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Research article

STUDY ON THE POTENTIAL OF RAPESEED CANOPY IN COMPENSATING PLANT DENSITY LOSS IN GROWING SEASON YIELD AND SEED YIELD COMPONENTS

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ABSTRACT: The potential of rapeseed canopy in compensating the loss of plant density during growing season yield and seed yield components 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 evaluated traits included seed yield, and seed yield components (the number of pods per area, the number of seeds per pod, single-seed weight). It was found that rapeseed was more sensitive to the intensity of plants removal than to the growth stage at which the plants were removed. The loss of plant number per unit area resulted in higher seed yield per plant. Although as plants removal was delayed, the plants had more opportunity to compensate the removed plants by increasing seed yield per plant, the increase in seed yield per plant (20.7%) with the removal of 15% of plants was equal to the decrease in seed yield per unit area (20.8%). Therefore, maximum seed yield can be obtained in Bam, Iran by reducing the density to 57 plants m^{-2}. The evaluation of the trend of the response of different seed yield components to the variation of plant density showed that plants removal was most effective on the number pods per unit area followed by seed number per plant and single-seed weight. The potential of the plants to offset plant deficiency by increasing pod number per plant was decreased by retarding plants removal from vegetative to reproductive growth stage.

Keywords: Bam, rapeseed, plants removal time, plants removal method, seed yield.

INTRODUCTION

Increasing growth of population is an important problem in the modern world, particularly in undeveloped and developing countries [1]. Under these conditions, the deficiency of high-quality oil production resources is strongly felt [2]. Oilseeds are regarded as the second most important food source of the world after grains. Rapeseed is one of the most important oilseeds throughout the world [3]. One of the requirements for high yield is to provide optimum conditions for the interception of solar radiation for the production of assimilates with the highest efficiency possible [2] which can be made possible by manipulating plant density and distribution per unit area [4]. In a study in Rasht, Iran, Ozoonidooji et al. [5] reported that out of the three studied densities of 33, 67 and 133 plants m^{-2}, the density of 67 plants m^{-2} resulted the highest dry matter and consequently, the highest grain yield owing to the utilization of space and other resources by plants, the decreased competition among plants, higher leaf area index and higher plant growth rate [5]. Sajedi et al. [6] reported that reducing seeding rate (to 4 kg ha^{-1}) maximized seed oil production (1157.2 kg ha^{-1}) [6]. Ahmadi [7] reported the significantly decrease in pod number per plant with the increase in plant density per unit area [7]. Fathi [8] stated that the effect of density was significant on pod number at 5% probability level and that the increase in the density from 50 to 90 plants m^{-2} resulted in higher number of pods per unit area [8]. Poorsiah Bidi et al. [9], also, reported that plant density did not significantly influence the number of seeds per pod [9]. Fathi [8] showed that the effect of density was not significant on the number of seeds per pod [8]. However, this trait declined with the increase in plant density. Many researchers have reported that the variations in plant density do not impact 1000-seed weight of rapeseed [10, 11]. Emphasizing the non-significant effect of plant density on 1000-seed weight, Behzadi et al. [12] reported that the highest (2.80 g) and lowest (2.60 g) 1000-seed weight were obtained from the densities of 100 and 40 plants m^{-2}, respectively [12].

Fanaye et al. [13] reported the positive correlation of oil yield with seed yield and oil percentage and that oil extraction was increased with the increase in seed yield [13]. However, they showed that the effect of seeding rate was non-significant on oil percentage.

MATERIALS AND METHODS

The study was carried out in Natural Resources Nursery of Bam, Iran (Long. 58°18' E., Lat. 29°05' N.) in 2009-2010. Mean precipitation was 112 mm, mean maximum temperature was 37°C and mean minimum temperature was 7.8°C. The soil texture was loam-sandy with mean pH of 467 and electrical conductivity of 3.37 dS m^{-2}. Soil analysis showed that the soil of study field was deficient in organic matter, absorbable N, and absorbable P (0.47%, 0.025 mg kg^{-1}, 8.63 mg kg^{-1}, respectively) but the field was in a better status in terms of absorbable K (200 mg kg^{-1}).The study was a factorial experiment on the basis of a Randomized Complete Block Design with three replications in which the first factor was devoted to plants removal time including seedling emergence, stemming and flowering and the second factor was devoted to plants removal intensity including the removal of 25, 50 and 75% of plants. Each replication was composed of nine plots and each plot included a control. Each sub-plot was composed of six rows with inter-row spacing of 30 cm. The rows were 6 m long. The soil was fertilized according to fertilizer recommendations of regional research center. The weeds were controlled by Terfelan which was applied as prerequisite of hand weeding. The field was weeded by hand during growing season, too. The seeds were sown on November 22, 2010 by hand. Two seeds were sown in each sowing space. One plant was thinned at 2-4-leaf stage. The first irrigation was carried out after sowing followed by another one three days later. To study the number of pods, the number of seeds per pod and single-seed weight, 10 plants was randomly selected from each plot 5 days before final harvest to do the calculations on them. 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. Then, the total yields of the plots were measured. 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). Yazdpour et al. [14] showed that the effect of density was significant only on seed yield and that the highest seed yield was obtained under the density of 60 plants m^{-2} [14[. Fathi [8] stated that the effect of density was significant on seed yield at 5% probability level and the maximum (4.1 t ha^{-1}) and minimum (2.4 t ha^{-1}) seed yield was produced under the densities of 110 and 50 plants m^{-2}, respectively [8].

Pod Number

Different treatments of plants removal time and intensity significantly impacted pod number per unit area at 1% probability level (Table 1a). Pod number per unit area with the removal of 75% of plants at seedling emergence (4478 pods m^{-2}) and stemming (3960 pods m^{-2}) and with the removal of 50 and 75% of plants at flowering (6480 and 4840 pods m^{-2}) had significant differences with control (10688 pods m^{-2}; Table 1b). The investigation of the effect of growth stage and intensity of plants removal revealed that the plants removal stage had no significant effects on pod number per unit area, but the intensity of plants removal influenced this trait significantly at 1% probability level (Table 1c). The trend of the effect of increased intensity of plants removal on pod number per unit are was so that the removal of 50 and 75% of plants resulted in 18.3 and 55.0% loss of pod number per unit area as compared with the removal of 25% of plants (9842.3 pods m^{-2}; Table1d). Ahmadi [7] mentioned the significant loss of pods per plant with the increase in plant density per unit area [7]. On contrary, Fathi [8] stated that the effect of density was significant at 5% probability level on pod number per unit area and that the increase in density from 50 to 90 plants m^{-2} increased the number of pods m^{-2} [8]. Also, Hajazy [15] reported the increase in pod number per unit area with the increase in density up to 100 plants m^{-2} [15].

Seed Number per Pod

Different treatments of plants removal time and intensity did not significant impact the number of seeds per pod (Table 1a). Thus, the number of seeds per pod under various levels of the studied treatments was ranked in same statistical group with control (27.713 seeds pod^{-1}; Table 1b). Plants removal stage did not significant affect seed number per pod too, but its intensity influenced it significantly at 5% probability level (Table 1c). The least number of seeds per pod (26.473) was produced with the removal of 50% of plants which did not significantly differ with that with the removal of 25% of plants (29.363) but it showed significant differences with the number of seeds per pod with the removal of 75% of plants (30.237; Table 1d). In other words, the removal of 50 and 75% of plants resulted in 9.8 and 3.0% loss of seed number per pod as compared with that under the removal of 25% of plants (29.363), respectively (Table1d). Poorsiah Bidi et al. [9], also, reported the non-significant effect of plant density on seed number per pod [9]. In addition, Fathi [8] showed that the effect of density on seed number per pod was not significant [8]. Nonetheless, as plant density was increased, seed number per pod was decreased. Also, Leach et al. [16] stated that the percentage of barren pods was increased with plant density resulting in the loss of seed number per pod [16].

Table 1. Summary of (a) analysis of variance and (b) means comparison for the traits related to seed and yield components 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	Pod no./m^2	Seed no./pod	Single-seed wt
Replication	2	0.126ns	333025.393ns	370401.433^{ns}	5.628 ^{ns}	0.001 ^{ns}
Treatment	9	0.831ns	1057203.408*	19786476.300**	16.167 ^{ns}	0.012 ^{ns}
Experimental error	18	0.433	445713.702	2231037.878	10.158	0.007
Coefficient of variations (%)		29.14	19.80	19.24	11.15	19.81
(b) Means comparison for treatment combinations(b)						
Treatment combinations		g plant-1	kg ha-1	/m^2	Seeds/pod	mg
Control		1.533 a	3653.340abc	10688.000a	27.713a	0.417a
Removal of 25% of plants at seedling emergence		1.947 a	4055.533ab	10014.000a	28.867a	0.407a
Removal of 50% of plants at seedling emergence		2.723 a	3648.590abc	8966.667ab	22.930a	0.573a
Removal of 75% of plants at seedling emergence		2.537 a	2689.633c	4478.000c	28.797a	0.393a
Removal of 25% of plants at stemming		1.813 a	4436.517a	9580.000a	28.757a	0.397a
Removal of 50% of plants at stemming		2.370 a	3448.477abc	8676.000ab	27.763a	0.387a
Removal of 75% of plants at stemming		2.507 a	2687.990c	3960.000c	30.707a	0.403a
Removal of 25% of plants at flowering		1.687 a	3254.497abc	9933.000a	30.467a	0.333a
Removal of 50% of plants at flowering		2.217 a	3071.117bc	6480.000bc	28.727a	0.477a
Removal of 75% of plants at flowering		3.247 a	2763.583bc	4840.000c	31.207a	0.430a
(c) Analysis of variance of the effect of time and intensity of plants removal (a)						
Replication	2	0.096 ns	115994.191 ns	456771.370 ^{ns}	2.625 ^{ns}	0.001 ^{ns}
Plants removal time (A)	2	0.080 ns	655937.064 ns	1222759.148 ^{ns}	25.040 ^{ns}	0.009 ^{ns}
Plants removal intensity (B)	2	2.086 *	3266390.413 **	68473935.815 **	34.916 *	0.024 ^{ns}
A × B	4	0.350 ns	349803.106 ns	2534547.481 ^{ns}	5.753 ^{ns}	0.011 ^{ns}
Experimental error	16	0.486	447923.259	2491217.370	10.494	0.008
Coefficient of variations (%)		29.80	20.04	21.22	10.29	20.93
(d) Means comparison for the effect of time and intensity of plants removal (b)						
Time of plants removal		g plant-1	kg ha-1			
50% seedling emergence		2.402 a	3464.586 a	7819.556 a	26.864 a	0.458 a
50% stemming		2.230 a	3524.328 a	7405.312 a	29.076 a	0.396 a
50% flowering		2.383 a	3029.732 a	7084.333 a	30.133 a	0.413 a
Intensity of plants removal		g plant-1	kg ha-1			
Removal of 25% of plants		1.816 b	3915.516 a	984.333 a	29.363 ab	0.379 a
Removal of 50% of plants		2.437 ab	3389.394 a	8040.889 b	26.473 b	0.479 a
Removal of 75% of plants		2.763 a	2713.736 b	4426.000 c	30.237 a	0.409 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.

Single-seed Weight

The effect of different treatments of plants removal time and intensity was non-significant on single-seed weight (Table 1a). Therefore, this trait did not show any responses to the variations of plant density during growing season. It can be associated with the timing of applying plants removal treatments. Since the plants had been removed until the initiation of flowering, single-seed weight which reflects post-pollination growth conditions did not show any responses. In total, single-seed weight varied in the range of 0.333-0.477 mg under different treatments. The examination of the effect of the stage and intensity of plants removal on single-seed weight revealed that they did not significantly affect this yield component (Table 1c). Many researchers have reported the lack of the effect of plant density variations on 1000-seed weight of rapeseed [9, 10]. The results reported by Samani [21] show that 1000-seed weight is a cultivar-depended genetic trait, whereas some studies reveals the loss of 1000-seed weight with the increase in plant density [7, 13, 17].

Table 2. Response of seed yield per plant and unit area 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)		
Control	1.533			3656.340		
Time of plants removal						
Plants removal intensity	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
50%	+77.6	+54.6	+44.6	-0.2	-5.7	-16.0
75%	+65.5	+63.5	+46.6	-26.4	-26.5	-24.4

Table 3. Response of seed and oil yield components to the intensity of plants removal at different growth stages of rapeseed in Bam region, Iran in 2010

Trait	Pod number per unit area			Seed number per pod			Single-seed weight (mg)		
Control	10688			27.713			0.417		
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%	-6.3	-10.4	-7.1	+4.2	+3.8	+9.9	-2.4	-4.8	-20.1
50%	-16.1	-18.8	-39.4	-17.3	+0.2	+3.7	+37.4	-7.2	+14.4
75%	-58.1	-62.9	-54.7	+3.9	+10.8	+12.6	-5.8	-3.4	+3.1

DISCUSSION

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 (Table2). 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 5). 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 [18] 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% [18]. 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.

Seed Yield Components

The evaluation of the response of seed yield components to the variations of plant density during growing season indicated that plants removal had the highest impact on pod number per unit area followed by seed number per plant and single-seed weight. In fact, the negative correlation between pod number per unit area and seed number per pod in different rapeseed cultivars resulted in a marked negative correlation between seed number per pod and plant density [19]. In the present study, the removal of 25, 50 and 75% of plants at seedling emergence decreased pod number per unit area by 6.3, 16.1 and 58.1%, respectively (Table 3). The numerical difference of the loss of plant number and the loss of pod number per unit area can be regarded as the compensatory contribution of the increase in pod number per plant. Therefore, when 25, 50 and 75% of plants were removed at seedling emergence, 18.7, 33.9 and 16.9% of the loss of plant number was compensated by the increase in pod number per plant, respectively. The contribution of this compensatory effect was 14.6, 31.2 and 12.1% at stemming and 17.9, 10.6 and 20.3% at flowering, respectively. It seems that the potential of plants in offsetting the loss of plants by increasing pod number per plant was declined as the plants removal was retarded from vegetative to reproductive growth stage. The trend of the response of seed number per pod to the variations of plant density during growing season showed that the decrease in plant number was generally responded with the increase in pod number per pod. The greatest increase (12.6%) was devoted to the removal of 75% of plants at flowering (Table3). Taylor and Smith (1992) reported a negative correlation between pod number per unit area and seed number per pod of rapeseed cultivars and a strong negative correlation between seed number per pod and plant density [19]. In Clarck and Simpson (1978)'s study, the highest yield was obtained for the lowest seeding rate (1.5 kg ha^{-1}) and they concluded that the bearing of auxiliary branches and pod offset the effect of the decrease in density and the yield did not change or change slightly [20]. As plant density was increased, dry weight and yield components per plant were decreased. But in most cases, the increase in the number of plants per unit area compensated the loss of single-plant yield and so, the yield per unit area did not change or even increased.

Recommendations

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

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