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Effects of Sowing Date, Cultivar and Chitosan on Quality and Quantity of Rapeseed (*Brassica napus* L.) Oil

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ABSTRACT

The effects of cultivars and sowing date along with chitosan application on oil yield, yield components and fatty acids of rapeseed (*Brassica napus* L.), were investigated. Five cultivars (RGS003, Sarigol, Zafar, Dalgan, and Julius) were sown in three sowing dates (October 7, 17, and 27), for two years (2014-2015 and 2015-2016). A factorial split-plot experiment was conducted in a complete randomized blocks design with three replications, where the sowing dates and the two levels of chitosan (0 {control} and 0.2% concentrations) were allotted to main plots and the cultivars were allotted to subplots. ANOVA revealed a significant ($P<0.01$) effects of the three studied factors on studied characters. Sarigol cultivar had the highest amount of seed yield (4447 kg ha^{-1}), seed oil (45.51%) and biological yield (15672 kg ha^{-1}). These characters had the highest values in the first sowing date. Application of chitosan solution increased the amount of seed yield from 3916 to 4233 (kg ha^{-1}), seed oil from 44.83 to 45.24% and biological yield from 13628 to 14797 (kg ha^{-1}). Delayed sowing dates, increased the linolenic and erucic acids and decreased the palmitic, oleic, and linoleic acids. The results of the present study indicated that early sowing date and chitosan application had positive effects on the quantity and quality of rapeseed oil. Cluster analysis divided the cultivars into two main clusters. The PCA revealed that the three first PC confirmed about 96% of the total variance among the studied cultivars.

Keywords: Rapeseed (*Brassica napus* L.); Seed oil; Biological yield; Year

1. Introduction

Rapeseed or oilseed rape (*Brassica napus* L.) is one of the most important oilseeds with 40-44% oil and it is the world's third annual edible oil after soybean (*Glycine max* Merril.) and oil palm (*Elaeis guineensis* Jacq.) (Enjalbert et al 2013). Also, the oil of the plant is currently considered as the best oil in human nutrition with 61% oleic acid, 20% linoleic acid (Spasibionek et al 2003).

Oil yield and glucosinolate accumulation in canola are inheritable, however, they are affects by environmental factors, too (Fieldsend et al 1991; Azizi et al 2006). Early and late sowing dates causes the plant to be exposed to undesirable environmental conditions. The determination of the best sowing

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date plays an important role in the confirmation of plant growth stages to desirable environmental conditions, resulting in maximum quality and quantity yield (Siadat & Hemayati 2009). The sowing date is the most effective treatment on the physiological and physiological characteristics of the crop (Khayat 2007). Optimum sowing date cause in the better seedling establishment and improved cold tolerance (Sultan & Angadi 2016). However delay sowing date cause decreasing in plant height and seed yield (Alisial et al 2005). The early and late sowing date of this plant causes the plant to face a variety of stresses during its growth. The chitosan is a useful natural polymer that produced by alkaline N-deacetylation of chitin. It is a component of the cell walls of some algae, fungi, and insects. The chitosan can be sprayed on plant aerial parts to induce the accumulation of bioactive secondary metabolites (Lei et al 2011; Yin et al 2011). Spraying plants with chitosan compensated to some extent for the negative impact of drought stress on some main characters. Reduction of the negative impact of drought on some characters by foliar application of chitosan has been reported in different plants (Dzung et al 2011; Mahdavi et al 2011). Bittelli et al (2001) reported that it reduced plant transpiration in pepper (*Capsicum* sp. L.), resulting in 26-43% reduction in water use without a reduction in dry matter yield. With increased levels of chitosan and drought stress, the amount of oil of Thymus (*Thymus daenensis* Celak.) increased (Bistgani et al 2017). The chitosan is used to cover seeds, leaves, and fruits (Devlieghere et al 2004). Studies on the effect of sowing time and application of the chitosan on quality and quantity of rapeseed oil using different cultivars are limited in number. Therefore, the aim of this study was to determine the effects of three sowing times and chitosan on some traits in rapeseed cultivars.

2. Material and Methods

2.1. Experiment conditions

The study was conducted at the Karaj Seed and Plant Improvement Research Institute, Karaj, Iran (35°49´N, 50°59´E; altitude of 1321 m asl) during the 2014-2015 and 2015-2016. This area has average annual rainfall and temperature of 354 mm and 14.2 °C, respectively. The soil of the experimental was a loam clay, with montmorllionite clay mineral, low in nitrogen (0.06-0.09%), with a Ec= 0.66 dS m^{-1} and pH of 7.2-7.9 (Table 1). The experiment was organized in a randomized complete block design, with factorial split plot arrangement, with three replications. There were three factors including (5) cultivars of rapeseed (RGS003, Sarigol, Zafar, Dalgan and Julius), (3) sowing dates (October 7, 17

Table 1- The result of soil analysis

Parameter	*2014- 2015*		*2015-2016*	
	Depth (0-30 cm)	*Depth (30-60 cm)*	*Depth (0-30 cm)*	*Depth (30-60 cm)*
Electrical conductivity (dS m^{-1})	1.45	1.24	1.33	1.15
pH	7.90	7.20	7.80	7.40
Total neutralizing value (%)	8.56	6.68	8.25	8.46
Moisture content (%)	36.00	38.00	35.00	37.00
Organic carbon (%)	0.91	0.99	0.83	0.96
Total N (%)	0.09	0.07	0.08	0.06
Available P (mg kh^{-1})	14.70	15.80	14.20	15.30
Available K (mg kh^{-1})	197.00	155.00	165.00	148.00
Clay (%)	28.00	25.00	29.00	27.00
Silt (%)	47.00	49.00	45.00	46.00
Sand (%)	25.00	26.00	26.00	27.00
Soil texture	Clay loam	Clay loam	Clay loam	Clay loam

and 27) and (2) levels of chitosan (0: control and 0.2%). The sowing dates and chitosan were allotted to main plots. However the cultivars were allotted to subplots. A solution of chitosan (0.2%) was sprayed at budding time. Soil samples were collected at the depth of 0-30 cm and 30-60 cm, before seed sowing. The soil physicochemical properties were presented in Table 1. According to the soil analysis, 150 kg ha^{-1} of ammonium phosphate and potassium sulphate before sowing date and 350 kg ha^{-1} urea at (3) different times (100, 150 and 100 kg ha^{-1} at sowing time, stem elongation and flowering stage, respectively), were applied.

Each experiment plot consisted of 6 lines 6 meters with lines of 60 cm and plant spacing on the 4 cm line, as well as two lateral lines as margins and its four middle lines were used to determine all phonological stages of the plant and various traits. Irrigation and disease control measures were done as per requirement. At full maturity ten randomly selected sample plants were collected separately from each plot.

2.2. The measured characters

In the maturity stage the following characters were measured, seed yield, number of pods per plant, number of seeds per pod, 1000-seed weight, biological yield, and seed oil yield. The oil content was extracted by Soxhlet method (Joshi et al 1998). Also, seed glucosinolate content and fatty acids in the oilseeds were measured using with a high-performance liquid chromatography device (HPLC; Unicam 4600, England) (Yang et al 2009).

2.3. Data analysis

In order to verify the homogeneity of error variance of 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. The data were analyzed using Statistical Analysis Software (V. 9.1; SAS Institute, Cary, NC). In addition, the mean values were compared by using the LSD test (Steel &Torrie 1980). Cluster analysis was conducted to distinguish among the five cultivars based on the arithmetic mean (UPGMA) method. The cluster analysis was performed by SPSS software on Windows 20.0 (SPSS Inc., Chicago, IL).The principal component analysis (PCA) was conducted with MetaboAnalyst Software (v. 3.0) (Xia & Wishart 2016).

3. Results and Discussion

3.1. Analysis of variance

The result of Bartlett's χ^2 test for all characters showed that the data of the two years had homogeneous variances, therefore the combined analysis was performed on the data. Analysis of variance indicated that the effects of the cultivar, year, sowing date, and the chitosan were significant ($P<0.01$) in all studied characters (Table 2). Rad et al (2015) reported that all assessed traits in canola were significant by the different sowing dates. Siadat & Hemayati (2009) described the variety factor had a significant effect on all rapeseed characters (except for single seed weight). The result revealed that interaction between sowing date and cultivar was significant ($P<0.01$) on all studied traits (except for palmitic and oleic acids). The factors interaction means that the sowing dates produced a differential effect on the response of cultivars for many traits. The similar significant interaction was found between sowing date and canola hybrid for seed yield and oil content (Lima et al 2017). The interaction between sowing date and chitosan was significant ($P<0.05$) only for a number of pods per plant. There was no any other significant interactions between the factors studied (Table 2).

3.2. Quantity characters

The highest number of pods per plant was observed on the first sowing date (October 7; Table 3). The delay in the sowing date from the first to the third had a 25.22% decrease in the number of pods per but 0.2% of chitosan increased the trait about 10% compared to the control. Sarigol and Julius cultivars had the highest (169.44) and lowest (140.18) mean values for this character, respectively. The delay in the cultivation time from September 12 to October 12 decreased the number of pods per plant and

Table 2- Variance analysis results of the measured agronomic traits in the cultivars

S.O.V	*df*	*Number of pods per plant*	*Number of seeds per pod*	*1000-seeds weight (g)*	*Seed yield (kg ha^{-1})*	*Biological yield (kg ha^{-1})*	*Oil (%)*	*Glucosinolate (µmole g^{-1})*	*Palmitic acid (%)*	*Oleic acid (%)*	*Linoleic acid (%)*	*Linolenic acid (%)*	*Erucic acid (%)*
Y	1	**	**	**	**	**	**	**	**	**	**	**	**
E	4	332.40	1.50	0.57	859383	1209269	0.49	11.35	0.14	0.73	3.27	1.58	0.01
S	2	**	**	**	**	**	**	**	**	**	**	**	**
Y×S	2	ns	*	**	ns	ns	ns	ns	ns	**	**	*	**
CH	1	**	**	**	**	**	**	**	**	**	**	**	**
Y×CH	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
S×CH	2	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Y×S×CH	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E	20	137.78	1.88	0.20	309898	677004	0.23	1.08	0.14	1.44	1.08	0.11	0.002
C	4	**	**	**	**	**	**	**	**	**	**	**	**
Y×C	4	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
S×C	8	**	**	**	**	**	**	**	ns	ns	**	**	**
Y×S×C	8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CH×C	4	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Y×CH×C	4	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
S×CH×C	8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Y×S×CH×C	8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
E	96	99.44	1.29	0.15	243283	784397	0.17	0.46	0.16	0.56	0.39	0.06	0.001
C.V (%)		6.58	6.37	9.20	12.10	6.23	0.91	5.24	8.17	1.17	3.28	4.38	9.39

S.O.V, source of variation; df, degree of freedom; Y, year; E, error; S, sowing date; CH, chitosan; C, cultivar; C.V, coefficient of variation. *, ** and ns indicate statistically significance at $P < 0.05$, 0.01 and not significant, respectively seed yield (Pasban-Easlam 2009). The interaction between the sowing date and the chitosan was significant (P<0.05) for this trait. The application of chitosan in 7th October had the highest mean value for this character (221.2; Figure 1).

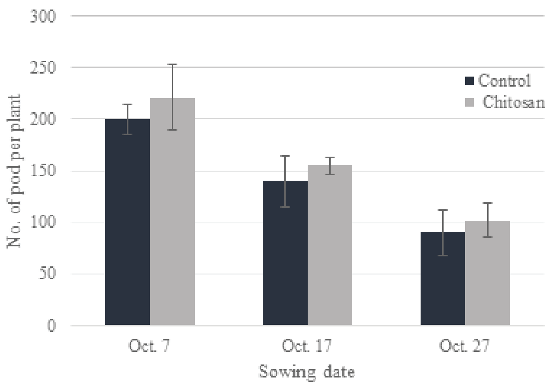

Figure 1- The interaction between the sowing date and the chitosan on a number of the pod^{-1} plant

Delay in sowing date from first to third reduced the number of seeds per pod about 33%, but the 0.2% chitosan solution increased to 4.76% compared to the control (Table 3). The reduction of this character due to a delay in sowing date was reported in some studies (Fagheh 2000; Rahnama & Bakhshandeh 2005). The interaction between cultivar and sowing date, and the interaction between Sarigol with the first sowing date and Julius with the third sowing date had the highest (22.88) and the lowest (13.45) mean value of a number of seed per pods (Table 4). The 1000-grain weight decreased from 5.26 g at the first sowing date to 3.18 g on the third sowing date (Table 3). In delay sowing date, the seed-filling period is associated with high temperature and the heat prevents grain seed filling (Robertson et al 2004; Fallah et al 2011). The application of 0.2% chitosan solution increased the character to 6.8% more than the control (Table 3). In the interaction between sowing date × cultivars, Sarigol in the first sowing date had the highest average (5.71 g) of this trait (Table 4).

The highest (5283 kg ha^{-1}) and the lowest (2844 kg ha^{-1}) grain yield were recorded on the first and third sowing dates, respectively. The chitosan solution 7.5% increased the seed yield than the control. RGS003 and Sarigol cultivars had more average for this character than the others cultivars (Table 3). When canola seeds were sown on 7th and 27th October, Sarigol and Julius cultivars showed the maximum and minimum mean value of seed yield, respectively (Table 4). In many studies, delay in sowing date caused seed yield reduction (Taylor & Smith 1992; Johnson et al 2006; Siadata & Hemayati 2009; Turhan et al 2011; Delkhosh et al 2012). Delay sowing date causes the maturity period to be exposed to high temperatures, which lead to reduced photosynthetic quantities and seed weight and ultimately reduced seed yield (Gan et al 2004; Rafiei et al 2011). Also, the delay sowing date cause reduces vegetative and reproductive growth times (Adamsem & Coffelt 2005). As seen in Table 3, delay in sowing date from the first (18321 kg ha^{-1}) to third (10260 kg ha^{-1}) reduced the biological yield about 44%. The biological yield was increased by chitosan solution than the control treatment. Sarigol cultivar had the highest biological yield (15672 kg ha^{-1}). In the interaction between cultivar and sowing date, the maximum (15533 kg ha^{-1}) and minimum (12912 kg ha^{-1}) biological yield were observed in the interaction between Sarigoa with first sowing date and Julius with the third sowing date, respectively (Table 4). The weather and soil temperatures in delay sowing time are colder than early sowing as date, it causes reduce in the growth and development of dry matter in leaves and stems (Karakaya & Altinok 2002). Sharif & Keshta (2002) obtained the highest biological yield and dry matter of the plant in November than December.

The highest amount of seed oil (46.43%) was observed at the first sowing date. Also, Sarigol cultivar had the maximum amount of the character (45.51%) than other cultivars (Table 3). The interaction between sowing date and cultivar showed that the highest and lowest seed oil were in Sarigol with first sowing date and Julius with third sowing date interactions, respectively (Table 4). Delay

Table 3- Main effects of the sowing date, chitosan and cultivar in agronomic traits

Factor	*Levels*	*Number of pods per plant*	*Number of seeds per pod*	*1000-seeds weight (g)*	*Seed yield (kg ha^{-1})*	*Biological yield (kg ha^{-1})*	*Oil (%)*	*Glucosinolate (µmole g^{-1})*	*Palmitic acid (%)*	*Oleic acid (%)*	*Linoleic acid (%)*	*Linolenic acid (%)*	*Erucic acid (%)*
Sowing date	October 7th	210.50a	21.27a	5.26a	5283a	18321a	46.43a	9.68c	5.46a	65.23a	20.87a	4.57c	0.21c
	October 17th	147.69b	17.84b	4.25b	4098b	14056b	45.04b	12.97b	4.96b	63.87b	19.06b	5.68b	0.32b
	October 27th	96.37c	14.42c	3.18c	2844c	10260c	43.63c	16.13a	4.10c	62.30c	17.40c	6.78c	0.47a
Chitosan	-	143.53b	17.41b	4.09b	3916b	13628b	44.83b	13.35a	4.75b	63.63a	18.89b	5.82a	0.35a
	+	159.51a	18.27a	4.37a	4233a	14797a	45.24a	12.50b	4.93a	63.97a	19.33a	5.53b	0.32b
Cultivar	RGS003	159.14b	18.46a	4.40a	4287a	14740a	45.30b	12.41b	4.99a	64.08a	19.41a	5.49b	0.32b
	Sarigol	169.44a	18.93a	4.55a	4447a	15672a	45.51a	11.95c	5.03a	64.27a	19.62a	5.31c	0.29c
	Zafar	143.81cd	17.35b	4.10b	3913b	13598b	44.83c	13.38a	4.77b	63.62b	18.88b	5.83a	0.35a
	Dalgan	145.04c	17.38b	4.10b	3914b	13722b	44.83c	13.33a	4.74b	63.59b	18.89b	5.83a	0.35a
	Julius	140.18d	17.11b	4.01b	3814b	13328b	44.70c	13.57a	4.67b	63.43b	18.76b	5.92a	0.36a

In each column, the same letters show that there are no significant

Table 4- The interaction between the sowing date and cultivar in agronomic traits

Cultivar	*Number of pods per plant*			*Number of seeds per pod*			*1000-seed weight (g)*			*Seed yield (kg ha^{-1})*			*Biological yield (kg ha^{-1})*		
	7th	*17th*	*27th*	*7th*	*17th*	*27th*	*7th*	*17th*	*27th*	*7th*	*17th*	*27th*	*7th*	*17th*	*27th*
RGS003	194.24d	169.67a	113.50a	20.47b	19.22a	15.67a	5.00b	4.59a	3.62a	4996b	4546a	3317a	17030b	15533a	11656a
Sarigol	239.58a	159.62b	109.10a	22.88a	18.54a	15.35a	5.71a	4.43a	3.52a	5791a	4374a	3176a	20769a	14974a	11273a
Zafar	200.10cd	140.84c	90.48b	20.72b	17.40b	13.95b	5.12b	4.13b	3.04b	5109b	3952b	2678b	17495dc	13576b	9725b
Dalgan	213.01b	135.91cd	86.19bc	21.27b	17.16b	13.70b	5.28b	4.10b	2.92b	5296b	3866b	2581b	18391b	13284bc	9491b
Julius	205.55bc	132.42d	82.57c	21.02b	16.86b	13.45b	5.19b	4.01b	2.83b	5225b	3752b	2466b	17918bc	12912c	9155b
	Oil (%)			*Glucosinolate (µmole g^{-1})*			*Linoleic acid (%)*			*Linolenic acid (%)*			*Erucic acid (%)*		
	7th	*17th*	*27th*	*7th*	*17th*	*27th*	*7th*	*17th*	*27th*	*7th*	*17th*	*27th*	*7th*	*17th*	*27th*
RGS003	46.10c	45.58a	44.23a	10.50a	11.73c	15.00b	20.48b	19.77a	17.99a	4.86a	5.24c	6.37b	0.24a	0.28b	0.42b
Sarigol	47.11a	45.33a	44.09a	8.26d	12.24c	15.35b	21.56a	19.46a	17.83a	4.07d	5.42c	6.45b	0.14d	0.30b	0.43b
Zafar	46.21bc	44.87b	43.42b	10.17ab	13.35b	16.61a	20.63b	18.84b	17.17b	4.75ab	5.81b	6.94a	0.23ab	0.34a	0.49a
Dalgan	46.42b	44.78b	43.27b	9.60c	13.64ab	16.77a	20.89b	18.69b	17.08b	4.56c	5.92ab	7.02a	0.21c	0.35a	0.50a
Julius	46.32bc	44.65b	43.15b	9.89bc	13.88a	16.93a	20.78b	18.55b	16.95b	4.64bc	6.00a	7.13a	0.215bc	0.36a	0.51a

In each column, the same letters show that there are no significant sowing date typically reduces the amount of canola seed oil (Hocking & Stapper 2001). Temperature change during the filling stage can reduce the oil yield. The delay on sowing date causes flowering period falls in May-June when evaporation and transpiration reach high values caused the crop to confront water stress (Yau 2007). During the flowering period, rapeseed is susceptible to drought stress, however, the cultivars were found to possess varying sensitivity. Water stress decreased the seed yield of the crop, during the flowering stage (Bitarafan & Shirani-Rad 2012).

3.3. Fatty acid compositions and glucosinolate

As seen in Table 3, the highest range of fatty acid value in the cultivars, was oleic acid (63.43-64.27%), and it was followed by linoleic acid (18.76-19.62%), Linolenic acid (5.31-5.92%), palmitic acid (4.67-5.03%) and erucic acid (0.29-0.36%). According to review literature, the amount of fatty acid compositions in canola oil is as follows: palmitic acid 2-6%, oleic acid, 55-75%, linoleic acid 10-24%, linolenic acid 8-15%, and erucic acid <1% (Naseri 1991; Shariati & Ghazi Shahinzadeh 2000; Azizi et al 2006). The effects of sowing date and chitosan were significant for all fatty acids measured. Delay in sowing dates causes to increase of linolenic and erucic acids and a decrease of oleic, linoleic, and palmitic acids (Table 3). Sowing time significantly affected on oleic and linoleic acids and the mean values of them decreased as sowing times were delayed (Turhan et al 2011). The application of 0.2% of chitosan solution cause to increase of oleic, linoleic, and palmitic acids and a decrease of linolenic and erucic acids. The highest (19.62%) and lowest (18.76%) oleic and linoleic acids were found in Sarigol and Julius, respectively (Table 3). As known as oleic and linoleic acids are the most important components of unsaturated fatty acids, which are important in terms of nutrition (Weber et al 2008). On the other hand, the quality of seed oil is mainly determined by oleic and linoleic acids contents (Ul-Hassan et al 2005). However linoleic acid is not synthesized in the body and must be supplied by diet (Naseri 1991; Dastpak 2001). Sarigol and Julius cultivars had the highest (5.03%) and lowest (4.67%) average of palmitic acid (Table 3). Gecgel et al (2007) showed that the level of palmitic and oleic acids decreased when oil synthesis happened in hot weather. The result indicated that delayed sowing from 7th to 27th October increased the percentage of linoleic and erucic acids. The chitosan solution reduced both of these two harmful fatty acids than control treatment. Sarigol and Julius cultivars had the lowest and highest percentages of the two acids, respectively (Table 3). The interaction of the treatments showed that the lowest percentage of linolenic and erucic acids were recorded in Sarigol cultivar in the first sowing date (Table 4). These two fatty acids are very harmful to human health, and cultivars without these fatty acids have a high nutritional value (Dastpak 2001).

The result of this study showed delayed sowing date had a negative effect on the oil quality. It should be noted that the increase in temperature during seed formation changes the amount of fatty acids in seeds and affects the quantity and quality of seed oil (Ul-Hassan et al 2005). The three studied factors had effects on glucosinolate content. Sarigol and Julius cultivars had the lowest and highest glucosinolate content, respectively (Table 3). The interaction between sowing date and cultivar showed that Sarigol and Julius cultivars had the lowest and highest glucosinolate content at the first and third sowing dates, respectively (Table 4). Fieldsend et al (1991) showed that glucosinolate accumulation in canola seed is inherited, but also affects by environmental factors (Jan et al 2002; Grant et al 2003). Glucosinolate component is considered toxic to human and unfavorable for animal feed and egg production, however, its play an important role in plant's defense mechanism against pests (Kozlowska et al 1990). Early sowing date and application of the chitosan had a positive affected to reduce of this component. Sulisbury et al (1987) reported that an increase in glucosinolate reduces the quality and nutritional value of canola meal. The result of the present study showed that early sowing date and application of chitosan were useful to obtained high seed oil quality.

3.4. Cluster and PC analyses

All measured characters were used to dendrogram generated, and the cluster analysis classified for the five rapeseed cultivars into two main clusters (Figure 2). Three cultivars including Zafar, Dalgan, and Julius were in the first cluster. The cultivars of this group had high values of linolenic acid, erucic acid, and glucosinolate than the second group. However, for the valuable fatty acids, the first group had lower values than the second group. The result indicated that the quality and quantity of the cultivars in the first cluster were more than the second cluster. The second group consist of two other cultivars (RGS003 and Sarigol cultivars). These cultivars had high levels of grain and oil yields and oleic and linoleic acids, indicated that the cultivars are suitable to cultivate in the area. The PCA revealed that the three first PC confirmed about 96% of the total variance among the five cultivars (Figure 3). The measured characters correlated substantially with the first component (PC1); therefore, it was named "Genotype". About 78% of the total variance among the cultivars was affected by different genotype, because the cultivars were cultivated in the same condition, so their variation due to genetic factors. The second and third components confirmed about 12.2 and 5.52% of the total variance among the cultivars, respectively. The three plots revealed that the results of the cultivars were in agreement with the results of the cluster analysis (Figure 3). In both of them, the cultivars were divided in to main groups.

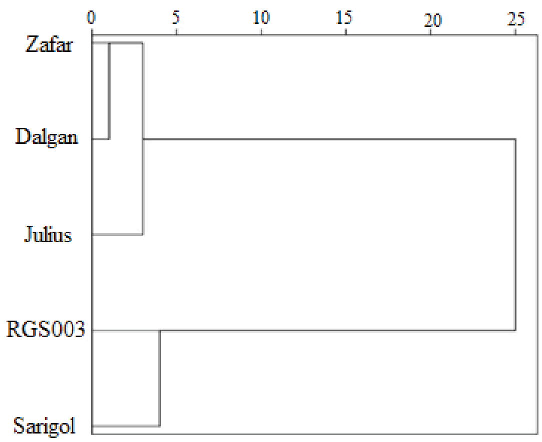

Figure 2- Dendrogram generated based on traits measured using the UPGMA method

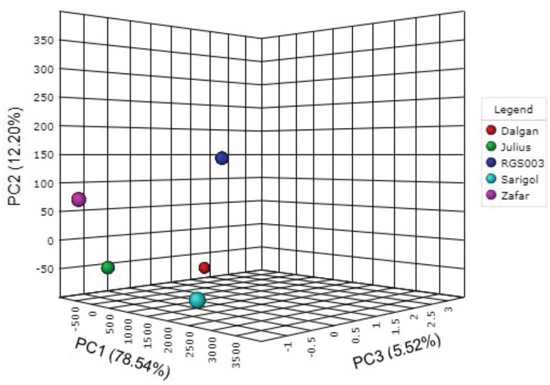

Figure 3- Three plots derived from the principal component analysis

4. Conclusions

The results of the study showed that the rapeseed cultivars responded differently to the sowing dates. Therefore, choosing a suitable sowing date is essential depending upon growing conditions and cultivar. The amount of three beneficial fatty acids including palmitic, linoleic, and oleic acids decreased due to delayed sowing date. Application of 0.2% of chitosan solution increased these three useful fatty acid and decreased harmful fatty acids including erucic and linolenic acids. The result of the present study showed that early sowing date and application of chitosan had a positive effect on the quality and quantity oil yield of the plant. According to the result, it can be suggested that the most appropriate sowing time to obtain a high quantity and quality of rapeseed oil, is early of October and application of chitosan and Sarigol cultivar as a way to increase canola yield. In the end, the determination of sowing date and choosing a suitable cultivar for each region are very important to obtain high quality and quantity of rapeseed oil.

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