EFFECTS OF ROW SPACING AND SEEDING RATES ON SOME AGRONOMICAL TRAITS OF SPRING CANOLA (BRASSICA NAPUS L.) CULTIVARS

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ABSTRACT

The objective of the study was to evaluate the effects of row spacing and seeding rates on agronomical traits of three spring canola (Brassica napus L.) cultivars in Iran during 2003-2004. Traits evaluated were plant height, number of seeds pod^{-1}, number of pods main stem^{-1}, number of pods plant^{-1}, 1000-seed weight, seed yield, and seed oil content. The experimental lay-out was split-split plot based on randomized complete block design with 4 replications. 3 row spacing of 12, 18 and 24 cm constituted the main plot, 2 seeding rates of 4 and 6 kg ha^{-1} as split plot and 3 spring canola cultivars of Hyola 401, Hyola 60 and RGS-003 (lately-used hybrid, new hybrid and new cultivar, respectively) comprised the split-split plot. Results showed that the highest seed yield was obtained at 12 cm row spacing, followed by 7.4% reduction in seed yield as row spacing increased to 24 cm. An increase in seeding rates from 4 to 6 kg ha^{-1} resulted in a decrease in number of pods plant^{-1} but other traits were not influenced. The highest number of pods plant^{-1} was obtained by applying 4 kg ha^{-1} seeding rates. The hybrid Hyola 401 had better performance than two other cultivars in plant height, number of grains pod^{-1}, number of pods main stem^{-1}, seed yield and seed oil content. The interaction of row spacing × seed rates and also row spacing × cultivars were significant only for the number of pods main stem^{-1}. The lowest one was obtained at 12 cm row spacing with 6 kg ha $^{-1}$ seed rates. RGS-003 at 12 cm row spacing showed the highest number of pods main stem^{-1}, statistically equal to Hyola 401 grown at 24 cm row spacing.

Key words: Canola, spring cultivars, row spacing, seeding rates, seed yield, seed oil content

INTRODUCTION

Rapeseed (Brassica napus and B. rapa L., Brassicaceae) is now the second most important source of vegetable oil in the world and canola oil is considered healthy for human nutrition due to its lowest content of saturated fatty acids among vegetable oils and moderate content of poly-unsaturated fatty acids [20]. Thus, it constitutes a great portion to supply the food requirements of the growing population. One of the major aspects of crop ecology, production and management which often limit crop production is improper crop spacing in the field [6]. The seed yield is a function of interaction between genetic and environmental factors including soil type, sowing time and method, seed rate, fertilizers and time of irrigation among which, row spacing plays a vital role in getting higher yield [8]. Some investigators concluded that narrow row spacing was superior in yield and more economical than boarder rows [17]. Plants growing in too wide rows may not efficiently utilize the natural resources such as light, water and nutrients, whereas growing in too narrow rows may result in sever inter and intra-row spacing competition [1]. Therefore, it is of crucially important to manipulate the row spacing in order to increase plant productivity. Christensen and Drabble [3] reported that either B. napus or B. rapa showed higher grain yield in the narrower row spacing (7.5 cm) compared with those wider (15 and 23 cm) and different seed rates (7-14 kg ha^{-1}) had no significant effect on seed yield.

Seeding rate, as well as the row spacing, is considered an important factor to optimize plant population. The establishment of an adequate and uniform canola stand is critical to achieve high grain yield. Seed yield of canola is a function of population density, number of pods per plant, number of seeds per pod and seed weight. However, yield structure is very plastic and adjustable across a wide range of population [5]. Hence, by adopting improved technologies alongside the use of proper management practices and high yielding varieties, productivity would be enhanced substantially [1]. Potter et al. [18] reported an increase in seed yield up to density of 50 plants m^{-2}, while seed yield was unaffected when density was between 50 and 130 plants m^{-2}. However, Lythgoe et al. [13] and Bilgili et al. [2] reported lower seed yield in lower plant densities. Besides, they indicated more efficiently control of weeds in higher plant densities.

This study was conducted to investigate the effect of row spacing and seeding rates on some agronomical traits of three spring canola cultivars, two of which are newly-introduced in the north of Iran, and also to assess the relationships between traits.

MATERIALS AND METHODS

The experiment was carried out at Baye-Kola agricultural research station (lat 36° 44´ E, long 53° 14´ N), Neka, Iran in 2003-2004. The soil texture of the experimental site was loam clay (25% clay, 19% silt and 23% sand) with pH of 8 and EC of 0.59 ds. 100 kg ha^{-1} ammonium phosphate and 75 kg ha^{-1} urea were applied prior to planting and appropriate practices were used for weed and insect control. The experimental lay-out was split-split plot based on randomized complete block design, with 4 replications. Experimental factors included 3 row spacings of 12, 18 and 24 cm as the main plot, 2 seeding rates of 4 and 6 kg ha^{-1} as the split plot and 3 spring canola cultivars of hybrid Hyola 401, hybrid Hyola 60 and RGS-003 as the split-split plot. Hyola 401 has extensively cultivated in the north of Iran in recent years, whereas two other cultivars are newly introduced in the north of Iran. Each plot was 8.4 m^{-2} and the length of sowing lines in each plot was 5 m. Plots allocated to 12, 18 and 24 cm row spacings, comprised 14, 9 and 7 sowing lines, respectively. Regarding different row spacings and seed rates in each plot, inter row spacings and plant density varied in each plot (Table1). The cultivation operations were carried out in each plot based on plant densities tabulated in Table 1. The required water was supplied through precipitation (248 mm) during growth stages. Sevin insecticide was applied at the rate of 135 g ha^{-1} at flowering stage to control pests. Weeds were removed by hand weeding during growth stages. At the time of harvest, in order to control boarder effects, plants from the sides of each plot were removed. To measure yield components including plant height, number of seeds pod^{-1}, number of pods main $stem^{-1}$, number of pods $plant^{-1}$ and 1000-seed weight, ten plants were harvested from each plot at the time of maturity. To measure seed yield, 6.5 m^2 of each plot were harvested after removing boarder effects. Evaluated traits were determined as followed:

1) Plant height was determined from a 10-plant sample. The height of plants was measured from the top of the stem to the soil surface and then divided by 10.

2) Number of pods main $stem^{-1}$ was determined from the 10-plant sample. Pods in the main stems were counted and then divided by 10.

3) Number of pods $plant^{-1}$ was determined from the same 10-plant sample. The number of pods in plants was counted and then divided by 10.

4) Number of seeds pod^{-1} was also determined from the 10-plant sample. The number of grains in the pods of branches was counted and then divided by 10.

5) 1000-seed weight was determined by counting 500 seeds from each yield sample. Then seeds were dried at 30° C in a forced air dryer, weighted and then multiplied

Table 1: Inter row spacing and plant population obtained based on applied row spacing and seeding rates in each plot

Row spacing (cm)	Seeding rates (kg ha^{-1})	Inter row spacing (cm)	Plant population (m^2)
12	4	10	84
18	4	7	80
24	4	5	84
12	6	7	120
18	6	4.5	124
24	6	3.5	120

Table 2: Variance analysis of the agronomic traits based on randomized complete block design

Source of variation	Df	Plant height (cm)	Number of seeds pod^{-1}	Number of pods main stem^{-1}	Number of pods plant^{-1}	1000-seed weight (g)	Seed yield (kg ha^{-1})	Seed oil content (%)
Replication	3	92.9	5.35	28.29**	1972.77**	0.07	100723	3.76
RS	2	23.16	5.88	14.74	1476.83	0.14	486582.3**	1.25
Error rs	6	357.07	3.69	1.73	316.1	0.13	39943.73	2.17
SR	1	131.36	4.37	1.52	1330.42*	0.01	11705.79	0.08
RS × SR	2	92.09	6.64	12.29*	11.9	0.07	1158017	0.25
Error sr	9	110.71	3.24	1.93	204.6	0.04	57119.73	0.57
C	2	778.42**	314.69**	16.79**	4740.9**	3.82	3595255**	43.12**
RS × C	4	120.92	2.32	16.63**	91.61	0.03	20515.32	0.37
SR × C	2	85.12	5.51	1.69	76.62	0.03	8698.05	0.22
RS × SR × C	4	57.52	3.89	1.65	264.95	0.02	328832.9*	0.23
Error c	36	71.3	2.76	1.74	161.38	0.04	97241.96	0.36
CV (%)	-	6.99	9.28	5.66	13.55	5.22	9.91	1.36

*, **: significant at 5% and 1%, respectively. **RS**: Row Spacing (cm), **SR**: Seeding Rates (kg ha^{-1}), **C**: Cultivars

by 2.

6) To measure seed yield, after removing boarder effects 6.5 m^2 of each plot were harvested at the time of maturity. Seed yield samples were forced air-dried at 30° C to a uniform moisture level, cleaned in the seed lab and then weighted.

7) To determine seed oil content samples were taken from each seed yield sample. They were oven-dried at 130° C for 3 hours, cooled in a desiccator and then oil percentages were determined using Nuclear Magnetic Resonance (NMR) system. The obtained data were subjected to variance analysis as a split-split plot design using the Statistical Analysis System (SAS Institute, 1998). The source of variation, degrees of freedom and expected mean square for evaluated traits appear in Table 2. Comparison of means was performed by Duncan's Multiple Range Test at P<0.05.

RESULTS AND DISCUSSION

The results indicated that 3 cultivars were significant for all traits expect for 1000-grain weight (Table 2). However, row spacing and seeding rate were just significant for seed yield and number of pods plant^{-1}, respectively.

Plant height

Plant height was only influenced (P<0.01) by cultivars whereas other factors did not affected this trait (Table 2). The shortest plant height was found in Hyola 401 and the highest in Hyola 60 (table 3). Generally, dwarf canola cultivars are more desirable due to the tolerability against lodging and also the high potential of receiving fertilizers. The significant and negative correlation between plant height and seed yield (Table 5) implies the seed yield magnitude of Hyola 401 exhibiting the shortest height. Although plant height was not affected neither by row spacing nor seeding rates, environmental factors

Table 3: Means comparison of the agronomic traits for 3 row spacing, 2 seeding rates and 3 canola cultivars

Treatments (cultivars)	Plant height (cm)	Number of seeds pod^{-1}	Number of pods main stem^{-1}	Number of pods plant^{-1}	1000-seed weight (g)	Seed yield (kg ha^{-1})	Seed oil content (%)
Row spacing (cm)							
12	121.12 a	18.46 a	23.78 a	84.73 b	3.99 a	3309.44 a	45.46 a
18	119.79 a	17.52 a	22.38 a	72.69 a	3.92 a	3084.84 b	45.04 a
24	121.71 a	17.72 a	23.69 a	98.88 a	3.84 a	3097.70 b	45.09 a
Seeding rates (kg ha^{-1})							
4	119.52 a	17.66 a	23.43a	98.06 a	3.92 a	3133.24 a	45.17 a
6	122.22 a	18.15 a	23.14 a	89.47 b	3.85 a	3158.75 a	45.23 a
Cultivars							
Hyola 401	114.32 c	21.46 a	23.4 a	77.59 b	4.11 a	3459. 57a	45.51 a
RGS-003	124.59 a	18.02 b	24.05 a	100.74 a	3.46 a	3264.99 b	43.83 c
Hyola 60	123.71b	14.22 c	22.3 b	102.97 a	4.18 a	2713.43 c	45.26 b

The means with at least one same letter do not have statistically significant difference.

such as the quantity and quality of light prompts plant height increase in higher plant densities, particularly in an unequidistant plant distribution. The level of light, as well as the red and far red ratio, plays an important role in stem elongation and consequently on final plant height. Besides, the stem sections of plants receiving more light usually tend to have slower elongation rates [7].

Number of seeds pod^{-1}

Cultivars showed a significant difference ($P<0.01$) in number of seeds pod^{-1}, whereas other factors were not significant for this trait (Table 2). Hyola 401 had the highest number of seeds pod^{-1}, 19% and 50.9% more than RGS-003 and Hyola 60, respectively. In this study, number of seeds pod^{-1} had the most significant and positive correlation with seed yield (Table 5) implying the magnitude of hybrid Hyola 401 compared with two other genotypes. Therefore, any agronomical performance with the aim of an increase in number of seeds pod^{-1} would result in an increase in seed yield. This trait was not affected by row spacing and seeding rate. Nevertheless, as plant population decreases, individual plants progressively produce more branches, pods plant^{-1} and seeds pod^{-1}. Canola Seed yield is a function of population density, number of pods plant^{-1}, number of seeds pod^{-1} and seed weight. However, yield structure is very plastic and adjustable across a wide range of populations [5]. These results agree with those of Kuchtova and Vasak [11] and Leach et al. [12].

Number of pods main stem^{-1}

Cultivars also exhibited significant difference ($P<0.01$) in number of pods main stem^{-1} (Table 2). Hyola 401 and RGS-003 showed higher number of pods main stem^{-1} compared with Hyola 60 (Table 3). In this study, number of seeds main pod^{-1} had a positive but insignificant correlation with seed yield. Therefore, an increase in pods main stem^{-1} would not result in a great proportional contribution in seed yield increase. Moreover, row spacing × seed rate interaction was significant ($P<0.05$) for number of pods main stem^{-1} (Table 2). The lowest number of pods main stem^{-1} was observed when plants grew at 18 cm row spacing and 6 kg ha^{-1} seed rate whereas, other interaction treatments showed higher and statistically equal number of pods main stem^{-1} (Table 4). In this study, an increase in seeding rates from 4 to 6 kg ha^{-1} led to an increase in number of pods main stem^{-1}. This can be attributed to a decrease in number of branches per plant and consequently more pods formation in main stem. Plants grow in low plant density receive more solar radiation compared to denser populations resulting in a greater portion of vegetative dry matter to allocate into the branches. Therefore, plants in low populations are more able to benefit from resources to increase the number of branches. The row spacing × cultivar interaction was also significant ($P<0.01$) for number of pods main stem^{-1} (Table 2) indicating the fact that regarding different cultivars, the process of this trait varied in different row spacings. The lowest number of pods main stem^{-1} was observed in RGS-003 when grew at 12 cm row spacing however, the lowest number of pods main stem^{-1} in Hyola 60 and Hyola 401 were found in 18 and 24 cm row spacing, respectively (Table 4). In narrow rows the yield of main stem is the primary contributor to total yield. Therefore, cultivars that have higher main stem yield potential are

Table 4: Means comparison of the number of pods main stem^{-1} influenced by interaction effects of row spacing × seeding rates and row spacing × cultivars

Row spacing	Seeding rates (kg ha^{-1})		Cultivars		
(cm)	4	6	Hyola 401	RGS-003	Hyola 60
12	23.66 a	23.89 a	22.18 bc	25.73 a	23.43 b
18	23.33 a	21.43 b	22.95 b	23.23 b	20.96 c
24	23.29 a	24.10 a	25.08 a	23.21 b	22.79 b

The means with at least one same letter do not have statistically significant difference.

Table 5: Correlation coefficient analysis among the agronomic traits

Traits	PH	NSP	NPMS	NPP	1000- SW	SY	SOC
PH	1						
NSP	-0.52**	1					
NPMS	0.19	0.23	1				
NPP	0.46	-0.74**	-0.2	1			
1000-SW	-0.27	-0.09	-0.35	-0.33	1		
SY	-0.24	0.86**	0.40*	0.67**	0.25	1	
SOC	-0.62**	0.44*	-0.04	0.70**	0.78**	0.21	1

*, **: significant at 5% and 1%, respectively. **PH:** Plant Height (cm), **NSP**: Number of Seeds Pod^{-1}, **NPMS**: Number of Pods Main Stem^{-1}, **NPP**: Number of Pods Plant^{-1}, **1000-SW**: 1000-Seed Weight, **SY**: Seed Yield (kg ha^{-1}), **SOC**: Seed Oil Content (%).

the best suited in narrow row spacing cultivation.

Number of pods plant^{-1}

Obtained results indicated that number of pods plant^{-1} was influenced (P<0.05) by different seeding rates (Table 2). The number of pods plant^{-1} decreased 8.7% as the seeding rate increased from 4 to 6 kg ha^{-1}. The number of pods plant^{-1} is the most responsive of all the yield components in canola [5] and is determined by the survival of branches, buds, flowers and young pods rather than the potential number of flowers and pods [14]. An increase in plant population results in the canopy closure. Accordingly, inter plant competition increases and plant ability for utilizing environmental resources and consequently plant dry matters dwindle. To resolve the stress and to establish equilibrium among photosynthesis, respiration and storing nutritional matters, the plant hastens filing out the grains resulting in a decrease in the number of branches, number of pods plant^{-1}, number of seeds pod^{-1}, the time of filling out seeds and 1000-seed weight [22]. These results agree with those of Kuchtova and Vasak [11] and Leach et al. [12] that they separately reported a decrease in number of pods plant^{-1} due to an increase in plant density. However, James and Anderson [9] reported a decrease in number of pods plant^{-1} as a result of an increase in plant density but, the number of pods per area unit increased resulting in an increase in seed yield. Cultivars also exhibited significant difference (P<0.01) for this trait (Table 2). Hybrid Hyola 401 showed the lowest number of pods plant^{-1}, 24% lower than both Hyola 60 and RGS-003 (Table 3). This trait showed a negative and significant correlation with seed yield indicating the fact that the lower the number of this trait is, the higher the seed yield will be (Table 5). Moreover, the magnitude of Hyola 401 would be distinguished by possessing the lowest quantity of pods plant^{-1}. Therefore, other yield components such as number of seeds pod^{-1} and pods main stem^{-1} are more contributed to higher seed yield (Table 5).

Seed yield

The results indicated that row spacing had significant effects (P<0.01) on seed yield (Table 2). The highest seed yield was obtained at 12 cm row spacing and it reduced 7.4% as row spacing increased from 12 to 24 cm (Table 3). In this study, a decrease in row spacing alongside an increase in inter row spacing resulted in an approximate equidistant arrangement which led to a uniform distribution and provided each plant with equal opportunity to intercept more light and to produce more dry matter resulting in earlier establishment of canopy closure. On the other hand, later plant canopy closure due to wider row spacing may result in greater interspecies competition in weedy commercial fields where hand weeding is not practiced. Moreover, the mutual shading - large number of leaves per land area- increases lodging due to excessive stems elongation and plant competition in nonuniform and high plant densities caused by unequal row spacing and inter row spacing arrangement would culminate in seed yield reduction. Potter et al. [18] reported significantly greater yield at 15 cm row spacing compared with 30 cm spacing at a low rainfall region whereas, no effect on seed yield was observed at a medium rainfall region. Narrower rows have also been reported to give higher seed yield than wide rows in Brassica napus [15]. Greater yield at narrower than wider row spacings was partially due to lower interplant competition which resulted in a greater number of pods plants^{-1}, seeds pod^{-1} and greater dry weight per unit area [16]. Seeding rates were not significant for seed yield (Table 2). Therefore, regarding the spread of the fungus Sclerotinia sclerotiorum in the north of Iran, to which canola is quite susceptible and is really damaged, beside the risk of lodging in high plant densities it is recommended to apply less seed rates. Similar results have been separately reported by Degenhardt and Kondra [4] Christensen and Drabble [3] McGregor [14] Van Deynze et al. [21] Leach et al. [12] and Bilgili et al. [2]. Cultivars exhibited significant difference for grain yield (Table 2). Hybrid Hyola 401 yielded greater than other cultivars, 27.49% more than hybrid Hyola 60 and 5.9% more than cultivar RGS-003 implying the better performance of Hybrid canola Hyola 401(Table 3). Hybrids typically average 10 to 15% grater yield than open-pollinated cultivars, but their seed cost is approximately twice as great, meaning higher yields are needed to offset greater seed input costs for planting [10]. Van Deynze et al. [21] reported that hybrids produced 50% more dry matter and 24% more seed yield than conventional cultivars.

Seed oil content

Obtained results indicated that only cultivars showed significant effects ($P<0.01$) on seed oil content and other factors were not significant for this trait (Table 2). Hybrid Hyola 401 showed the highest seed oil content, 3.8% more than cultivar RGS-003, indicating the better performance of hybrids compared with other types (Table 3). Row spacing and seed rates had no significant effects on this trait. Potter et al. [18] reported that oil content was not affected neither by row spacing nor plant density in both low and medium rainfall regions. Morrison et al. [15] and Leach et al. [12] reported no effects of sowing rates on seed oil content while Van Deynze et al. [21] showed a small decrease in oil content as sowing rate increased to 9 kg ha^{-1}. Similarly, Morrison et al. [15] found few consistent effects of row spacing on oil content.

CONCLUSIONS

This study showed that the narrow row spacing, where an equidistant arrangement is applied, results in the highest seed yield of canola cultivars. Although seed rate was significant for number of pods plant^{-1}, considered the most responsive yield component, it did not affect seed yield and seed oil content, the primary features determining the crop value. Therefore, regarding the climatic condition in the north of Iran, application of 4 kg ha^{-1} seed rate is recommended. Except for 1000-seed weight, all traits were influenced by cultivars. Hybrid Hyola 401, Lately-used in the north of Iran, had the best performance and exhibited the highest seed yield and seed oil content. Hence, this genotype would be considered a suitable cultivar in region although more comprehensive investigations should be carried out, particularly for new varieties of RGS-003 and Hyola 60. Based on results from this study, application of Hyola 401 considering 12 cm row spacing and 4 kg ha^{-1} seed rates is recommended.

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