)	**7294**	**1270**	**0.02**	**0.16**	**0.08**	**0.07**
V×G (df=5)	**88,583**	**15,135**	**0.01**	**0.09**	**0.23**	**0.01**
Gs×V×G (df=5)	**43,651**	**7,191**	**0.02**	**0.03**	**0.07**	**0.007**
Sd×V×G (df=5)	**48,274**	**9,647**	**0.01**	**0.31**	**0.26**	**0.05**
Gs×Sd×V×G (df=5)	**27,939**	**5,392**	**0.06**	**0.01**	**0.16**	**0.009**
Error (df=80)	**173,743**	**31,163**	**0.10**	**0.41**	**0.30**	**0.35**
C.V (%)	**10.01**	**9.95**	**0.75**	**5.07**	**0.86**	**3.23**

**P < 0.05* and ***P < 0.01*; [1]: Bold values across the main parameters in the table indicate mean squares; [2]: Mean values with the similar letter in each column are not significantly different. ns: non- significant.

Increase in glucosinolate reduces canola food quality and nutritional value (Salisbury et al., 1987). The highest value of glucosinolate content was recorded by DIE710.08 hybrid (16.79 mg g^{-1} dw) and BAL104 line (16.63 mg g^{-1} dw) sown on the late sowing date. By contrast, the lowest value was detected in FJL290 and BAL102 lines sown on the optimum sowing date (Table 6). Glucosinolate content depends on genetic and environmental factors (Fieldsend et al., 1991). Genetic variations in glucosinolate content exist across canola genotypes (Burton, 2004). Generally, under optimum growth conditions nitrogen increases the glucosinolate concentration of seeds

(Bilsborrow et al., 1993). The highest value glucosinolate (13.08 mg g^{-1} dw) was obtained when vermicompost was non-applied (Table 5). Vermicomposting could reduce the glucosinolat content by 6.35%. Mostafavi Rad et al. (2013) observed that grain yield and glucosinolate content significantly differ among canola genotypes. Application of vermicompost increased plant production and total glucosinolate in plant tissue (Pant et al., 2011).

Table 6. Interaction effect of sowing date and genotype on assessed traits

Sowing date	Genotypes	Grain yield, kg ha^{-1}	Oil yield, kg ha^{-1}	Oil percentage, %	Glucosinolate content, mg gr^{-1} dw	C18:1, %	C18:2, %
	BAL104	5,352b	2,322b	43.34b	9.52c	64.65bc	19.89bc
	DIE710.08	5,280b	2,285bc	43.24bc	9.81bc	64.41c	19.77c
17 October	BAL102	5,762a	2,528a	43.85a	8.41d	64.93ab	20.37ab
	FJL330	5,049b	2,176c	43.05c	10.41d	64.37c	19.48c
	FJL290	5,853a	2,576a	43.98a	8.19d	65.23a	20.51a
	Okapi	5,163b	2,229bc	43.15bc	10.08ab	64.48c	19.63c
LSD (5%)		324.98	141.45	0.25	0.44	0.41	0.52
	BAL104	2,608b	1,055b	40.40cd	16.63a	61.44b	16.26b
	DIE710.08	2,492b	1,007b	40.28d	16.79a	61.34b	16.12b
27 October	BAL102	3,130a	1,285a	40.99b	15.49b	62.06a	16.84a
	FJL330	3,353a	1,386a	41.29a	14.88c	62.32a	17.12a
	FJL290	3,209a	1,322a	41.16ab	15.22bc	62.22a	16.97a
	Okapi	2,706b	1,099b	40.54c	16.48a	61.57b	16.34b
LSD (5%)		294.38	120.31	0.24	0.52	0.43	0.35

Means with similar letters in each column are not significantly different.

The kind and amount of fatty acids in oilseed reflect the quality of oil. Rapeseed is a good source of oleic or monounsaturated fatty acid and linoleic and linolenic acid or polyunsaturated fatty acids (Dmytryshyn et al., 2004; Carvalho et al., 2006). The desaturated change the saturated fatty acid into unsaturated ones, which is of great significance for the production of vegetable oils. The interaction sowing time and genotype affected significantly oleic, linoleic and linoleic acids percentage. The highest values oleic (65.23 and 64.93%.), linoleic (20.51 and 20.37%) and linolenic (7.20 and 7.09%) acids were obtained by FJL290 and BAL102 lines sown on the optimum sowing date (Tables 6 and 8, respectively). Suggesting that more work is needed to improve oil quality among canola genotypes. Reducing long chain and saturated fatty acids in canola genotypes is one of the main objectives in canola breeding. On the other hand, sowing time is known as an important factor that not only affect grain yield, but also affect grain oil quality through changing fatty acids composition. It has been reported that reduction in seed germination speed, due to late sowing, increases fatty acid content (May et al., 1994) which is in disagree with the current results. These results agree with the findings of Turhan et al. (2011) that revealed the influence of sowing time and different genotypes on fatty acid synthesis of rapeseed (linoleic, linolenic and oleic acids).

Comparison of means revealed that the highest values linoleic acid, linolenic and oleic acid were obtained when vermicomost was applied (Tables 5 and 7, respectively). Mohammadi et al. (2011) reported that the vermicompost application in comparison with chemical fertilizers significantly increased the linoleic and oleic acids in rapeseed.

Mohammadi et al. (2011) reported that the vermicompost application in comparison with chemical fertilizers significantly increased the linoleic and oleic acids in rapeseed. Monir & Malik (2007) reported that the increase in the content of linoleic acid in comparison to the control is less pronounced, as in the variant with 40 t/decare of vermicompost it reaches 76.70%.

Table 7. Analysis of variance and means of some quality traits of rapeseed genotypes under various sowing dates and vermicompost treatments

Parameters	Mean squares[1] and mean values					
	C18:3, %	C18:0, %	C16:0, %	C20:0, %	C20:1, %	C22:1, %
Growth season (Gs)	**6.05****	**2.18****	**5.10****	**0.007****	**0.0008**	**0.02****
First	5.48b	2.97a	4.82b	0.57a	1.43a	0.30b
Second	5.89a	2.73b	5.20a	0.55b	1.43a	0.32a
$LSD_{0.05}$	0.07	0.05	0.09	0.01	0.08	0.009
Sowing date (Sd)	**185.41****	**56.25****	**70.39****	**6.72****	**14.50****	**2.30****
Optimum sowing date	6.82b	2.22b	4.31b	0.34b	1.11b	0.18b
Late sowing date	4.55a	3.47a	5.71a	0.78a	1.74a	0.44a
$LSD_{0.05}$	0.08	0.11	0.14	0.02	0.18	0.01
Vermicompost (V)	**3.19****	**3.37****	**8.43****	**0.14****	**0.54**	**0.04****
Non application	5.54a	3a	5.25a	0.59a	1.49a	0.33a
Application	5.83b	2.70b	4.77b	0.53b	1.37a	0.29b
$LSD_{0.05}$	0.08	0.11	0.14	0.02	0.18	0.01
Genotype (G)	**1.64****	**0.35****	**0.59****	**0.06****	**0.17***	**0.02****
BAL104	5.85a	2.94a	4.89b	0.58b	1.46a	0.33a
DIE710.08	5.95a	2.97a	4.84b	0.61a	1.50a	0.34a
BAL102	5.43c	2.73bc	5.15a	0.50c	1.36ab	0.28c
FJL330	5.67b	2.80b	5.10a	0.58b	1.48a	0.31b
FJL290	5.31c	2.69c	5.20a	0.48c	1.29a	0.27c
Okapi	5.90a	2.95a	4.89b	0.60a	1.50a	0.34a
$LSD_{0.05}$	0.13	0.08	0.15	0.01	0.15	0.01
Gs×Sd	**0.54****	**0.62****	**0.29**	**0.004***	**0.40***	**0.004***
Gs×V	**0.002**	**0.009**	**0.01**	**0.0005**	**0.01**	**0.0001**
Sd×V	**0.002**	**0.28**	**0.008**	**0.01**	**0.10**	**0.0001**
Gs×Sd×V	**0.0001**	**0.05**	**0.08**	**0.002**	**0.09**	**0.0003**
Error	**0.04**	**0.09**	**0.16**	**0.003**	**0.26**	**0.001**
Gs×G	**0.009**	**0.001**	**0.03**	**0.0005**	**0.02**	**0.0002**
Sd×G	**0.83****	**0.15****	**0.36****	**0.04****	**0.12**	**0.01****
Gs×Sd×G	**0.006**	**0.001**	**0.06**	**0.0005**	**0.01**	**0.0003**
V×G	**0.01**	**0.005**	**0.02**	**0.0004**	**0.01**	**0.0007**
Gs×V×G	**0.0007**	**0.004**	**0.02**	**0.0001**	**0.01**	**0.0004**
Sd×V×G	**0.01**	**0.006**	**0.01**	**0.0001**	**0.01**	**0.0005**
Gs×Sd×V×G	**0.001**	**0.01**	**0.04**	**0.0004**	**0.02**	**0.0002**
Error	**0.05**	**0.02**	**0.07**	**0.001**	**0.06**	**0.0008**
C.V (%)	**4.15**	**5.47**	**5.49**	**5.80**	**18.21**	**9.35**

**$P < 0.05$* and ***$P < 0.01$*;

[1]: Bold values across the main parameters in the table indicate mean squares;

[2]: Means with similar letter in each column are not significantly different. ns: non-significant.

Table 8. Interaction effect of sowing date and genotype on assessed traits

Sowing date	Genotypes	C18:3, %	C18:0, %	C16:0, %	C20:0, %	C20:1, %	C22:1, %
	BAL104	6.65b	2.26a	4.47cd	0.36d	1.11abc	0.20c
	DIE710.08	6.52bc	2.29a	4.54d	0.38dc	1.16ab	0.20bc
17 October	BAL102	7.09a	2.11b	4.09b	0.25e	1.01bc	0.15d
	FJL330	6.44c	2.34a	4.62a	0.44a	1.29a	0.23a
	FJL290	7.20a	2.07b	4.01ab	0.23f	0.90c	0.13d
	Okapi	7.01a	2.31a	4.16c	0.42b	1.20ab	0.22ab
LSD (5%)		0.19	0.10	0.11	0.01	0.22	0.01
	BAL104	4.21d	3.64a	5.83bc	0.82ab	1.81ab	0.47a
	DIE710.08	4.11d	3.66a	5.87c	0.83a	1.84a	0.48a
27 October	BAL102	4.69b	3.37b	5.80ab	0.75c	1.71ab	0.42b
	FJL330	4.90a	3.28b	5.58c	0.73c	1.66b	0.39c
	FJL290	4.60c	3.32b	5.79a	0.74c	1.69ab	0.41bc
	Okapi	4.79ab	3.60a	5.63c	0.80b	1.79ab	0.47a
LSD (5%)		0.15	0.13	0.15	0.03	0.16	0.02

Means with the similar letters in each column are not significantly different.

Erucic acid is one of the most important fatty acids within Brassica genus. This 22-carbon fatty acid is harmful to the human health (Cazzato et al., 2014). The highest value of erucic acid (0.48%) was recorded from the interaction between (late sowing date and DIE710.08 hybrids), while the lowest value (0.13 and 0.15%) was recorded from (optimum sowing date and FJL290 and BAL102) (Table 8). The lowest value erucic acid was obtained when vermicompost was applied (Table 7). So, the results showed that application of vermicompost reduced this harmful fatty acid. Grain and oil yield and fatty acid composition are function of genotype, climate conditions, morphology and physiology as well as crop management (Arsalan, 2007). The highest values of palmitic (5.87 and 5.83%), stearic (3.66 and 3.63%) ecosanoiec (1.84 and 1.81%) and arachidic (0.83 and 0.81%) acids were recorded from interaction between (late sowing date, DIE710.08 hybrid and BAL104 line). Also the highest values of palmitic (5.25%), stearic (3%), arachidic (0.59%), and ecosanoeic (1.49%) acids were also determined when vermicompost were non-applied. According to the present results, vermicompost reduced of stearic, arachidic and ecosanoeic saturated fatty acids. The highest value of palmitoleic acid (0.59%) was recorded from the interaction between late sowing date, non-application vermicompost and DIE710.08 hybrids, while the lowest value (0.13%) was recorded from optimum sowing date, vermicompost application and FJL290 line. (Fig. 1). Kumar, (1994) reported that the addition of vermicompost can increase the fatty acid content of the seeds. Angelova et al. (2015) the addition of vermicompost and compost leads to an increase in the content of palmitic acid and linoleic acid, and a decrease in the stearic and oleic acids compared with the control. A significant increase in the quantity of saturated acids was observed in the variants with 20 t per decare of compost and 20 t per decare of vermicompost (9.1 and 8.9% relative to the control).

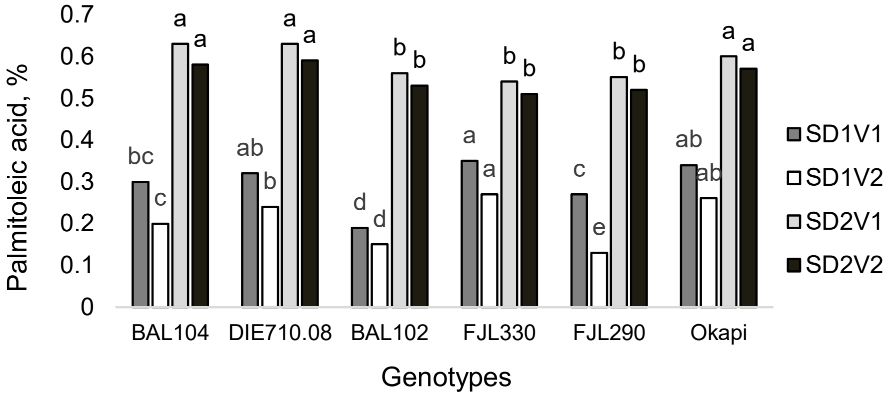

Figure 1. The interaction effects of sowing dates, vermicompost and genotypes on the palmitoleic acid content.

Notes: SD_1V_1: optimum sowing date and non-application vermicompost; SD_1V_2: optimum sowing date and vermicompost application; SD_2V_1: late sowing date and non-application vermicompost; SD_2V_1: late sowing date and vermicompost application.

CONCLUSIONS

In conclusion the sowing dates, genotypes and vermicompost fertilizer treatments substantially influenced fatty acid composition of rapeseed oil. The highest grain yield, oil percentage, fatty acid composition linoleic, linolenic and oleic was obtained in FJL290 and BAL102 lines under optimum sowing date. Application of vermicompost reduced harmful fatty acid (erucic acid) and increase useful fatty acids such as oleic, linoleic and linolenic acids. Considering the low organic matter of agricultural lands of Iran (less than 0.5%) application of vermicompost is recommended.

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