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Oil content, seed yield and morphological changes of canola cultivars in response to different sowing dates

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ABSTRACT

Sowing date affects different plant growth stages, however, information on optimum sowing date for successful production of canola is limited. Therefore, a field experiment was carried out to evaluate the response of canola cultivars to different sowing dates. Sowing dates included 2, 12 and 22 October, and cultivars were included 11 cultivars (Okapi, Opera, Zarfam, Talaye, SW102, L72, L14, HL3721, Wpn-6, L155 and HL2012). The highest oil percentage was recorded in the first sowing date in L72 (41.093%) followed by L155 and Zarfam. Delaying in sowing date until October 22 reduced 33.59% of seed yield in each year in comparison with the first sowing date. The decline in seed weight due to delayed sowing resulted in significant seed yield reduction in 2014-15 (7.69%) and in 2015-16 (14.8%). Generally, it seems L72, Zarfam and L155 canola cultivars are suggestible in first sowing date due to the best agronomic traits.

Key words : Canola, growth, oil content, seed yield, sowing date

INTRODUCTION

Canola is a specific edible type of rapeseed genus, introduced in 1970s, which contains about 35-40% oil. The term "canola" is a registered and formal name by the Western Canadian Oilseed Crushers Association. Canola varieties must have the minimum of the acid erucic amount less than 2-3% and the least of glucosinolates about 30 micromoles of per gram of seed canola. This makes it acceptable as an edible oil and animal and human protein feed. Canola oil is considered one of the unique quality edible oils available throughout the world (Kandel and Knodel, 2011). It has been the second greatest oil crop after soybean in the world in just two decades (FAO, 2014). Recent rapid increase in production of canola is associated with increase in demand for oil feed (as the healthy oil for human use) and meal for animal feed (USDA, 2013). It is notable to mention that the interaction of environmental and genotypic agents affects the quality and quantity of canola seed oil (Hamrouni *et al.,* 2001).

It is very beneficial to introduce canola cultivars with high levels of oil via simple agronomical practices (Begna and Angadi, 2016). Furthermore, it is worth to note that a large part of oil seeds for human consumption in Iran is imported into the country, so cultivation and appropriate management of edible oil to increase yield is very important and even necessary (Khayat *et al.,* 2015). Both genotypic (cultivars) and environmental parameters (sowing dates) determine the quality and amount of canola oil (Omidi *et al.,* 2010). Among the environmental and natural agents affecting the concentration of canola oil, temperature and growth period (sowing date) are the main important factors, decreasing the oil per cent in seed if they are not enough (Anastasi *et al.,* 2010). Sowing date is one of the main agent and manageable agronomic practices that affected dry matter production, growth and oil yield (Wang *et al.,* 2012). Accordingly, in order to produce good quality canola seeds with a high content of oil, it is

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necessary to manage both the genotypic (including the breeding and selection of good varieties) and environmental parameters (including tillage practices, sowing date and fertilization), properly (Dmytryshyn *et al.* 2004).

The sowing window for canola in the Karaj (Alborz province, Iran) is a wide-ranging from Late-September to Late-October. Good and high emergence seedling in winter crops is not a guarantee for the final good plant stand since final plant stand is determined by spring not fall plant stand, and this, in turn, can be affected via weather and cultural practices including sowing date (Robertson *et al.,* 2004). Si and Walton (2004) suggested that a combination of an early sowing date would be essential for the production of high seed yield and quality in the lower rainfall area.

Since Iran is facing a large deficit of edible oil, in view of the importance of this crop, we are able to increase the yield of canola, it will mitigate the oil deficiency of our country. Thus, the main objective of this study was to determine a relationship between yield potential of 11 canola cultivars and three sowing dates in Karaj province conditions, Iran.

MATERIALS AND METHODS

Experimental Site, Soil and Climate

The study was conducted at the Seed and Plant Research Institute in Meshkin-Dasht, Karaj, Iran (35° 50′ 8″ N latitude, 51° 0′ 37″ E longitude and M. S. L 1300 m). Physical features and soil characteristics of the site have been reported in Table 1. Growing season weather data were collected from a National Weather Service Station located at the Agricultural Science Center at Karaj, Iran. Precipitation was not adequate in both the growing seasons (total precipitation from sowing to final harvest was only 19 and 17 mm for 2014-15 and 2015-16 growing seasons, respectively). Irrigation was terminated on 18 May and 4 June, respectively, in 2014-15 and 2015-16 growing seasons.

Based on Koppen classification, the region could be classified as warm and semi-arid Mediterranean climate. This type of climate is concomitant with hot-dry summers and cold-wet winters, with the amount and pattern of rainfall and temperatures fluctuating widely from year to year. Generally, the rainfed cropping season usually begins from September to November and extends to April-May in both the years.

Treatments and Irrigation

The field experiment was laid out in a factorial based on randomized complete block design with three replications. The three sowing dates were D_1 : 2 Oct. as early-Oct., D_2 : 12 Oct. as mid-Oct. and D_3 : 22 Oct. as late-Oct. The cultivars were 11 canola cultivars. The canola cultivars were selected based on yield potential, flowering/maturity groups and seed yield (Table 2).

Table 2. Canola cultivars used in the experiments during 2014-16

S. No.	Line	Origin
1.	Okapi	France
2.	Opera	Sweden
3.	Zarfam	Iran
4.	Talaye	Germany
5.	SW102	Iran
6.	L72	Iran
7.	L14	Iran
8.	HL3721	Iran
9.	Wpn-6	Iran
10.	L155	Iran
11.	HL2012	Iran

The previous crop for both the growing seasons was maize. Prior to begging to sow, some soil samples were taken at a depth of 0-15 and 16-30 cm from different places of fields, and according to soil test data, fertilization was applied. The field preparation, fertilization and chemical weeding were conducted in the mid-August of each year. In both the years, herbicide treflan (trifluralin) at the rate of 2.4 l/ha was applied before sowing to weed control. Hand-hoeing was also done as needed before

Table 1. Basic characteristics and nutrition status of soil and total element contents in experiment

Soil depth (cm)	Soil type	Zn (mg/kg)	Fe (mg/kg)	EC (dS/m)	pH	C_{org} (%)	P (ppm)	K (ppm)
0-30	Loamy-sandy	1.2	7.8	1.43	8.1	1.03	26.6	330

Available nutrients were determined in extracts obtained by Mehlich III procedure.

sowing. P and K were preplant-incorporated to supply 60 kg P_2O_5/ha and 100 kg K_2O/ha from triple super phosphate and potassium sulfate, respectively. N was applied at 150 kg N_2 (as urea)/ha, that a third of this amount was applied preplant, a third of that was side-dressed at beginning of stem elongation and the rest at the beginning of flowering growth stage. Surface irrigation was performed twice at seeding, with a 10-day interval, to let the seeds grow at their highest germination. The field was also irrigated at stemming and flowering stages along with N fertilization, and twice at the pod producing and grain filling stages. Plants were thinned at the 6-leaf stage.

In both the years, canola cultivars were planted into a conventionally tilled seedbed under syphon irrigations. The row spacing was 30 cm with a plot having six rows, each row was 80 cm. Canola cultivars were planted at the seeding rate of (kg/ha) in both the years and based on the recommended seeding rate for canola production in this region. The size of each plot was 3 × 3 m with samples taken from the inner 2 × 2 m of each plot. Each treatment was harvested three times (i. e. H_1, H_2 and H_3) according to sowing date when 75% of the seeds in the main pods and primary branches turned brown. $Harvest_1$ was 170 days after sowing, H_2 was five days after H_1 and H_3 was six days after H_2. Each plot was harvested manually by cutting canola ripen plants with a sickle ~10 cm above ground level.

Growth Analysis and Yield

Duplicates of 500 g of representative samples were to determine 1000-seed weight and kept for chemical analysis. Before harvest, the height of plant was measured from two random lines of each plot. Pod number per main stem and seed number per main pod were calculated and recorded. After harvesting, the oil content was determined by Ghadge and Raheman (2005) method.

The phenological observations were recorded as described by Harper and Berkenkamp (1975). The flowering and seed filling periods were considered as the number of days between the beginning of the flowering stage to the end of it, and between the beginnings of seed filling stage to the end of it, respectively. The average temperature was calculated as the sum of the daily temperatures divided by the number of days during the period.

Analysis of Fatty Acid Composition

Oil from seed was extracted in hexane in a soxhlet apparatus (Extraction unit, E-816, Buchi). Methyl esters were obtained by a two-step catalytic process according to the method of Ghadge and Raheman (2005). The extracted oil (100-150 mg) was treated with 2% sulphuric acid in methanol (5 ml) for 2 h at 60°C. After the reaction, the mixture was allowed to settle for one hour and methanol-water mixture separated and the top was removed. In the second step, product at the bottom was transesterified using 2 ml of 13% methanolic KOH for 30 min at 55°C. The organic phase was extracted with hexane and washed with water till neutral pH. The hexane was dried over anhydrous sodium sulfate and concentrated with nitrogen to get methyl esters.

Data Analysis

Statistical analysis was performed using SAS 9.2 through PROC MIXED procedures to detect the significant differences between treatments. Significance was considered at $P<0.05$ and protected Duncan was obtained using the statement in the LSMEANS option within SAS PROC MIXED to decide where differences occurred within significant interactions.

RESULTS AND DISCUSSION

In this study, we evaluated the response of canola cultivars to different sowing dates during two years (2014-15 and 2015-16). Our results demonstrated that the canola cultivars in all sowing dates were significantly different in seed yield, oil content as well as growth parameters in both the years, indicating the extended genetic diversity in the material selection for this study. The significant varieties proved an interaction between cultivars and sowing dates. The results revealed that there was a significant difference in the performance of cultivars from one sowing date to another and in each year.

Plant Height

The significant variation in the plant height was observed due to different sowing dates (Figs. 1 and 2). The highest plant height was obtained in 2 October sowing date in the second year (147.44 cm), while it was the minimum in delayed sowing i. e. 22 Oct. The

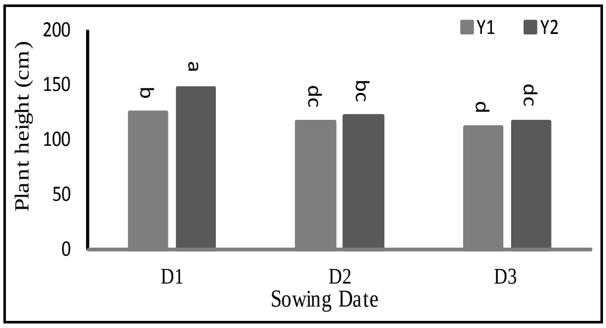

Fig. 1. Plant height of three sowing dates during 2014-15 in canola (D_1 : Sowing date on 2 Oct., D_2 : Sowing date on 12 Oct., D_3 : Sowing date on 22 Oct., Y_1 : 2014-15 and Y_2 : 2015-16).

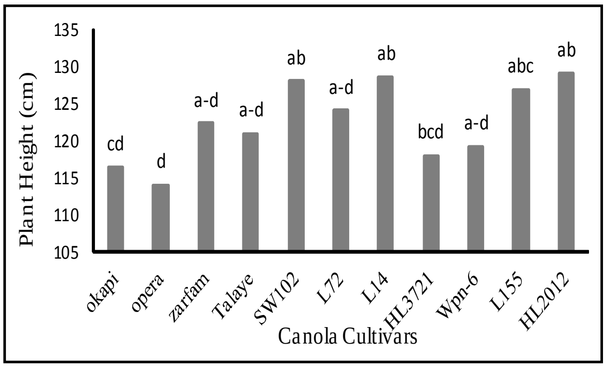

Fig. 2. Plant height of canola cultivars after sowing in different times during 2014-16.

plant height varied significantly among cultivars from 114.31 to 129.11 cm in Opera and HL2012, respectively (Fig. 2). The lowest plant height (114.31 to 118.09) was recorded from Opera, Okapi and HL3721 cultivars, respectively. Obtained data from first sowing date (2 Oct.) in the first year (D_2Y_1) were similar to third sowing date in both the years (D_3Y_1 and D_3Y_2).

Pod Number in Main Stem

A significant difference observed among pod numbers in the main stem which showed that there was an interaction between studied canola cultivars, sowing dates and year. Results demonstrated that L14 cultivar (52.55) recorded highest pod number in the main stem values as clearly illustrated in Fig. 3. The lowest pod number (37.43) was obtained from Opera followed by Talaye (42.28).

Seed Number in Main Pod

The sowing date had much influence on seed number in the main pod (Fig. 4). The

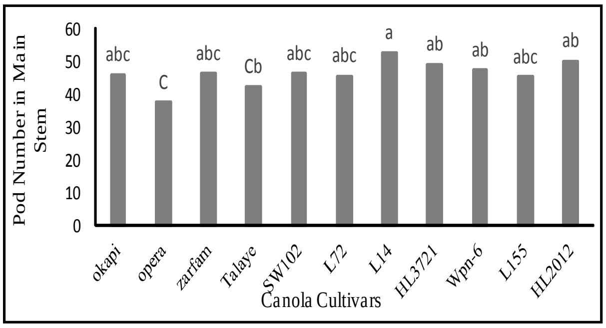

Fig. 3. Pod number in main stem in canola cultivars different sowing dates during 2014-16 (D_1 : Sowing date on 2 Oct., D_2 : Sowing date on 12 Oct., D_3 : Sowing date on 22 Oct., Y_1 : 2014-15 and Y_2 : 2015-16).

seed number in the main pod was in the highest level at the first sowing date (2 Oct.) in both the years (D_1Y_1 and D_1Y_2) and in the second sowing date in 2014-15 (D_2Y_1), the seed number was more than third sowing date (D_3) in both the years (Fig. 4). In each year, with a delay in three sowing dates, seed number of canola cultivars gradually decreased, ranging from 716.48 to 661.36 in 2014-15, and from 679.42 to 578.84 in 2015-16, respectively (Fig. 4). In both the years, the highest seed number was achieved when canola cultivars were sown in early-Oct. (D_1).

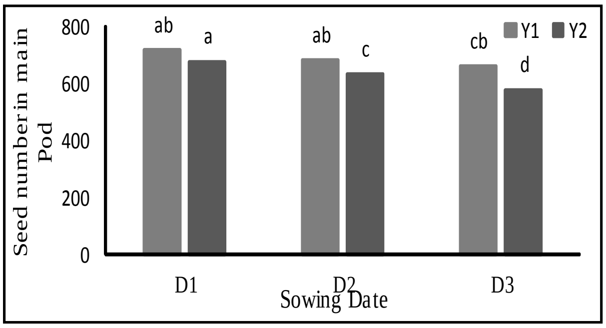

Fig. 4. Seed number in main pod at different sowing dates during 2014-16 in canola (D_1 : Sowing date on 2 Oct., D_2 : Sowing date on 12 Oct., D_3 : Sowing date on 22 Oct., Y_1 : 2014-15 and Y_2 : 2015-16).

1000-seed Weight

It was also concluded from Fig. 5 that the interaction effect of sowing dates and year significantly influenced the 1000-seed weight. In the first year (2014-15), the highest amount of 1000-seed weight was recorded in three sowing dates (4.03, 4.007 and 3.95 g) without statistically significant difference, but this significant difference was lower (27.29%) in 2 Oct. sowing (D_1) than two other times of sowing (D_2 and D_3 : 52.26 and 48.03%).

The effect of year on the 1000-seed weight in 11 canola cultivars is shown in Fig. 6, as can be seen all cultivars had distinct performance during two years, while Okapi cultivar with 52.94% and L72 with 34.21% were, respectively, the highest and the lowest variety among others.

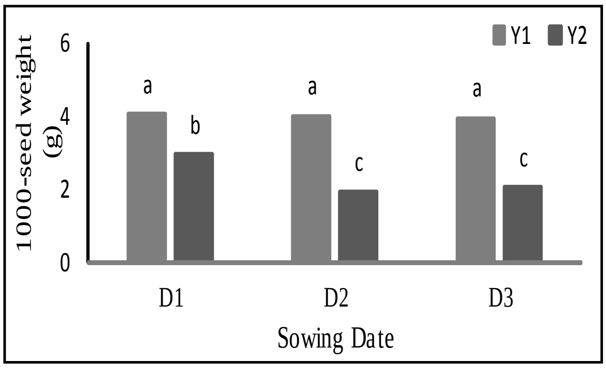

Fig. 5. 1000-seed weight at different sowing dates during 2014-16 in canola (D_1 : Sowing date on 2 Oct, D_2 : sowing date on 12 Oct., D_3 : Sowing date on 22 Oct., Y_1 : 2014-15 and Y_2 : 2015-16).

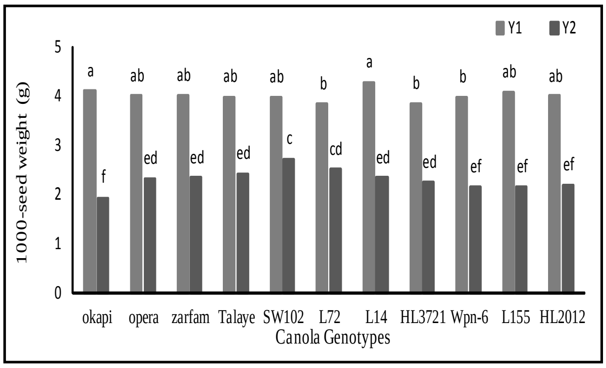

Fig. 6. 1000-seed weight of canola cultivars in two years (Y_1 : 2014-15 and Y_2 : 2015-16).

Seed Yield

Generally, seed yield in all the cultivars was significantly high in 2014-15, in comparison with the second year. In addition, the highest seed yield was found in SW102 cultivar in the first sowing date (D_1 : 2 Oct.) as compared to other sowing dates (D_2 and D_3 : 12 and 22 Oct.) during two years (Fig. 7), while the lowest amount of seed yield was given from third sowing date (D_3 : 22 Oct.) in Opera cultivar during 2015-16 (0.08 g). The effect of cultivars in the third sowing date (D_3 : 22 Oct.), during

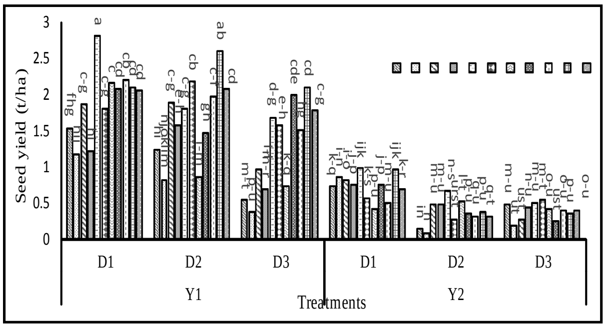

Fig. 7. Seed yield of canola cultivars in three sowing dates during 2014-16 (D_1 : Sowing date on 2 Oct., D_2 : Sowing date on 12 Oct., D_3 : Sowing date on 22 Oct., Y_1 : 2014-15 and Y_2 : 2015-16).

the second year (2015-16), had not a statistically significant difference (Fig. 7). According to these data, date of sowing on 2 Oct. (D_1) was found to be the optimum date of sowing for the SW102 cultivar.

Oil Content

According to Fig. 8, sowing date and year clearly affected oil content in canola cultivars. The highest oil content was the result of the first year and sowing date (D_1Y_1 : 2 Oct. 2014-15) from L72 (41.093) followed by Zarfam (40.98) and L155 (40.97), and the lowest oil content was related to the second year and sowing date (D_2Y_2 : 12 Oct. 2015-16) from the Opera cultivar (39.59). The interaction effect between the year and sowing dates varied significantly at three groups, but the difference was not identical. The first sowing date (2 Oct.) from year to year decreased 7.36%, for the second and third sowing date was recorded 6.97 and 3.211%, respectively (Fig. 9).

The results clearly showed that the highest values of crop growth and oil content were obtained from early sowing date (2 Oct.)

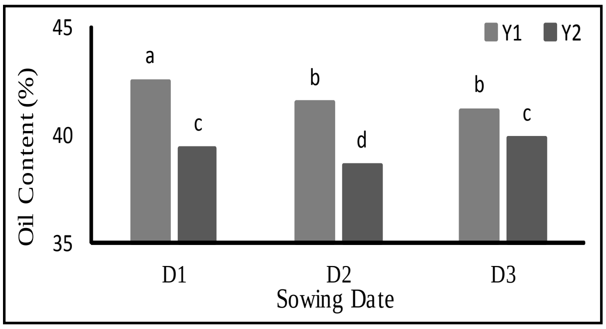

Fig. 8. Oil content at different sowing dates during 2014-16 in canola (D_1 : Sowing date on 2 Oct., D_2 : Sowing date on 12 Oct., D_3 : Sowing date on 22 Oct., Y_1 : 2014-15 and Y_2 : 2015-16).

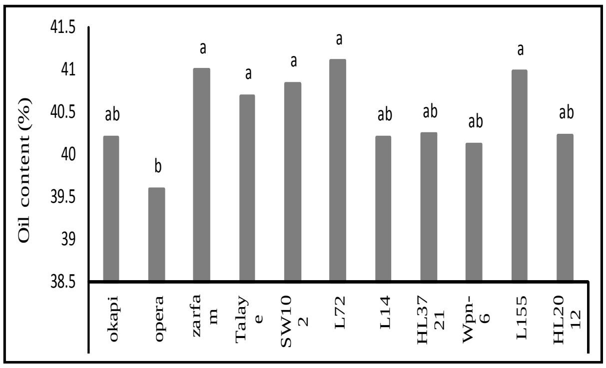

Fig. 9. Oil content of canola cultivars at different sowing dates during 2014-16.

than late sowing (22 Oct.), which could be attributed to short stature of canola crop in late sowing date. So, there was reduction in canola crop growth and development duration, especially the vegetative growth period and the quick transfer to reproductive stage and seed maturity in late sowing date (De Bruin and Pederson, 2009).

In the present study, seed oil content was much influenced by year, cultivar and sowing date (early, standard and delay), also the amount of seed oil was an action to genotypic parameters (Ginwal *et al.,* 2005). Hence, a significant amount of effort was made to produce genetically modified canola cultivars with a high amount of oil yield (Vlahakis and Hazebroek, 2000). The amount of oil content in Oct. 2 (D_1) was significantly different from other sowing dates (D_2 and D_3). This can be ascribed to the favourable and suitable weather conditions (rain and temperature) at this time (Figs. 8 and 9).

Our results implied that early sowing (D_1 : 2 Oct.) due to cooler temperature could increase weight and seed number (Figs. 3 and 4), however, when the temperature rose to higher during the seed filling stage, the seed weight was the lowest and vice-versa (D_2 and D_3 : mid and late Oct.). These results are in conformity with those of De Bruin and Pedersen (2009) and Angeloni *et al.* (2017). Water stress and high temperature at seed-filling stage decreased grain yield of all cultivars, especially in Okapi and Opera cultivars. A reduction in seed yield because of delay in sowing date was mainly explained by the decline in the final aboveground dry matter due to the shortening of vegetative growth period as seen in this study as well (Figs. 5, 6 and 7). The much higher seed yield was recorded by L155, HL3721 and HL2012 cultivars, however, Opera, Okapi, L14 and Talaye cultivars, noted the least seed yield in the same sowing date (Oct. 2, 2014-15), of course, it can be related to the difference among genetic makeup cultivars. Consequently, increase in oil content may be related to increase in seed yield, as was observed in L72, L155 and Zarfam at the first sowing date (D_1 : 2 Oct.), similar conclusions were presented by De-Bruin and Pedersen (2009).

Delay in sowing operation led to fast development of the canola crop, so reduced the days from emergence seedling to flowering stage and to physiological maturity, duration of late-flowering and seed filling, aboveground dry matter, plant height, pod number in main shoot (Figs. 1 to 8, some data not shown). It showed that L72, L14, Wpn-6 and L155 cultivars in the longer growth period had the highest main shoot length, as a result, these led to a high seed number and ultimately high oil seed content. Earlier sowing date more closely matched to rainfall time, reduced terminal heat and water deficit stress (Table 2), led to increase in plant height (Figs. 1 and 2), as could be seen in some literature (Gunasekera *et al.,* 2006). Therefore, the ability to accordance key phenological growth period of the canola crop to a less stressful growth period in the growing season was an effective and important strategy for avoiding the negative impact of high normal temperature and drought stress, as pointed out per Ludlow and Muchow (1990). These results imply that agronomic management and environmental conditions that plant height (Figs. 1 and 2) was not identical statistically in all treatments. This emphasizes that the contribution of assimilates supply was a very significant source for increasing height plant and its shoot. The obtained results of the present study show that optimum environmental conditions around vegetative stages, as such we can see in early sowing dates than other sowing dates.

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