A Study on The Yields of Different Lines of *Camelina sativa* L. Crantz

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ABSTRACT

The effects of spring and autumn planting seasons on grain, biological, and oil yields, oil percentage, and yield based on water consumption were investigated in a factorial experiment as a randomized complete block design with three replications in the central district of Fasa city, Fars province, during the crop year of 2018-2019. Five *Camelina* lines (133, 132, 131, 80, and 114) were the main factor and two planting dates of February 20 (spring planting) and November 1 (autumn planting) were considered as secondary factors. All the studied traits were affected significantly by the planting date. The highest average grain, biological, and oil yields (67.2267, 00.5184, and 27.666 kg/ha, respectively) and the coefficient of oil extraction (53.29%) belonged to autumn crops. Spring crop gained a grain yield of 0.49 kg/ha/m³ based on water consumption. The lines were not different statistically in the percentage of extracted oil. L 114 gained the highest amounts of these traits in spite of no significant differences with L 131 in all the measured traits. Significant interactions of different lines and planting date in spring and autumn crops indicated that L 114 had the highest amounts of the measured traits in the autumn crop, except the grain yield based on water consumption. The highest average grain yield based on water consumption (60.0 kg/ha/m³ belonged to L 131 in the spring crop, which was not different significantly from L 114 with an average of 54.0 kg/ha/m³. Lines 132, 133, and 80 gained the lowest levels of the measured experimental traits and contained the lowest grain and biological yields. These three lines were not different statistically in the comparison to the average oil yields in spring and autumn crops.

Key Words: *yield base, water consumption, Camelina lines*

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INTRODUCTION

Camelina sativa L. Crantz is an annual plant that belongs to the Brassicaceae family and is believed to be endemic to northern Europe [1], as well as the Mediterranean region and Central Asia [2]. Additionally, the availability of spring and winter biotypes to *Camelina* shows its potential to grow under different environmental conditions [3-8]. *Camelina* is an endemic plant known as a weed in flax farms called false flax [9, 10]. *Camelina* seeds contain an average oil content of 350-450 $g.kg^{-1}$, with approximately 900 $g.kg^{-1}$ of unsaturated fatty acids present in the oil [10].

However, for such a plant as *Camelina* with a short growing season (85-100 days) [1], the plant may be able to compensate for insignificant delays without significant differences in growth, yield, and quality of completing its cycles before the summer drought period depending on the cultivar [11, 12]. Crop cultivars differ in the absorption and transfer of soil moisture, plant nutrients, photosynthesis, and, most importantly, interaction with environmental factors. In addition, tolerance of cultivars to extreme temperatures, drought, toxicity, and deficiency of some nutrients varies due to genetic diversity [13]. Although it does not grow well in drained clay soils [14], it is a drought-tolerant plant [1].

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French et al. (2009) showed that a 20% reduction in irrigation reduced grain yield by 20% and the minimum water requirement was 333-423 mm during the growing season in Arizona [15]. The growth period of spring cultivars lasts about 120 days in Denmark [14], and 85-110 days in Havre and Montana [16], and Austria [17].

Grain yields reported in different countries include 1500-3250 kg/ha in Austria [17, 18], 2600-3300 kg/ha in Denmark [14], 700-1600 kg/ha in Montana [1], 600-1700 kg/ha in Rosemont [19], and 720-2000 and about 1000 kg/ha in the United States [15].

The effect of planting date on the yield is examined in two parts. First, the effect of planting date on the final yield at the end of the plant growth period, which can be calculated by determining the grain yield or oil and protein contents, etc. [20]. Second, the effect of planting date on yield components during growth stages because morphological and physiological traits have significant effects on the final yield [21, 22]. These traits are affected by the temperature in autumn crops of *Camelina* lines compared to their spring crops. Therefore, this study aimed to determine the best line and suitable planting date of *Camelina* according to the environmental conditions and climatic adaptation to Fasa city.

MATERIALS AND METHODS

This experiment was carried out in the central district of Fasa city in Fars province, 145 km east of Shiraz, located at the geographical coordinates of 53° 24′ E and 28° and 58′ N with an altitude of 1382 m above sea level, during 2018-2019 crop year. The study was performed as a factorial experiment in a randomized complete block design with three replications. Factors were different planting dates at two levels of February 20 (spring planting) and November 1 (autumn planting) with five *Camelina* seed lines of 131, 132, 133, 80, and 114. Seedbed preparation for spring crops began and autumn crops on February 1 and mid-October, respectively, with a deep plow and two perpendicular discs to crush the lumps. Leveling operations were done using a leveler. After testing the soil and according to the plant needs, 40 kg/ha of nitrogen fertilizer from urea source and 30 kg/ha of phosphorus fertilizer from a triple superphosphate source were applied uniformly to the land for each planting date along with the disk operation. Besides, 20 kg/ha of urea as top-dress was applied to the land at the early flowering stage. *Camelina* seeds were planted manually in plots with 4 m long and 2.40 m wide with a row spacing of 20 cm. The plots were 50 cm apart, with a distance of was 100 cm between the blocks. The first irrigation was carried out immediately after planting and the subsequent irrigations during the growing season in order to prevent signs of stress in the plant. After ensuring the establishment of plants, a density of 100 plants m^{-2} (a distance of 4 cm on the row) was achieved by thinning additional *Camelina* plants at the 4-leaf stage. All weeds in the plots were weeded during the growing season. The stemborer larvae and moths, leaf borer larvae and moths, and wheat bug in May were controlled using diazinon at a rate of 5.1 per thousand at one time only for spring planting.

To obtain grain yield, plant dry weight, and extracted oil, an area of 1.0 m^2 per plot was bottom cut by considering the margin (0.5 on both sides). To determine the grain oil yield, 200 g of grains from each experimental unit was extracted using a compressing machine 100 by means of pencil meal method at 80 °C for 166 seconds and then calculated in kilograms per hectare by measuring the percentage of oil.

To calculate the amount of consumed water, a 20-L container was placed in the mouth of the irrigation pipe at the beginning of the plot followed by calculating its filling time. Then, the filling time of the plot was measured three times and the amount of water used from the irrigation per plot in each irrigation cycle was calculated based on the following equation:

$$\frac{20\times540}{35}=308.57 \text{ Lit} = V_2=\frac{V1\times T2}{T1}$$

where T1 and T2 are filling times (in seconds) of the container and the plot, respectively, and V1 and V2 are the amounts of water (in liter) filled in the container and the plot (the amount of water consumed per plot), respectively. After that, the amount of water entered the plot was multiplied by the plot area (9.6 m^2) and then divided by 1000 to convert it to cubic meters. Using the following equation, the amount of water consumption was calculated based on cubic meters per hectare.

Water consumption per plot = water consumption per cycle × 10,000 (m^2)/plot area (m^2)
= 0.31 × 10000/9.6 = 323 m^3/ha

Then, this value was multiplied by the performed irrigation cycles to calculate the amount of water consumed under applied irrigation. To calculate the amount of rainwater in cubic meters, the amount of rainfall (in ml) was converted to meters. Then, the circle area (cross-section) and the cylinder volume of a class A evaporation pan were calculated from the diameter (1.207 m) of the evaporation pan, multiplied by the amount of precipitation, and the volume of rainwater was obtained in cubic meters.

The cross-sectional area of evaporation pan = $A = \pi r^2 = 3/14 \times (1.207 \div 2)^2 = 1/14$

Rainwater volume = cross-sectional area of evaporation pan × rainfall (m)
Volume of rainfall in spring planting (2017) = 0.053 × 1.14 = 0.06 m^3 × 10,000 m^2/1.14 m^2 = 526.32 ha^{-1} m^3
Volume of rainfall in autumn planting (2018) = 0.295 × 1.14 = 0.34 m^3 × 10,000 m^2/1.14 m^2 = 2982.46 ha^{-1} m^3

All statistical analyses and regression calculations were performed using SAS software. Mean values were compared by Duncan's test at 0.01 significance. Figures and tables were drawn by Excel software.

RESULTS AND DISCUSSION

Grain yield

The comparison of mean grain yields (Table 1) indicates that grain yield decreased from 2226.67 kg/ha in autumn to 1249.33 kg/ha in the spring crop.

Hocking and Stapper (2001) and Miralles et al. (2001) attributed reduced grain yield and plant growth to delayed sowing date and reported that dropped grain yield to be because of the shortened canola growth period and declined synthesis of photosynthates transferred to seeds [23, 24]. Berti et al. (2011) observed that the effect of *Camelina* planting date and cultivars, as well as grain yield components (e.g. 1000-grain weight), had significant effects on grain yield [3].

The lines studied in this experiment were significantly different in terms of quality so that the highest (2120 and 1967.67 kg/ha, respectively) average grain yields were observed in lines 114 and 131, whereas lines 80, 132, and 133 had lower levels of grain yield (Table 1).

According to the comparison of mean interactions between the tested lines and planting dates, the highest average grain yields were recorded in autumn planting of lines 114 and 131 (2843.33 and 2373.33 kg/ha, respectively) and in spring planting of lines 131 and 114 (1560 and 1396.67 kg/ha). Line 133 had the lowest average grain yields in autumn (1903.33 kg/ha) and spring (1156.67 kg/ha) planting seasons (Table 2 and Fig. 1).

Table 1: Comparison of mean values of studied traits in five *Camelina* lines

Factors	Yield ($kg.ha^{-1}$)			Oil (%)	WUE Based on grain yield ($kg.ha^{-1}.m^{-3}$)
	Grain	Biological	Oil		
Planting Date					
Spring (20 Feb)	1249.33 b	3275.33 b	343.47 b	27.53 b	0.49 a
Autumn (1 Nov)	2266.67 a	5184.00 a	666.27 a	29.53 a	0.37 b
Seeding Line					
L 131	1966.67 a	4688.3 a	543.83 ab	28.17 a	0.50 a
L 132	1571.17 b	3551.5 c	480.17 b	29.83 a	0.38 b
L 133	1530.00 b	4171.7 b	421.33 b	26.50 a	0.38 b
L 80	1602.17 b	3908.3 bc	464.17 b	29.17 a	0.38 b
L 114	2120.00 a	4828.5 a	614.83 a	29.00 a	0.50 a

Means with at least one similar letter in each column do not differ significantly (Duncan 1%)

Biological yield

The comparison of mean biological yields (Table 1) showed that autumn planting led to a significant increase (5184 kg/ha) compared with spring planting (3275.33 kg/ha), indicating that this trait decreased by 63% in spring compared to autumn planting season (Table 1). Kirkland and Johnson (2000) reported that autumn planting increased the straw yield of different rapeseed cultivars by 51-126% compared to spring planting [25].

Among the cultivars, the highest biological yield belonged to lines 114 and 131 (4828.5 and 4688.3 kg/ha, respectively), which seems to be natural considering a high grain yield (Table 1). Based on the comparison of mean interactions of planting season and the tested lines, line 114 had the highest biological yield in autumn and spring planting seasons, which was quite similar to the results of grain yield (Table 2 and Fig. 1). This can be attributed to a positive and significant correlation between biological yield and grain yield, which was also mentioned by Robertson et al. (2004) [26].

The examined *Camelina* lines apparently produced higher dry matter in autumn than in spring planting season by the use of a prolonged growing period and more optimal environmental conditions. On the other hand, the lines planted in spring had a shorter growth period and also dealt with the end-season heat, drought, and more unfavorable environmental factors, showing different reactions regarding the synthesis of photosynthates and consequently dry matter, as reported by Berti et al. (2011) as well [3].

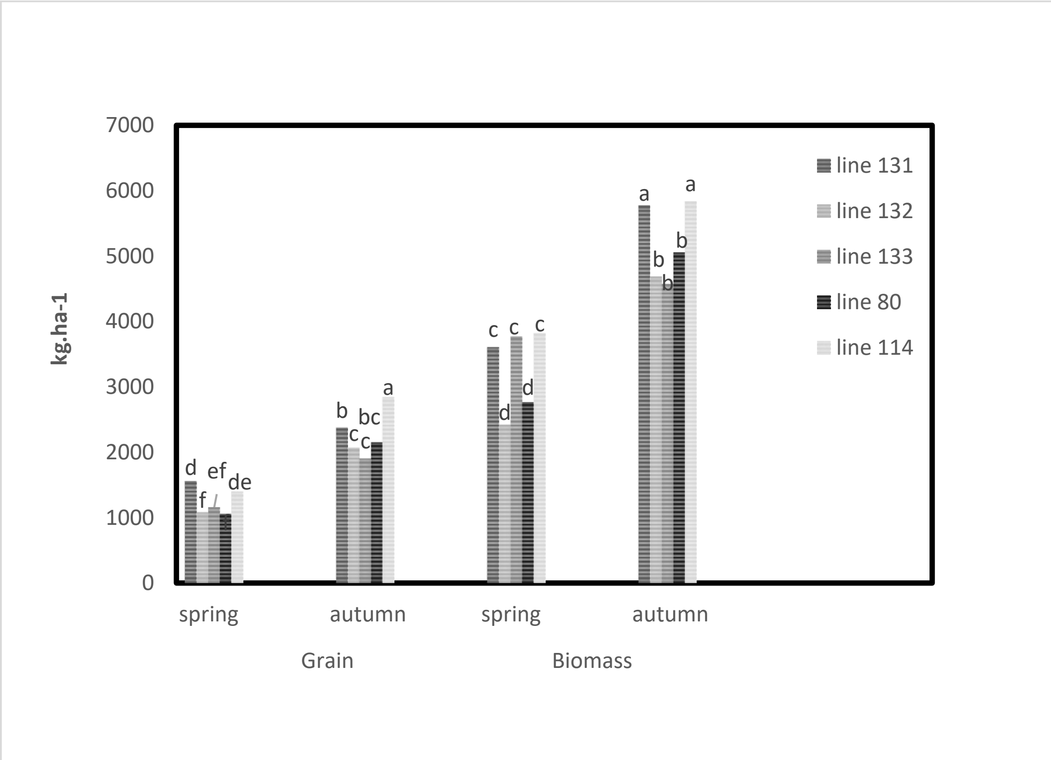

Fig1. Comparison of grain and biological yields for different *Camelina* lines in spring and autumn crops

Oil yield

Autumn and spring crops were different significantly with average oil yields of 666.27 and 344.47 kg/ha, respectively (Table 1). The reason for this is probably due to the coincidence of the grain-filling period with higher temperatures in spring than in autumn planting, which corresponds to those of Robertson et al. (2004) and Shirani et al. (2013) in rapeseed [26, 27]. The average oil yield of *Camelina* is 420-640 L/ha and protein and fiber contents in its products are comparable to those of soybean meals [28, 29].

In this study, lines 114 and 131 contained the highest average oil yields (614.83 and 543.83 kg/ha, respectively) without significant differences. There was no significant difference between lines 131 and 132, 133, and 80. Line 133 had the lowest average oil yield (421.33 kg/ha) (Table 1).

Comparison of mean interactions between planting seasons and tested lines revealed that lines 114 and 131 contained the highest average oil yield in autumn (830.33 kg/ha) and spring (466 kg/ha) crops, respectively. Lines 131, 132, 133, and 80 did not differ significantly and in autumn planting. Besides, oil yields were not different significantly in lines 131 and 114 as well as in lines 132, 133, and 80 in spring planting season (Table 2).

Therefore, the higher oil yield in the tested lines can be considered to be proportional to the increased grain yield. Waldiani and Tajbakhsh (2008) also reported that rapeseed cultivars with superior grain yields would also have higher oil yields [30].

Obour et al. (2017) found no significant differences in oil content between *Camelina* genotypes and differences were observed in oil yields per year and study site [31].

Grain oil content

The autumn crop contained 2% higher oil content than the spring crop and no significant differences in oil content were observed between the experimental lines (Table 1). Comparison of mean interactions between planting season and experimental lines showed that average grain oil content (29%) was desirable in spring and autumn crops of lines 114 and 80 without significant differences. Line 131 contained the lowest (26%) and the highest (30.3%) average grain oil levels in autumn and spring crops, respectively. Furthermore, the highest (32.3%) and the lowest (22%) average percentages of oil belonged to lines 132 and 133 in autumn and spring, respectively (Table 2). Studies by Kirkland and Johnson (2000) indicated that rapeseed oil content was 5 to 20% higher in autumn than in the spring planting date [25]. The percentage of oil was found to be influenced by genetic factors and if there was no end-season stress, the percentage of grain oil would remain constant in each cultivar.

Grain yield based on water consumption

The average water use efficiency (WUE) on grain yield decreased in the autumn crop (0.37 kg/ha/m^3) compared with the spring crop (0.49 kg/ha/m^3). Among the experimental lines, there was no significant difference between L 131 and L 114 and both were significantly superior to lines 132, 133, and 80, which were also at the same level without significant differences (Table 1). Comparison of the mean interactions between planting seasons and experimental lines revealed that average WUE values on grain yield were uppermost in L 131 (0.6 kg/ha/m^3) and L 114 (0.54 kg/ha/m^3) in spring and autumn crops, respectively. The lowest average WUE values on grain yield were recorded in L 80 and L 133 in autumn (0.41 kg/ha/m^3) and spring (0.31 kg/ha/m^3) crops, respectively.

Hergert et al. (2011) stated that different rainfall levels provided excellent conditions for the development of production factors with moderate rainfall in drought and increased the yields of *Camelina* and rapeseed [32]. They also reported that about 5 inches of water were needed to produce *Camelina* and that *Camelina* grain yield increased 150-160 pounds with each inch of irrigation. Besides, 1.8 and 7.20 inches of water were used to increase *Camelina* grain yield by 520-2560 pounds per hectare, respectively. Maximum grain yields were 2500-2300 and 1200-500 pounds per hectare with maximum irrigation and without irrigation (rainfed), respectively.

Table 2. Comparison of the means of the interaction of different *Camelina* lines and planting dates

Seed line	Yield (kg.ha^{-1})									
	Grain		Biological		Oil		Oil (%)		WUE based on grain yield (kg.ha^{-1}.m^{-3})	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
L 131	1560.00 d	2373.33 b	3606.3 c	5773.3 a	466.00 c	621.67 b	30.3 ab	26.0 c	0.60 a	0.39 cde
L 132	1079.00 f	2063.33 c	2419.7 d	4683.3 b	296.67 d	663.67 b	27.3 bc	32.3 a	0.42 bc	0.34 ef
L 133	1156.67 ef	1903.33 c	3770.0 c	4573.3 b	254.00 d	588.67 b	22.0 d	31.0 ab	0.45 bc	0.31 f
L 80	1054.33 f	2150.00 bc	2763.3 d	5053.3 b	301.33 d	627.00 b	29.0 abc	29.3 abc	0.41 bcd	0.35 def
L 114	1396.67 de	2843.33 a	3820.3 c	5836.7 a	399.33 c	830.33 a	29.0 abc	29.0 abc	0.54 a	0.46 b

Means with at least one similar letter in each column do not differ significantly (Duncan 1%)

CONCLUSION

There were significant positive correlations between the measured traits, namely grain yield, biological yield, oil yield, percentage of extracted oil, and grain yield based on water consumption. These traits were affected significantly by planting dates so that they decreased significantly in spring crops compared with autumn crops, except for grain yield based on water consumption. The highest grain yield, biological yield, and oil yield belonged to L 114 in autumn planting, although it was not different statistically from L 131. No significant differences were observed in the experimental lines in percentages of extracted oil in the spring planting date, which can be attributed to the genetic traits of the lines. A comparison of the mean interactions between lines and planting dates showed that L 114 contained the highest grain yield, biological yield, and oil yield in the autumn crop. These traits decreased significantly in the lines in the spring crop, except for grain yield based on water consumption.

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