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REGULAR ARTICLE

Effect of plant density on yield and physiological characteristics of six canola cultivars

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Abstract

An experiment was performed in the Seed and Plant Improvement Institute, Karaj, Iran to study the influence of plant densities on physiological traits of six canola cultivars. Treatment conditions included three different plant densities (40, 60, and 80 plants m-2) for triplicates of six canola cultivars, namely, Ahamadi, Opera, Okapi, L72, Karaj1, and Sw102. Results indicated that L72 cultivar exhibited the highest yield at the lowest plant density (40 plants m-2). For all cultivars, both plant densities of 60 and 80 plants m-2 resulted in lower relative water content than 40 plants m-2. Proline and carbohydrate content significantly increased with increasing plant densities. The highest proline content was obtained from L72 under the highest plant density, whereas the lowest was also detected in this cultivar at the lowest plant density. All cultivars grown at the lowest density showed higher amounts of photosynthetic pigments chlorophylls a and b than those at the highest density. Glucosinolate increased with increasing plant densities, with L72 yielding the highest quantity when grown at the highest density. In conclusion, a density of 40 plants m-2 is recommended for growing L72 in this region.

Key words: Chlorophyll, glucosinolate, plant density, proline, rapeseed, yield

Introduction

Canola is the second edible oil resource in the world with high seed oil and lowest saturated fatty acid among oilseed crops (Raymer, 2002; Shahsavari et al., 2014). Canola oil has higher nutrient value than other oilseeds due to its high unsaturated fatty acid content (Naseri et al., 2012; Shahsavari and Dadrasnia, 2016).

Using suitable cultivars that match the climate conditions and choosing ideal plant density with minimum competition among plants are methods of increasing seed yield. Previous studies showed that plant density plays an important role in canola yield and a uniform distribution is required for yield stability (Diepenbrock, 2000). Plant density had significant effect on number of pod, secondary branch, and seeds per plant

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(Salehian et al., 2002; Ozone Davaji et al., 2008). The same researcher reported that the maximum number of pod and seeds per plant was observed at 50 plants m^{-2}. Also, Naseri et al. (2012) showed the highest canola seed yield (3636.6 kg h^{-1}) and oilseed yield (1603.4 kg h^{-1}) was from Hyola 401 at 60 plants m^{-2}. Ozer (2003) suggested that seed yield was affected by the spacing between rows. Leach et al. (1999) also reported that plant density had no influence on seed oil, but more branches and fewer pod-bearing branches per plant were produced at the highest plant density. Similarly, Al-Barzinjy et al. (1999) concluded that seed weight and pods per plant decreased with increasing plant density. Prasad and Shakla (1991) found that the highest seed yield could be achieved by increasing plant density and nitrogen levels.

Proper density is the best means of improving crop yield and water use efficiency in plants. This study aims to evaluate effects of different plant densities on seed yield, photosynthetic pigments, and relative water content (RWC) of six canola cultivars in Iran and to select the best cultivar and density in this region.

Materials and methods

Outdoor experiments were conducted in 2014 and repeated in 2015 under identical conditions in the Seed and Plant Improvement Institute (35°59′N, 51°6′E; 300 m), Karaj, Iran. The study was designed as a factorial experiment based on a complete block design to evaluate effects of different plant densities on physiological traits of six canola cultivars, namely, Ahamadi, Opera, Okapi, L72, Karaj1, and Sw102. Treatment conditions comprised three plant densities (40, 60, and 80 plants m-2) for triplicates of six canola cultivars.

Each plot consisted of four lines (5 m), and each plot measured 6 m2. Soil texture was clay-loam with electrical conductivity, pH, organic carbon percentage, total N, total P, Fe, Zn, and Cu of 2.22, 7.24, 0.58%, 0.06, 12.6, 5.02, 0.32, and 1.47, respectively. Seeds were obtained from the Oil Seed Research Department of Seed and Plant Improvement Institute (Karaj, Iran) and were planted manually. Urea (46% N) was applied thrice at 350 kg h^{-1} (1/3 planting time, 2/3 before flowering), and triple superphosphate (46% P_2O_5) was applied at 50 kg h^{-1}. Irrigation was performed regularly. At the end of plant maturity, plants were harvested to measure seed yield, seed oil, and fatty acid composition.

Fatty acids composition of was determined by gas liquid chromatography (GC). The chlorophyll (chl) concentration in leaf was determined according to the method of Hiscox and Israeltem (1979).

Relative water content (RWC) was calculated according to the method of Ritchie and Nguyen (1990).

Proline content was measured by spectrophotometer (V-530, JASCO, Japan) at 520 nm (Bates et al., 1973).

The study was conducted thrice as a factorial split-plot experiment based on a complete block design. Data set was analyzed using SAS software. All data were subjected to two-way analysis of variance (ANOVA), and means were compared for significance using the least significant difference test at $p < 0.05$.

Results

ANOVA showed that simple and interaction effects of plant density and cultivars significantly affected seed yield, stomata resistance, canopy temperature, proline and glucosinolate content, RWC, and chlorophylls a and b at P = 0.01 (Table 1).

Table 1. Summary of combined F significance from analysis of variance.

S.V	df	RWC	Proline	Carbohydrate	Chl a	Chl b	Total Chl	Stomata resistance	Canopy temperature	Seed yield	Glucosinolate
D	2	3687**	2318.04**	7882.4**	9.7**	0.26**	13.1**	43.85.4**	365.5**	240464610**	782.2**
Cv	5	132.2**	69.2**	223.8**	0.27**	0.009**	0.4**	135.2**	11.55**	7233759**	24.4**
D * Cv	10	41.6**	21.9**	95.1**	0.1**	0.003**	0.14**	40**	5.2*	2697107**	6.4**
CV		3.9	7.2	5.5	6	7.2	4.97	6	5.17	8.4	8.7

Note: ns: Non-significant, * Significant at 5%, and ** Significant at 1%; D: Density, C: Cultivar

Seed yield significantly decreased in both 60 and 80 plant/m2 in comparison with that in 40 plants m-2 (Table 2). Stomata resistance, canopy temperature, proline, and glucosinolate improved with increasing plant densities. RWC and chlorophylls a and b significantly decreased at 60 and 80 plants m-2 (Table 2). As shown in Table 3, the Ahmadi cultivar featured the highest seed yield, whereas Karaj1 and Opera cultivars exhibited the lowest.

Ahmadi, L72, and SW102 cultivars showed the highest RWC, whereas Opera and Karaj1 presented the highest stomata resistance and canopy temperature. Glucosinolate and proline significantly increased in Okapi, Opera, and Karaj1 cultivars. The highest carbohydrate yield was detected in Opera and Karaj1 and the lowest in Ahmadi. Highest level of chlorophyll a was obtained in Ahmadi, whereas the lowest was present in Opera and Karaj1 cultivars. Ahmadi, L72, and SW102 cultivars yielded the highest levels of chlorophyll b (Table 3).

Seed yield significantly decreased with increasing plant density, and L72 featured the highest and lowest seed yield under the lowest and highest densities, respectively (Table 4).

Table 2. Mean comparisons of plant density on yield and physiological characteristics.

Plant densities	Seed yield	RWC (%)	Stomata resistance (mmol CO_2 m^{-2} s^{-1})	Canopy temperature (℃)	Glucosinolate (%)	Proline	Carbo-hydrate	Chl a	Chl b
						(mg g^{-1} FW)			
40	63377a	91.1a	8.3c	27.3c	8.7c	12.6c	26.6c	1.5a	0.4a
60	4233b	83.2b	16.9b	29.5b	12.2b	18.7b	34.4b	1.1b	0.3b
80	2741c	76.8c	23.8a	31.8a	15.3a	23.9a	47.5a	0.7c	0.25c

Mean values with different letter **(**s**)** across treatments are significantly different at $p < 0.05$

Table 3. Mean comparisons of canola cultivars on yield and physiological characteristics.

Cultivar	Seed yield	RWC (%)	Stomata resistance (mmol CO_2 m^{-2} s^{-1})	Canopy temperature (℃)	Glucosi nolate (%)	Proline (mg g^{-1} FW)	Carboh ydrate (mg g^{-1} FW)	Chl a (mg g^{-1} FW)	Chl b (mg g^{-1} FW)
Ahmadi	5065a	86.07a	13.65d	28.64c	10.92c	16.42c	32.96e	1.24a	0.33a
Okapi	4225c	82.37b	17.61b	29.76ab	12.56a	19.24a	38.16b	1.06c	0.30b
Opera	3990d	81.90b	18.10a	30.08a	12.87a	19.69a	39.22a	1.03d	0.29b
L72	4700b	85.34a	15.14c	29.41ab	11.61b	17.58b	36.29c	1.16b	0.32a
Karaj1	3983d	81.72b	18.37a	30.04a	12.95a	19.81a	39.30a	1.03d	0.29b
SW102	4739b	84.78a	15.21c	29.09bc	11.60b	17.58b	35.33d	1.15b	0.32a

Mean values with different letter (s) across treatments are significantly different at $p < 0.05$.

Table 4. Interaction effects of plant density and cultivar on yield and physiological characteristics.

Plant density	Cultivars	Chl b (mg g^{-1} FW)	Chl a (mg g^{-1} FW)	Leaf carbohydrate (mg g^{-1} FW)	Leaf proline (mg g^{-1} FW)	Glucosinolate (%)	RWC (%)	Canopy temperature (°C)	Stomata resistance (mmol CO_2 m^{-2} s^{-1})	Seed yield
40	Ahmadi	1.5	0.4	25.2	11.6	8.1	92.0	26.9	6.9	6712.6
	Okapi	1.4	0.4	28.0	13.6	9.3	89.3	27.7	9.7	6032.0
	Opera	1.4	0.3	28.9	14.1	9.7	88.7	27.9	10.4	5777.3
	L72	1.6	0.4	23.7	10.6	7.5	94.8	26.4	5.5	7167.9
	Karaj1	1.4	0.3	29.4	14.4	9.9	88.4	28.0	10.9	5620.8
	SW102	1.6	0.4	24.5	11.1	7.8	93.1	26.7	6.2	6950.8
60	Ahmadi	1.3	0.33	31.3	15.7	10.6	87.1	28.4	12.8	5087.2
	Okapi	1.0	0.28	39.7	20.5	13.1	80.8	30.1	19.6	3745.5
	Opera	1.0	0.28	39.1	20.2	13.0	81.2	30.0	19.0	3785.9
	L72	1.3	0.33	32.2	16.4	11.0	86.4	28.7	13.7	4912.0
	Karaj1	0.9	0.28	40.3	20.8	13.4	80.4	30.2	20.0	3666.9
	SW102	1.1	0.30	36.2	18.6	12.3	83.6	29.4	16.6	4200.6
80	Ahmadi	0.88	0.27	42.4	21.9	14.0	79.1	30.6	21.3	3395.1
	Okapi	0.77	0.25	46.7	23.7	15.2	77.0	31.5	23.6	2896.5
	Opera	0.70	0.24	49.7	24.7	15.9	75.8	32.3	24.8	2408.0
	L72	0.63	0.23	52.9	25.8	16.3	74.8	33.1	26.2	2020.8
	Karaj1	0.74	0.25	48.2	24.2	15.6	76.4	31.9	24.3	2661.0
	SW102	0.81	0.26	45.3	23.1	14.8	77.6	31.2	22.9	3066.5

Mean values with different letter **(**s**)** across treatments are significantly different at $p < 0.05$.

Stomata resistance and canopy temperature of all studied cultivars increased at both plant densities of 60 and 80 plants m^{-2}. High plant densities negatively affected on RWC such that RWC decreased both under 60 and 80 plants m^{-2}. The lowest glucosinolate content indicates better oil quality. At the lowest density, L72 yielded the lowest glucosinolate content. As expected, leaf proline levels increased with increasing plant densities. Carbohydrate levels also increased with increasing plant density in all cultivars, with L72 grown at 80 plants m^{-2} yielding the highest amount of carbohydrate. Photosynthetic pigments chlorophylls a and b significantly declined at the highest density. L72 grown at 40 and 80 plants m^{-2} produced the highest and lowest amounts of chlorophyll a, respectively (Table 4).

Discussion

Guerfel et al. (2010) showed that RWC of olive increased when plant densities decreased from 156 trees ha^{-1} to 51 trees ha^{-1}. Our study showed that RWC in all samples of canola cultivars significantly decreased with increasing plant densities, and this result may be a consequence of competition of plants for absorbed water in soil. Rafiee (2012) showed that plant density posed no significant effect on chlorophyll and proline levels of corn. Results showed increased chlorophyll a levels at high density and decreased quantities of chlorophyll b and proline. Low penetration of light at high plant density may cause decrease in chlorophyll.

Similar to our results, proline content in sorghum leaves increase under increasing plant densities (Alderfasi et al., 2016). In our study, proline content of canola leaves increased with increasing plant density (80 plants m^{-2}). This phenomenon may result from tight competition of plants for water, light, and nutrient under high plant density, thus increasing the amount of proline.

Reta-Sanches and Fowler (2002) suggested that changing plant densities and increasing light penetration in lower parts of the canopy can improve plant yield. In the present study, seed yield decreased with increasing plant densities (60 plants m^{-2}) for all canola cultivars, which possibly resulted from reduction of light penetration under high plant densities. Naseri et al. (2012) indicated that sunlight absorption and photosynthetic production decreased under thicker plant density (80 plants m^{-2}) due to competition among plants. In our study, reduction in photosynthetic pigments, such as chlorophylls a and b, lowered seed yield when plant density was increased to 60 plants m^{-2}.

Similar to our results, Larry et al. (2002) observed that increasing plant density decreased plant seed yield. In contrast to our results, James and Anderson (1994) reported that seed yield improved from increasing plant densities through raising pod m^{-2}. This difference may be attributed to variations between cultivars and densities in both studies.

Conclusion

The present study indicated that plant density significantly affects all physiological traits and poses an advantageous effect on seed yield by elevating photosynthetic pigment levels and RWC with increasing sunlight absorption. Different cultivars yielded different responses to plant densities, and canola L72 cultivar featured the highest yield because of its highest levels of chlorophylls a and b and RWC and its lowest proline content, stomata resistance, and canopy temperature. Among canola cultivars, L72 cultivar exhibited the lowest glucosinolate content under the lowest plant density. Based on these results, growing canola L72 cultivar at a plant density of 40 plants m^{-2} can be employed to improve canola yield, especially in regions similar to Karaj, Iran.

Authors' contributions

A. Nasiri conducted the study and prepared the manuscript. M. Samdaliri and A. Shirani Rad supervised all the research activities and criticized the manuscript. N. Shahsavari contributed to correction and manuscript preparation. A. Mosavi Mirkale and H. Jabbari contributed to experiment design and samples collection.

Reference

Al Barzinjy, M., Stolen, O., Christiansen, J.L. & Jensen, J.E. (1999). Relationship between plant density and yield for two spring cultivars of oilseed rape (*Brassica napus* L.). *Acta Agriculturae Scandinavica, Section B- Soil and Plant Science,* 49, 129–133.

Alderfasi, A., Selim, M. & Alhammad, B. (2016). Evaluation of plant densities and various irrigation regimes of sorghum

(*Sorghum bicolor* L.) under low water supply. *Journal of water resource and protection*, 8, 1-11.

Bates, L., Waldren, R.P. & Teare, I.D. (1973). Rapid determination of free proline for water-stress studies. *Plant and Soil,* 39, 205-207.

Diepenbrock, W. (2000). Yield analysis of winter oilseed rape. A review. *Field Crops Research*, 67, 35-49.

Guerfel, M., Ouni, Y., Boujnah, D. & Zarrouk, M. (2010). Effects of the planting density on water relations and production of 'Chemlali' olive trees (*Olea europaea* L.). *Trees*, 24, 1137-1142.

Hiscox, J.D. & Israelstam, G.F. (1979). A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany,* 57, 1332-1334.

James, S.B. & Anderson, N.J. (1994). Dry matter accumulation nitrogen, potassium and plant density on yield, oil and yield in spring oilseed rape. *Pakistan Journal of Agricultural Research*, 8(2), 143-149.

Larry, C.P., Rosalind, A.B., Reaper, J.D. & Earl, D.V. (2002). Radiation use efficiency and biomass production in soybean at different plant population densities. *Crop Science,* 42, 172-177.

Leach, J.E., Stevenson, H.J., Rainbow, A.J. & Mullen, L.A. (1999). Effects of high plant populations on the growth and yield of winter oilseed rape (*Brassica napus* L.). *The Journal of Agricultural Science,* 132, 173-180.

Naseri, R., Kazemi, E., Mahmoodian, L., Mirzae, A. & Soleymanifard, A. (2012). Study on effect of different plant density on seed yield, oil and protein content of four canola cultivars in western Iran. *International Journal of Agriculture and Crop Sciences,* 4(2), 70-78.

Ozer, H. (2003). The effect of plant population densities on growth, yield and yield components of two spring rapeseed cultivars. *Plant, Soil and Environment*, 49(9), 422–426.

Ozone Davaji, A., Esfahani, M., Sami Zade, H. & Rabiei, M. (2008). Effect of planting pattern and plant density on seed yield and its components of apetalous flowers and petalled flowers rapeseed cultivars. *Iranian Journal of Crop Science*, 9(1), 60-76.

Prasad, S. & Shakla, D.N. (1991). The response of nitrogen and plant population on yield, percent of oil seed of rapeseed (*Brassica napus* L.). *Canadian Journal of Plant Science,* 38, 283-291.

Rafiee, M. (2012). Effect of every other furrow irrigation and planting density on physiological traits in corn (*Zea mays* L.). *World Applied Sciences Journal,* 17(2), 189-193.

Raymer, P.L. (2002). Rapeseed: an emerging oilseed crop. In: trends in new crops and new uses, Janick J, Whipkey A. ASHS press, Alexandrina. VA. pp. 122-126.

Reta-Sanches, G.D. & Fowler, J.L. (2002). Canopy light environment and yield of narrow-row cotton as affected by architecture. *Agronomy Journal*, 94, 1317-1323.

Ritchie, S.W. & Nguyen, H.T. (1990). Leaf water content and gas exchange parameters of two wheat genotypes differing in drought resistance. *Crop Science,* 30, 105-111.

Salehian, H., Rafiey, M., Fathi, G. & Siadat, S.A. (2002). Effect of plant density on growth and seed yield of colza varieties under andimeshk conditions. Proc. 7th Iranian Crop Sciences Congress. Karaj, Iran.

Shahsavari, N. & Dadrasnia, A. (2016). Effect of zeolites and zinc on the physiological characteristics of canola under late-season drought stress. *Communications in soil science and plant analysis*, 47(18), 2077-2087.

Shahsavari, N., Jais, H.M. & Shirani Rad, A.H. (2014). Effect of zeolite and zinc on the biochemical characteristics of canola upon drought stress. *Sains Malaysiana*, 43(10), 1549-1555.