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Effect of Sowing Date and Glycinebetaine on Seed Yield, Oil Content, and Fatty Acids in Rapeseed Cultivars

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ABSTRACT

This study primarily aimed to identify and suggest appropriate rapeseed cultivars and their optimum sowing time. A factorial split-plot experiment was conducted in a complete randomized block design with three replications during two years (2014-2016). The study was carried out using six rapeseed cultivars, namely, Elvis, HL2012, L155, KR2, HW113 and Danob, three sowing dates (October 7, 17, and 27), and two concentrations of glycinebetaine (0 as control and 0.2%). The sowing dates and the GlycineBetaine (GB) were allotted to main plots and the six cultivars were allotted to subplots. The HL2012 cultivar had the highest seed yield (4,584 kg ha^{-1}), seed oil content (44.6%) and seed oil yield (2,060 kg ha^{-1}), which were achieved optimally in the first sowing date. Application of GB increased the average seed yield from 4,089 to 4,419 (kg ha^{-1}), seed oil from 44 to 44.4% and seed oil yield from 1,818 to 1,976 (kg/ha). The amounts of proline and soluble carbohydrates in the plants increased from the first to the third sowing dates. The early sowing date and the application of GB had positive effects on the quantity and quality of rapeseed oil. The results of cluster analysis showed that three of the six cultivars could be suitable for cultivation in Karaj, Iran.

Keywords: *Brassica napus* L., Canola, Proline**,** Rapeseed cultivars**, S**oluble carbohydrates.

INTRODUCTION

Rapeseed (*Brassica napus* L.) is one of the most prevalent oilseed crops in the world (Kumar *et al*., 2016). The plant belongs to the Brassicaceae family. It is widely cultivated in different parts of the world for the production of vegetable oil and animal feed. The plant seeds contain 40% oil and 38-43% protein (Rashid and Farooq, 2008). Canola can be deemed suitable for animal feed because it contains low erucic acid (less than 2%) and glucosinolate (less than 30 μmol g^{-1}). The planting date can change the seed quality by affecting yield components (Thurling, 1974; Fathi *et al*., 2003). Many studies have reported the inconsistency of sowing dates in this plant, which is an unfavorable factor (Robertson *et al*., 2004; Uzun *et al*., 2009; Rad *et al*., 2015; Ratajczak *et al*., 2017; Kumar *et al*., 2018).

Early sowing has been reported as one of the most important strategies for increasing the seed and oil yield of rapeseed (Loof, 1960). Hampton *et al*. (2013) showed that changing the sowing date is a good strategy for hampering the loss that may occur in seed quality. The late sowing date of rapeseed can reduce the seed yield, biomass, harvest index and seed oil content (Mendham *et al*., 1981; Taylor and Smith, 1992). The decrease in the seed yield of rapeseed can be due to the late sowing of its

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seeds, which would increase the respiration rate of pods and the rise in un-kernel seed percentage (Whitefield, 1992). Asghari *et al*. (2018) reported that postponing the sowing date from 2 to 22 of October reduced 33.6% of the seed yield each year. Also, postponing the sowing from March to April reduces the seed yield (Trethewey, 2012). Rashid *et al*. (2017) obtained a higher yield and quality of the rapeseed product when sowing the seeds in April, rather than in March.

GlycineBetaine (GB) is an amino acid derivative and is one of the most effective compatible solutes that protect plants from different forms of stress. Application of GB can improve growth, survival, and tolerance of plants under different stress conditions (Ashraf and Foolad, 2007). Such improvements occur by the regulation of several biochemical and physiological processes, maintaining turgor pressure, enhancing the net CO_2 assimilation rate and protecting functional proteins and enzymes (Qureshi *et al*., 2013; Agboma *et al*., 1997; Lopez *et al*., 2002). Rapeseed production in Iran is limited by a variety of stresses such as drought, salinity, cold, and heat. Therefore, the selection of different varieties and finding the optimum sowing date is important for a successful agricultural practice. This study aimed to evaluate seed yield, oil content and fatty acids of different varieties of rapeseed in Karaj, Iran; and further investigated the appropriate sowing date of the seeds. We also aimed to consider the application of GB on rapeseed plants and assessed the interactions among rapeseed variety, sowing date, and GB concentration.

MATERIALS AND METHODS

Experiment Conditions

The research was carried out at Seed and Plant Improvement Research Institute, Karaj, Iran (35° 49´ N, 50° 59´ E; with an altitude of 1321 m above sea level) during 2014-2016. The soil of the experimental site was clay loam, with montmorllionite clay minerals, but was low in nitrogen (0.06-0.09%). The EC of the soil was 0.66 dS m^{-1} and the pH ranged from 7.2 to 7.9 (Table 1). Climate data, including temperature and precipitation for the growing seasons, are presented in Table 2. The experiment was organized in a randomized complete block design, with a factorial split plot arrangement having three replications. There were three factors including six genotypes of rapeseed (Elvis, HL2012, L155, KR2,

Table 1. Physical and chemical characteristics of the soil in the present study.

Specifications	First year		Second year	
	Sampling depth (cm)	Sampling depth (cm)	Sampling depth (cm)	Sampling depth (cm)
	0-30	30-60	0-30	30-60
Electric conductivity (dS m^{-1})	1.45	1.24	1.33	1.15
pH	7.9	7.2	7.8	7.4
Percentage of neutralizing agents	8.56	6.68	8.25	8.46
Moisture content of saturated soil (%)	36	38	35	37
Organic carbon (%)	0.91	0.99	0.83	0.96
Total nitrogen (percent)	0.09	0.07	0.08	0.06
Available phosphorus (mg kg^{-1})	14.7	15.8	14.2	15.3
Available potassium (mg kg^{-1})	197	155	165	148
Clay percentage	28	25	29	27
Silt percentage	47	49	45	46
Sand percentage	25	26	26	27
Soil pattern	Clay loam	Clay loam	Clay loam	Clay loam

Table 2. Climate data for the experimental site in Karaj for the growing seasons.

Month	October		November		December		January		February	
Year	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Rainfall (mm)	13.4	3.5	13.7	77.4	31.6	28.6	6	15.6	47.8	8.7
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	-	-	-
Temp (°C)	6.7	11.8	13.8	11.7	20	19.9	26.4	26.4	30.9	28.9

HW113 and Danob), three sowing dates (October 7, 17, and 27), and two levels of glycinebetaine (0 and 0.2%). The information of the six cultivars is listed in Table 3. The three sowing dates and the two levels of glycinebetaine were allotted to the main plots, while the six genotypes were allotted to the subplots. The liquid solution of glycinebetaine (0.2%; Sigma-Aldrich) was sprayed on the seedlings when they had 4 to 6 leaves.

Measuring the Parameters

During the maturity stage, the seed yield (kg ha^{-1}) and seed oil yield (kg ha^{-1}) were measured. Also, the seed glucosinolate content (mg g^{-1}) and fatty acids in the oil were measured using the High Performance Liquid Chromatography (HPLC; Unicam 4600, England) (Yang *et al*., 2009). Chlorophyll content was measured according to the method used by Wellburn *et al*. (1994). The contents of total Chlorophyll (Chl) was determined by the spectrophotometer according to the following formulae:

$$Cha = 16.72 \times A665.2 - 9.16 \times A652.4$$

$$Chb = 34.09 \times A652.4 - 15.28 \times A665.2$$

$$Chl = Cha + Chb$$

Soluble carbohydrates in the leaf were measured using the method proposed by Irigoyen *et al*. (1992). The photometric absorption of the samples was determined by the spectrophotometer at 620 nm. Total soluble carbohydrates in the leaf were estimated using the glucose standard curve. The proline content in the leaf was measured using the method proposed by Bates *et al*. (1973). The absorbance was measured at 520 nm using a spectrophotometer.

Data Analysis

In order to verify the homogeneity of the error variance of the combined analysis, Bartlett's χ^2 test was used. Since the data of the two years had homogeneous variances, the combined analysis was performed on the data, which were analyzed using Statistical Analysis Software (V. 9.1; SAS Institute, Cary, NC). The mean values were compared via the LSD test (Steel and Torrie, 1980). A cluster analysis was performed in order to distinguish among the six genotypes based on the arithmetic mean method (UPGMA).

Table 3. Growth type and origin of studied rapeseed cultivars.

Name	Origin	Growth type	Hybrid	Open pollinated
Danob	France	Winter	*	
Elvis	France	Winter	*	
HL2012	Iran	Winter		*
HW113	Iran	Winter		*
KR2	Iran	Winter		*
L155	Iran	Winter		*

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The cluster analysis was performed by the SPSS software on Windows 20.0 (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

Analysis of Variance

ANOVA revealed that the simple effect of the three studied factors, i.e. the six cultivars, the three sowing dates, and the two levels of GB, caused significant differences ($P< 0.01$) among the results of the measured parameters (data not shown). Rad *et al*. (2015) reported that all of the assessed traits were affected by the cultivars being used (Siadat and Hemayati, 2009). Sharafi *et al*. (2015) reported that a large genetic variation exists in the rapeseed cultivars that were cultivated in Iran. Differences among the six studied cultivars indicated that there was a high genetic variation among the cultivars. The effect of the cultivar and its interaction with the sowing date caused significant differences to be observed in all traits ($P< 0.01$), except in the oleic acid content. The arachidonic acid was the only parameter that was affected by the interaction between sowing date and GB. Other interactions between the factors were not significant among the studied traits.

Seed and Oil Yields

The three studied factors influenced the seed yield, seed oil, and seed oil yield. The HL2012 cultivar had the highest amount of seed yield (4,584 kg ha^{-1}), seed oil (44.6%) and seed oil yield (2,060 kg ha^{-1}) (Table 4), while the lowest values of these traits were obtained in the HW113 cultivar. These traits had the highest values in the first sowing date (October 7). According to Table 4, delaying the sowing date reduced the average values of these traits. Siadat and Hemayati (2009) reported that delaying the sowing date caused a reduction in all yield components, especially in oilseed yield. The delay in sowing date causes the flowering period to happen in May-June when evaporation and transpiration rates peak, thereby causing the crops to suffer from water stress (Yau, 2007). During the flowering period, rapeseed is susceptible to drought stress. Nonetheless, the cultivars showed varying degrees of susceptibility. Water stress reduced the seed yield of the crop during the flowering stage (Bitarafan and Shirani-Rad, 2012).

Application of GB increased the average seed yield from 4,089 to 4,419 (kg ha^{-1}), and increased the oil in the seed from 44 to 44.4%. The seeds oil yield increased from 1,818 to 1,976 (kg ha^{-1}). Dawood and Sadak (2014) proved that GB treatments (10, 15, and 20 mM) caused significant increases in seed yield and oil yield of canola. The result indicated that the interaction between sowing date and GB was not significant, while application of GB was useful to obtain more oil and seed yields. Application of GB can improve the plants tolerance to stress (Ashraf and Foolad, 2007). GlycineBetaine (GB) promotes plant yield under stress conditions due to its osmoprotective effect on the photosynthetic machinery of the plant and because of its contribution to the regulation of ion homeostasis (Raza *et al*., 2007). It improves CO_2 assimilation (Hussain *et al*., 2008) and assists the biosynthesis and transport of hormones (Taiz and Zeiger, 2006).

Proline, Soluble Carbohydrates and Total Chlorophyll Content in the Rosette Stage

Proline and soluble carbohydrates were higher in plants that were sown on October 7, compared to those sown on October 27. However, the amount of total chlorophyll decreased. The increase in proline and soluble carbohydrates can be explained by the occurrence of cold stress for later sowing

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Table 4. Main effects of sowing date, glycinebetaine and cultivar on all measured characters of canola.[a]

Factors	Proline	SC	TChl	SY	SO	SOY	AA	LA	OA	EA	GC
Crop year											
2014-2015	18.3 (0.43)^{a} [b]	40.7 (1)^{a}	1.53 (0.03)^{b}	3887 (109)^{b}	44 (0.12)^{b}	1724 (52)^{b}	0.6 (0.02)^{a}	18.8 (0.18)^{a}	62.6 (٠.١۶)^{b}	0.27 (0.01)^{b}	13.1 (0.27)^{a}
2015-2016	13.7 (0.35)^{b}	36 (0.94)^{b}	1.5 (0.04)^{a}	4630 (120)^{a}	44.4 (0.11)^{a}	2070 (58)^{a}	0.6 (0.01)^{a}	17.3 (0.1)^{b}	65.1 (0.11)^{a}	0.30 (0.01)^{a}	12.6 (0.29)^{b}
Planting date											
October 7	11.5 (0.23)^{c}	27.1 (0.44)^{c}	1.28 (0.02)^{a}	5518 (83)^{a}	45.6 (0.06)^{a}	2519 (40)^{a}	0.36 (0.01)^{c}	19.7 (0.18)^{a}	65.3 (0.15)^{a}	0.17 (0.005)^{c}	9.5 (0.14)^{c}
October 17	15.8 (0.38)^{b}	38.1 (0.57)^{b}	1.42 (0.02)^{b}	4283 (85)^{b}	44.2 (0.06)^{b}	1897 (39)^{b}	0.63 (0.01)^{b}	18 (0.12)^{b}	63.9 (0.17)^{b}	0.27 (0.006)^{b}	12.9 (0.14)^{b}
October 27	20.6 (0.37)^{a}	49.9 (0.58)^{a}	1.3 (0.01)^{c}	2975 (74)^{c}	42.8 (0.07)^{c}	1276 (33)^{c}	0.82 (0.01)^{a}	16.4 (0.07)^{c}	62.3 (0.21)^{c}	0.41 (0.005)^{a}	16.2 (0.14)^{a}
Glycinebetaine											
GB	15.4 (0.44)^{b}	36.9 (0.98)^{b}	1.47 (0.04)^{a}	4419 (119)^{a}	44.4 (0.12)^{a}	1976 (57)^{a}	0.57 (0.02)b	18.2 (0.2)^{a}	64 (0.18)^{a}	0.27 (0.01)^{b}	12.5 (0.28)^{b}
Control	16.5(0.45)^{a}	39.8 (0.99)^{a}	1.37 (0.03)^{b}	4098 (119)^{b}	44 (0.12)^{b}	1818 (56)^{b}	0.63 (0.01)a	17.8 (0.16)^{b}	63.7 (0.19)^{b}	0.30 (0.01)^{a}	13.3 (0.27)^{a}
Cultivar											
Danob	15 (0.76)^{b}	35.9 (1.71)^{b}	1.5 (0.06)^{a}	4548 (213)^{a}	44.5 (0.22)^{ab}	2040 (103)^{a}	0.54 (0.03)^{d}	18.4 (0.3)^{a}	64.2 (0.31)^{a}	0.26 (0.01)^{c}	12.1 (0.51)^{c}
Elvis	15.3 (0.64)^{b}	36.5 (1.3)^{b}	1.48 (0.04)^{a}	4419 (156)^{a}	44.4 (0.14)^{b}	1969 (74)^{a}	0.59 (0.02.)^{c}	18.2 (0.25)^{a}	64.1 (0.29)^{a}	0.27 (0.01)^{b}	12.5 (0.35)^{b}
HL2012	14.9 (0.76)^{b}	35.7 (1.6)^{b}	1.52 (0.06)^{a}	4584 (213)^{a}	44.6 (0.21)^{a}	2060 (104)^{a}	0.54 (0.03)^{d}	18.4 (0.3)^{a}	64.3 (0.3)^{a}	0.25 (0.01)^{c}	12.1 (0.52)^{c}
HW113	17.1 (0.83)^{a}	41.4 (1.8)^{a}	1.31 (0.05)^{b}	3932 (220)^{b}	43.8 (0.22)^{c}	1740 (105)^{b}	0.66 (0.03)^{a}	17.6 (0.3)^{b}	63.4 (0.33)^{b}	0.31 (0.01)^{a}	13.7 (0.51)^{a}
KR2	16.8 (0.82)^{a}	40.4 (1.8)^{a}	1.34 (0.06)^{b}	4035 (223)^{b}	43.9 (0.22)^{c}	1789 (106)^{b}	0.64 (0.03)^{b}	17.8 (0.3)^{b}	63.6 (0.34)^{b}	0.31 (0.01)^{a}	13.4 (0.52)^{a}
L155	16.8 (0.79)^{a}	40.3 (1.7)^{a}	1.35 (0.05)^{b}	4034 (198)^{b}	43.9 (0.20)^{c}	1786 (94)^{b}	0.65 (0.02)^{ab}	17.7 (0.28)^{b}	63.6 (0.32)^{b}	0.31 (0.01)^{a}	13.5 (0.48)^{a}

[a] In each column and for each factor, the same letters show that there are no significantly differences. SC: Soluble Carbohydrates, TChl: Total Chlorophyll, SY: Seed Yield, SO: Seed Oil, SOY: Seed Oil Yield, AA: Arachidonic Acid, LA: Linoleic Acid, OA: Oleic Acid, EA: Erucic Acid and GC: Glucosinolate Content. [b] The values are means (SEM).

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dates. At low temperatures, the accumulation of proline has been observed in canola cultivars (Moieni-Korbekandi *et al*., 2014). In this regard, the results of our study are in agreement with previous reports concerning plants such as potato hybrids (Koç *et al*., 2010), rice (Ghorbani *et al*., 2009), wheat (Jahanbakhsh-Godehkahriz *et al*., 2009; Javadian *et al*., 2010), and apricot (Rouhaninia *et al*., 2006). Proline accumulation is an important mechanism of response to cold stress as it can contribute to the repair of cell damage. The application of GB reduces the amounts of proline and soluble carbohydrates (Table 4). However, Dawood and Sadak (2014) reported that GB treatments cause significant increases in proline and total soluble sugars in canola under drought stress. These different reports regarding the application of GB and its effect on proline and soluble carbohydrates can be different depending on the kind of stress, sampling stage, and plant age (Park *et al*., 2006). As the leaf temperature is reduced, the accumulation of soluble carbohydrates becomes more prominent (Paul *et al*. 1992). Accordingly, Stitt *et al*. (1990) and Von-Schaewen *et al*. (1990) reported that the accumulation of soluble carbohydrates can suppress photosynthesis by down-regulating the enzymes involved in the photosynthetic-carbon reduction cycle and chlorophyll a/b-binding proteins. Delaying the sowing dates had a negative effect on the total amount of chlorophyll, whereas the application of GB had a positive effect (Table 4). In research made by Dawood and Sadak (2014), all concentrations of GB caused marked increases in photosynthetic pigments in fresh leaf tissues of canola plants. Application of GB was found to be influential in mitigating the harmful effects of different stress conditions on the photosynthetic capacity of plants, which is possibly due to its role in preventing photo-inhibition (Ma *et al*., 2008). The reduction in total chlorophyll content as a result of delayed sowing dates could be due to the destruction of chloroplasts and the decrease of pigments when multiple stress factors amount to substantial effects. Any significant changes to the chlorophyll concentration could be harmful to plant growth (Shweta and Agrawal, 2006). The interaction between cultivar and sowing dates was significant ($P< 0.01$) with respect to the three factors considered in this study. The highest amount of proline (22.33 μmol g^{-1}) and soluble carbohydrates (53.9 mg g^{-1}), and the lowest total chlorophyll (0.89 mg g^{-1}) were obtained in the interaction between the HW113 cultivar and the sowing date of October 27 (Table 5).

Fatty Acid Compositions and Glucosinolate

The highest fatty acid composition in the oil of seeds in the six cultivars included oleic acid (63.4-64.3%), linoleic acid (17.6-18.4%), arachidonic acid (0.54-0.66%), and erucic acid (0.25-0.31%), respectively. Delaying the sowing dates caused an increase in arachidonic and erucic acids, whereas it reduced oleic and linoleic acids. Similar to our research, Turhan *et al*. (2011) indicated that the sowing date significantly affected oleic and linoleic acids, and their mean values were lower in plants that were sown latest. Rapeseed oil is valued for its high oleic acid level. It also contains a good proportion of omega-3 linolenic acid. However, some rapeseed cultivars contain high levels of erucic acid, but the current cultivars were observed to have trace quantities only (< 0.1%). Our results indicated that the delay in sowing time reduced the quality of rapeseed oil and, in this regard, the results of our study are in agreement with a previous study made by Hashm and Mahmood (2016). However, the delay in sowing time reduced the quality of seed oil, whereas the application of GB increased it (Table 4). Similarly, Dawood and Sadak (2014) results on the fatty acids of rapeseed oils have shown different responses to GB treatments. Compatible solutes (like GB) are known to improve the

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Table 5. Interaction between sowing date and cultivar on all measured characters of canola.[a]

Sowing date	Cultivar	Proline	SC	TChl	SY	SO	SOY	AA	LA	OA	EA
October 7	Danob	10.54 (0.4)^{ib}	24.7 (0.76) k	1.9 (0.03)^{a}	5878 (165)^{a}	46 (0.14)^{a}	2707 (78)^{a}	0.27 (0.01)^{l}	20.1 (0.45)^{a}	0.14 (0)^{h}	8.59 (0.24)^{i}
	Elvis	12.64 (0.62)^{h}	29.7 (1.01) i	1.7 (0.05)^{b}	5151 (173)^{b}	45.2 (0.12)^{b}	2329 (82)^{b}	0.46 (0.02)^{i}	19.3 (0.46)^{b}	0.21 (0.01)^{f}	10.62 (0.28)^{f}
	HL2012	10.25 (0.37)^{j}	24 (0.7) k	1.9 (0.08)^{a}	5971 (189)^{a}	46 (0.13)^{a}	2759 (92)^{a}	0.24 (0.01)^{l}	20.3 (0.43)^{a}	0.13 (0.01)^{h}	8.36 (0.29)^{i}
	HW113	11.93 (0.6)^{i}	28.1 (0.97)^{ij}	1.8 (0.04)^{b}	5386 (188)^{b}	45.4 (0.1)^{b}	2447 (88)^{b}	0.41 (0.02)^{j}	19.5 (0.45)^{b}	0.19 (0.01)^{fg}	10.01 (0.24)^{gh}
	KR2	11.7 (0.55)^{i}	27.3 (0.98)^{j}	1.8 (0.04)^{b}	5460 (233)^{b}	45.5 (0.14)^{b}	2485 (106)^{b}	0.38 (0.02)^{k}	19.6 (0.42)^{b}	0.18 (0.01)^{g}	9.71 (0.26)^{h}
	L155	12.3 (0.64)^{hi}	28.9 (1.03)^{ij}	1.7 (0.05)^{b}	5267 (191)^{b}	45.3 (0.12)^{b}	2387 (90)^{b}	0.44 (0.02)^{i}	19.4 (0.46)^{b}	0.2 (0.008)^{f}	10.29 (0.28)^{fg}
October 17	Danob	14.76 (0.84)^{fg}	35.2 (1)^{gh}	1.5 (0.03)^{c}	4573 (217)^{c}	44.5 (0.1)^{c}	2039 (98)^{c}	0.58 (0.02)^{gh}	18.4 (0.31)^{c}	0.25 (0.01)^{e}	12.15 (0.23)^{e}
	Elvis	14.39 (0.81)^{g}	33.9 (1)^{h}	1.6 (0.04)^{c}	4687 (176)^{c}	44.6 (0.1)^{c}	2096 (82)^{c}	0.55 (0.02)^{h}	18.6 (0.31)^{c}	0.24 (0.01)^{e}	11.87 (0.2)^{e}
	HL2012	15.15 (0.86)^{f}	36.1 (1.2)^{gh}	1.5 (0.04)^{c}	4510 (208)^{c}	44.4 (0.1)^{c}	2005 (94)^{c}	0.6 (0.02)^{gh}	18.3 (0.28)^{c}	0.26 (0.01)^{e}	12.39 (0.27)^{e}
	HW113	17.26 (0.94)^{e}	42.2 (1.6)^{e}	1.3 (0.03)^{d}	3868 (195)^{d}	43.7 (0.14)^{d}	1695 (89)^{d}	0.7 (0.01)^{e}	17.4 (0.26)^{d}	0.32 (0.01)^{d}	14.05 (0.24)^{d}
	KR2	16.9 (0.98)^{e}	41 (1.1)^{ef}	1.3 (0.03)^{d}	3986 (205)^{d}	43.9 (0.16)^{d}	1752 (95)^{d}	0.69 (0.01)^{ef}	17.6 (0.23)^{d}	0.31 (0.01)^{d}	13.8 (0.36)^{d}
	L155	16.7 (1)^{e}	40.2 (1.2)^{f}	1.4 (0.04)^{d}	4074 (163)^{d}	43.9 (0.18)^{d}	1793 (75)^{d}	0.67 (0.01)^{f}	17.7 (0.25)^{d}	0.30 (0.01)^{d}	13.51 (0.31)^{d}
October 27	Danob	19.75 (0.9)^{c}	47.9 (1.3)^{c}	1.1 (0.04)^{e}	3193 (185)^{e}	43 (0.15)^{e}	1375 (81)^{e}	0.8 (0.02)^{c}	16.6 (0.18)^{e}	0.39 (0.01)^{b}	15.8 (0.26)^{b}
	Elvis	18.91 (1)^{d}	45.9 (1.2)^{d}	1.2 (0.04)^{e}	3420 (160)^{e}	43.3 (0.11)^{e}	1483 (70)^{e}	0.77 (0.01)^{d}	16.8 (0.18)^{e}	0.37 (0.01)^{c}	15.8 (0.27)^{c}
	HL2012	19.36 (0.9)^{cd}	47 (0.94)^{cd}	1.1 (0.02)^{e}	3274 (159)^{e}	43.2 (0.11)^{e}	1416 (70)^{e}	0.78 (0.02)^{cd}	16.6 (0.28)^{e}	0.38 (0.01)^{bc}	15.53 (0.33)^{bc}
	HW113	22.33 (0.7)^{a}	53.9 (1)^{a}	0.9 (0.02)^{f}	2543 (152)^{f}	42.3 (0.16)^{f}	1078 (68)^{f}	0.87 (0.02)^{a}	15.9 (0.13)^{f}	0.45 (0.01)^{a}	17.13 (0.32)^{a}
	KR2	21.89 (0.7)^{ab}	52.8 (1.3)^{ab}	0.9 (0.03)^{f}	2661 (149)^{f}	42.4 (0.13)^{f}	1129 (65)^{f}	0.86 (0.02)^{ab}	16.1 (0.15)^{f}	0.44 (0.01)^{a}	16.97 (0.27)^{a}
	L155	21.43 (0.9)^{b}	51.9 (1.1)^{b}	0.95 (0.03)^{f}	2761 (159)^{f}	42.5 (0.15)^{f}	1177 (70)^{f}	0.84 (0.02)^{b}	16.1 (0.17)^{f}	0.44 (0.01)^{a}	16.81 (0.34)^{a}

[a] In each column, the same letters show that there are no significantly differences. SC: Soluble Carbohydrates, TChl: Total Chlorophyll, SY: Seed Yield, SO: Seed Oil, SOY: Seed Oil Yield, AA: Arachidonic Acid, LA: Linoleic Acid, OA: Oleic Acid, EA: Erucic Acid, and Glucosinolate Content.[b] The values are means (SEM).

oil quality because of their protective effects on cellular structures during the biosynthesis of fatty oils and their storage (Taiz and Zeiger, 2006). Significant interactions between cultivars and the sowing dates were observed in fatty acid compositions (except in oleic acid). Arachidonic acid was the only parameter that was affected by the sowing date along with the GB interaction. The lowest mean value of arachidonic acid (0.32%) was observed by the application of GB and the first sowing date (Table 6). The three studied factors affected the glucosinolate content. The 'Danob' and 'HW113' cultivars had the lowest (12.1 mg g^{-1}) and highest (13.7 mg g^{-1}) glucosinolate content, respectively. Glucosinolate is considered toxic to humans; it is unfavorable for animal feed and egg production. Nonetheless, it plays an important role in the defense mechanism of plants and in their protection against pests (Kozlowska *et al*., 1990). An early sowing date and application of GB were observed to have a positive effect on reducing the amount of this compound.

Cluster Analysis

A dendrogram was generated using the measured traits that classified the rapeseed cultivars into two main groups (Figure 1). Three cultivars including L155, KR2, and HW113 were in the first group. The cultivars of this group had high values of proline, soluble carbohydrates, arachidonic acid, erucic acid, and glucosinolate, compared to the second group. However, other parameters in the first group had lower values than in the second group. The second group consisted of three other cultivars. These cultivars had higher levels of seed yield, oil yield, oleic acid and linoleic acid, which indicate that the cultivars are suitable for cultivation in the specific location where this study was performed.

CONCLUSIONS

All measured parameters were affected by the three studied factors, i.e. the six cultivars, the three sowing dates, and the two levels of GB. Apart from linoleic acid, other traits were affected by the interaction between cultivar and sowing date. The results of the present study showed that early sowing date (October 7) and application of GB had a positive effect on the quantity and quality of rapeseed oil. Furthermore, the results demonstrated that a late sowing date is unfavorable for the plants. The results of cluster analysis showed that three of the six cultivars were suitable for cultivation in the studied region. Finally, the sowing date and the type of cultivar are two of the most important parameters to be considered in any region, if the oil of rapeseed is to have high quality and yield.

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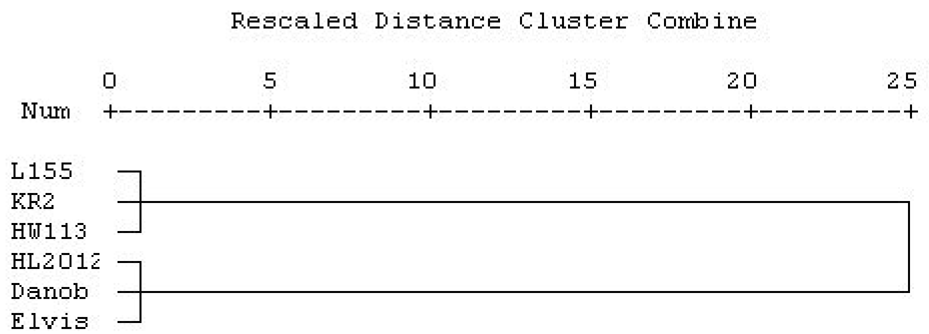

Figure 1. Dendrogram generated based on traits measured on the six rapeseed cultivars using UPGMA method.

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تأثیر تاریخ کاشت، گلایسین بتائین بر روی عملکرد دانه، مقدار روغن و اسیدهای چرب ارقام کلزا

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چکیده

هدف این آزمایش پیشنهاد مناسب‌ترین کولتیوارهای کلزا در بهترین تاریخ کاشت آن‌ها بود. آزمایش به‌صورت فاکتوریل اسپلیت پلات در طرح بلوک کامل تصادفی در سه تکرار طی دو سال (۲۰۱۴-۲۰۱۵ و ۲۰۱۵-۲۰۱۶) انجام شد. در این آزمایش از شش کولتیوار کلزا به اسامی Elvis، HL2012، L155، KR2، HW113 و Danob، سه تاریخ کاشت (۷، ۱۷ و ۲۷ اکتبر) و دو غلظت گلایسین بتائین (صفر و دو درصد) استفاده شد. فاکتورهای تاریخ کاشت و گلایسین بتائین در کرت‌های اصلی و شش کولتیوار در کرت‌های فرعی اختصاص یافتند. بیشترین مقدار عملکرد دانه (۴۵۸۴ کیلوگرم بر هکتار)، عملکرد روغن (۴۴/۶ درصد) و عملکرد روغن دانه (۲۰۶۰ کیلوگرم بر هکتار) را کولتیوار HL2012 دارا بود که در تاریخ کاشت اول به دست آمدند. کاربرد گلایسین بتائین موجب افزایش عملکرد دانه از ۴۰۸۹ به ۴۴۱۹ کیلوگرم بر هکتار، درصد روغن دانه از ۴۴ به ۴۴/۴ درصد و عملکرد روغن دانه از ۱۸۱۸ به ۱۹۷۶ کیلوگرم بر هکتار شد. میزان پرولین و کربوهیدرات‌های محلول از اولین به

آخرین تاریخ کاشت، در گیاهان افزایش یافتند. تاریخ کاشت اول و کاربرد گلایسین بتائین تأثیر مثبتی بر روی کیفت و کمیت روغن کلزا داشتند. نتایج تجزیه خوشه‌ای نشان داد که از شش کولتیوار سه تا از آن‌ها برای کشت در منطقه کرج، ایران مناسب هستند. مطابق با تجزیه به مؤلفه‌های اصلی سه مؤلفه اصلی اول حدود ۹۹ درصد واریانس بین کولتیوارهای کلزا را توجیه می‌کنند.

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