INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 4, No. 8, p. 209-214, 2014

RESEARCH PAPER OPEN ACCESS

Study on effect of plant density variations at different growth stages of rapeseed on seed yield, oil yield, seed oil content

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Key words: Bam, rapeseed, plants removal time, plants removal method, seed yield, oil yield.

http://dx.doi.org/10.12692/ijb/4.8.209-214 Article published on April 22, 2014

Abstract

The effect of Study on effect of plant density variations at different growth stages of rapeseed on seed yield , oil yield, seed oil content was investigated in Natural Resources Nursery of Bam, Iran in 2010-2011 as a factorial study based on a Randomized Complete Block Design with three replications in which the first factor was devoted to the time of plants removal including seedling emergence, stemming and flowering and the second factor was devoted to the intensity of plants removal at three levels of 25, 50 and 75%. There was a control in each replication. The measured traits included seed yield, oil yield, seed oil content, Harvest index. It was found that rapeseed is more sensitive to the intensity of plants removal than to its stage. The effect of plants removal intensity was significant on seed yield per plant and oil yield per unit area at 5% probability level and on total yield per unit area at 1% probability level, so that the removal of 25 and 50% of plants was compensated by greater growth and single-plant yield (by 34.2%) and only the removal of 75% of plants decreased seed yield per unit area by 30.7 and 19.9% as compared to the removal of 25 and 50% of plants, respectively. The interactions between the time and intensity of plants removal was significant for oil yield and seed yield at 5% probability level. The lowest seed yield (2668 kg ha^{-1}) was obtained by the removal of the plants at flowering and stemming which differed with control by 26.34%. Other evaluated traits were not affected by the treatments. It can be recommended that the maximum seed yield can be realized in Bam, Iran by decreasing plant density by 15% (57 plants m^{-2}).

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Introduction

Oilseeds are the second most important nutrient of the world after grains. Rapeseed is one of the most important oilseeds throughout the world (Nazardad, 2001). The number of plants per unit area is called density. The effect of uniform distribution of plants per unit area on appropriate distribution of intercepted radiation is reflected inside plant canopy. Therefore, the main effect of planting arrangement and plant density on yield is mainly caused by the difference in the manner of solar radiation distribution (Fathi, 2005). Special distribution of plants in a population is associated with radiation absorption which plays a decisive role in photosynthesis capacity (Wells, 1991). In a study on three densities of 33, 67 and 133 plants m^{-2} in Rasht, Iran, Ozoonidooji *et al.* (2007) reported that 67 plants m^{-2} resulted in the highest dry matter and consequently, the highest seed yield due to the adequate use of space and other resources by plants, lower competition between plants and higher leaf area index and crop growth rate. The results of another study have revealed that oil yield is not influenced by row spacing or plant density (Morrison *et al.*, 1990). Sajedi *et al.* (2009) reported that lower seeding rate (4 kg ha^{-1}) maximized seed oil production (1157.2 kg ha^{-1}). Some studies showed the non-significant influence of plant density on seed oil content of rapeseed (Poorsiah Bidi *et al.*, 2010; Yazdifar *et al.*, 2006; Fanaye *et al.*, 2008; Fathi, 2008). The decline of seed oil percentage under higher plant densities have been reported by Ahmadi (2010) and Leach *et al.* (1998). Finally, Sajedi *et al.* (2009) stated the significant effect of row spacing on seed oil content at 5% level. According to the findings of Appelquist and Ohlson (1972), Kimber and McGregor (1999) and Ilkayi and Imam (2003), it seems that the self-regulatory mechanism of the balance between vegetative and reproductive organs is the reason for the variations of harvest index at different densities.

Materials and methods

Materials

In order to study the compensation capacity of rapeseed canopy under the decrease in plant density during growing season at three phenological stages (seedling establishment, stemming and flowering) with three plant removal intensity (removal of 25, 50 and 75% of plants), the present study was carried out as a factorial experiment based on a Randomized Complete Block Design with three replications in Natural Resources Nursery of Bam, Iran (Long. 58°18' E., Lat. 29°05' N., Alt. 1051 m.) in 2009-2010. Beforehand, the soil of the study field was sampled to find its physical and chemical properties.

Methods

To supply the nutrients deficiency of the soil, it was fertilized with 73 kg ha^{-1} urea and 100kg ha^{-1} ammonium phosphate in concomitant with sowing. In addition, 73 kg ha^{-1} urea fertilizer was used at the beginning of stem elongation and 73kg ha^{-1} at flowering as heading. After implementing the experiment, rapeseeds were uniformly sown by hand in plots with the dimensions of 6 × 2 m^2 at the depth of 3 cm with inter-row spacing of 30 cm on November 30, 2010. Immediately after sowing, the first irrigation was conducted followed by the second irrigation three days after sowing. Then, the field was irrigated with the interval of 7 days. Cabbage aphid was controlled by Perimor insecticide (Perimicarb 1.5:1000) at two stages during growing season. After eliminating marginal rows, the rows from which the samples had been taken, and 0.5 m from both ends of the remaining rows, the plants were harvested from the third, fourth and fifth rows to determine the yield and oil. Then, the total yields of the plots were measured and some samples were taken according to the procedure to measure oil percentage in Seed Research Laboratory of Karaj, Iran.

Data analysis

At the end, the data were statistically analyzed by SAS and MS-TATC software and the means were compared by Duncan Test at 5% probability level.

Results

Seed Yield

Plant removal (removal intensity and time combinations) affected seed yield significantly at 5% probability level (Table 1a). The lowest seed yield (2689.6 and 2688.0 kg ha^{-1}) was produced by the removal of 75% of plants at seedlings emergence and stemming, respectively (Table 1b) suggesting higher sensitivity of rapeseed canopy to plants removal during vegetative growth (seedlings emergence and stemming). Plants removal time did not significantly influence seed yield per unit area, but the impact of plants removal intensity was significant on this trait at 1% probability level. Given the trend of the response of rapeseed seed yield per unit area, the results revealed that the removal of 25 and 50% of plants was compensated by the increased growth and yield of individual plants (by 34.2%) and only the removal of 75% of plants resulted in the significant loss of seed yield per unit area as compared to the removal of 25% of plants (3916 kg ha^{-1}) by 30.7% and the removal of 50% of plants (3389 kg ha^{-1}) by 19.9% (Table 1d). In a study on three densities of 33, 67 and 133 plants m^{-2} in Rasht, Iran, Ozoonidooji *et al.* (2007) reported that the highest studied density produced the highest dry matter and by which the highest seed yield due to the adequate utilization of space and other resources, lower inter-plant competition, higher leaf area index and increased plant growth. Behzadi *et al.* (2008) studied four plant densities (40, 50, 66.5 and 100 plants m^{-2}) on four cultivars of Hayola 308, Hayola 401 and Sarigol and concluded that the highest seed and oil yields (2393 and 1054 kg ha^{-1}, respectively) were obtained by Hayola 308 under the density of 40 plants m^{-2}.

Table 1. Summary of (a) analysis of variance and (b) means comparison for the traits related to seed and oil yield of rapeseed on the basis of a randomized complete block design and summary of results of (c) analysis of variance and (d) means comparison for these traits in Bam, Iran in 2010.

(a) Analysis of variance of the effect of treatment combinations[(a)]						
Sources of variations	df	Means of squares				
		Seed yield/plant	Seed yield/unit area	Oil yield	Seed oil content	Harvestindex
Replication	2	0.126ns	333025.393ns	125383.420ns	5.978 ns	9.070 ns
Treatment	9	0.831ns	1057203.408*	226101.795*	2.914 ns	8.172 ns
Experimental error	18	0.433	445713.702	105720.450	3.012	7.568
Coefficient of variations (%)		29.14	19.80	21.21	3.82	12.36
(b) Means comparison for treatment combinations(b)						
Treatment combinations		g plant-1	kg ha-1		%	%
Control		1.533 a	3653.340 abc	1700.852 ab	36.437 a	21.546 a
Removal of 25% of plants at seedling emergence		1.947 a	4055.533 ab	1782.961 ab	43.993 a	21.042 a
Removal of 50% of plants at seedling emergence		2.723 a	3648.590 abc	1633.336 ab	44.537 a	24.076 a
Removal of 75% of plants at seedling emergence		2.537 a	2689.633 c	1213.300 b	45.157 a	22.913 a
Removal of 25% of plants at stemming		1.813 a	4436.517 a	2055.712 a	46.150 a	19.982 a
Removal of 50% of plants at stemming		2.370 a	3448.477 abc	1556.237 ab	44.940 a	21.056 a
Removal of 75% of plants at stemming		2.507 a	2687.990 c	1195.075 b	44.167 a	21.485 a
Removal of 25% of plants at flowering		1.687 a	3254.497 abc	1521.817 ab	46.860 a	22.135 a
Removal of 50% of plants at flowering		2.217 a	3071.117 bc	1399.244 b	45.587 a	22.679 a
Removal of 75% of plants at flowering		3.247 a	2763.583 bc	1269.563 b	46.050 a	25.632 a
(c) Analysis of variance of the effect of time and intensity of plants removal (a)						
Replication	2	0.096 ns	115994.191 ns	58252.035 ns	5.206 ns	8.543 ns
Plants removal time (A)	2	0.080 ns	655937.064 ns	100687.601 ns	6.016 ns	16.491 ns
Plants removal intensity (B)	2	2.086 *	3266390.413 **	709359.837 **	1.086 ns	12.295 ns
A × B	4	0.350 ns	349803.106 ns	80173.389 ns	2.087 ns	3.575 ns
Experimental error	16	0.486	447923.259	107748.886	3.355	8.481
Coefficient of variations (%)		29.80	20.04	21.68	4.05	13.04
Time of plants removal		g plant-1	ha-1	kg		
50% seedling emergence		2.402 a	3464.586 a	1543.199 a	44.562 a	

50% stemming	2.230 a	3524.328 a	1602.341 a	45.086 a
50% flowering	2.383 a	3029.732 a	1396.875 a	46.166 a
Intensity of plants removal	g plant-1	kg ha-1		
Removal of 25% of plants	1.816 b	3915.516 a	1786.830 a	45.668 a
Removal of 50% of plants	2.437 ab	3389.394 a	1529.606 ab	45.021 a
Removal of 75% of plants	2.763 a	2713.736 b	1225.980 b	45.124 a

(a) ns, * and ** show non-significance and significance at 5 and 1% probability level.
(b) Figures in the columns with similar letter(s) did not have significant differences at 5% probability level.

Oil Yield

The combinations of plants removal time and intensity significantly affected rapeseed oil yield at 5% probability level (Table 1a). The non-significant effect of 25 and 50% removal of plants at seedling emergence and stemming and 25% removal of plants at flowering on rapeseed oil yield (Table 1b) showed that the control density (67 plants m^{-2}) was in excess to the density required for obtaining the maximum oil yield. The removal of 25% of plants at stemming and the decrease in density from 67 to 50 plants m^{-2} resulted in the highest oil yield (2056 kg ha^{-1}) among all treatments which, however, was in the same statistical domain with control (Table 1b). Among the evaluated combinations of plants removal time and intensity, the removal of 75% of plants at seedling emergence and stemming as well as the removal of 50 and 75% of plants at flowering resulted in significantly lower oil yield than control (1701 kg ha^{-1}; Table 1b) suggesting that rapeseed is less sensitive to plants removal at vegetative growth stages than at reproductive growth period. In other words, rapeseed population will have more opportunity to compensate the loss of plants by increasing the yield of the remaining plants if plants are removed during vegetative growth.

Table 2. Response of seed yield per plant and unit area and oil yield to the intensity of plants removal at different growth stages of rapeseed in Bam region, Iran in 2010.

Trait	Seed yield per plant (g/plant)			Seed yield per unit area (kg/ha)			Oil yield per unit area (kg/ha)		
Control	1.533			3656.340			1700.852		
	Time of plants removal								
Plants removal intensity	Seedling emergence	Stemming	flowering	Seedling emergence	Stemming	flowering	Seedling emergence	Stemming	flowering
	Percentage of variations as compared to control								
25%	+27.0	+18.3	+10.0	+10.9	+21.3	-11.0	+4.8	+20.9	-10.5
50%	+77.6	+54.6	+44.6	-0.2	-5.7	-16.0	-4.0	-8.5	-17.7
75%	+65.5	+63.5	+46.6	-26.4	-26.5	-24.4	-28.7	-29.7	-25.4

The growth stage at which the plants were removed did not significantly affect oil yield, but this trait was significantly related to the intensity of plants removal at 1% probability level (Table 1c). In spite of the loss of oil yield per unit area with the increase in the intensity of plants removal, only the removal of 75% of plants resulted in significant loss of oil yield (1226.0 kg ha^{-1}) as compared to that under the removal of 25% of plants (1786.8 kg ha^{-1}; Table 1d). Oil yield in the treatment of 50% plants removal (1529.6 kg ha^{-1}) did not significantly differ from that in the treatment of 25 and 75% plants removal (Table 1d). Some studies have shown that oil yield is increased with plant density (Danesh Shahraki *et al.*, 2008). The opposite has been reported by Hassan and Hakeem (1996) and Shiranirad (1994). Sajedi *et al.* (2009) reported that lower seeding rate (4 kg ha^{-1}) maximized seed oil production to 1157.2 kg ha^{-1}.

Seed Oil Content

Seed oil content was not significantly related to different treatments of plants removal time and intensity (Table 1a). Therefore, seed oil content behaved independent of the variations of plant density during growing season. In total, seed oil content ranged 43.99-46.86 under different treatments. The stage and intensity of plants removal did not significantly influence seed oil content, either (Table 1c). Many studies have shown the lack of the effect of plant density on seed oil content of rapeseed

(Poorsiah Bidi *et al.*, 2010; Yazdifar *et al.*, 2006; Fanaye *et al.*, 2008; Fathi, 2008). Finally, Sajedi *et al.* (2009) stated that the impact of row spacing was significant on seed oil content at 5% level. Out of the evaluated treatments, the row spacing of 50 cm and two-line sowing on furrow produced the highest seed oil percentage (47.28%).

Harvest Index

Harvest index was not significantly influenced by different treatments of plants removal time and intensity (Table 1a). The effect of stage and intensity of plants removal was not significant on this trait, either (Table 1c). Overall, harvest index was in the range of 20.0-25.6 under different treatments (Table 1b). The slight variations of harvest index showed its dependence on plant genetic structure (Imam and Niknejad, 1994). Ilkayi and Imam (2003) showed that the self-regulation mechanism for the balance between vegetative and reproductive organs was the reason for slight variations of harvest index at different densities.

Discussion

8-Seed Yield

The study of the response of seed yield per plant and per unit area to the time and intensity of plants removal revealed that the decrease in plants number per unit area increased seed yield per plant (Table 2). In other words, the removal of 25% of plants at seedling emergence, stemming and flowering increased seed yield per plant by 27.0, 18.3 and 10.0%, respectively. Also, the removal of 50% of plants at seedling emergence, stemming and flowering increased seed yield by 77.6, 54.6 and 44.6%, respectively and finally, the removal of 75% of plants at the mentioned stages resulted in the increase in this trait by 65.5, 63.5 and 44.6%, respectively (Table 2). Given the balance between the extent of the increase in seed yield per plant and the decrease in plant number per unit area, it can be seen that the removal of 50% of plants at seedling emergence and stemming increased seed yield by 77.6 and 54.6%, respectively, but this increase was only 65.5 and 63.5% under the removal of 75% of plants which was lower than the number of removed plants (Table 2). The removal of 25, 50 and 75% of plants at flowering resulted in much lower seed yield per plant than the number of removed plants which was increased by 10.0, 44.6 and 46.6%, respectively (Table 2). Therefore, as plants removal was delayed, the plants had less opportunity to compensate the impact of removed plants by increasing the seed yield per plant (Table 2). According to the graph of plant density and seed yield per plant by seed yield per unit area, the variations of this trait relative to the decrease in plant density showed that plants removal at flowering reduced seed yield of rapeseed, while the removal of 25 and 50% of plants at seedling emergence and the removal of 25% of plants at stemming not only did not reduce seed yield but also increase in by 10.9-21.3% (Table 2). Therefore, it can concluded that the maximum seed yield can be obtained in Bam region, Iran by reducing plant density to 57 plants m^{-2} (inter-plant spacing can be increased from 5.0 to 5.8 cm). Ogilvy (1984) showed that although optimum seeding rate in winter cultivation in the UK was about 4-8 kg ha^{-1}, similar yield was obtained by using 3-12 kg ha^{-1} with the differences of less than 10%. Also, he suggested that the existence of 80-100 plants m^{-2} in spring was optimum under which the field would be bald and exposed to more damages of pest and over which lodging would be likely to happen.

Oil Yield

As can be seen in Table 4, the removal of 25% of plants at seedling emergence and stemming increased oil yield by 4.8 and 20.9%, respectively, while oil yield negatively responded to the removal of 50 and 75% of plants at seedling emergence and stemming and all levels of plants removal at flowering (Table 2). Fanaye *et al.* (2008) reported that oil yield was positively correlated with seed yield and oil percentage and that the increase in seed yield was accompanied with the increase in extractable oil content. But, the effect of seeding rate was non-significant on oil percentage in their study.

Conclusion

According to the results of the present study:

Rapeseed is more sensitive to the intensity of plants removal than to its time.

The increase in seed yield per plant (20.7%) as 15% of plants was removed (the decrease in the density from 67 to 57 plants m^{-2}) was equal to the decrease in seed yield per unit area (20.8%). Therefore, the maximum seed yield in Bam region, Iran can be obtained by making use of the density of 57 plants m^{-2}.

The results regarding oil yield showed that the removal of plants up to 34% (the density of 45 plants m^{-2}) increased oil yield per unit area.

Recommendations

Revising the guidelines for determining the damages of the loss of plant number of rapeseed in Agriculture Insurance Fund.

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