Evaluation of Rapeseed Yield and Growth Indices as Affected by Nitrogen Fertilizer and Planting Density

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Abstract:
Nitrogen fertilizer application and optimal density are important factors in increasing the quantitative and qualitative yield of rapeseed. This study was carried out in order to investigate the effects of nitrogen fertilizers and plant density on physiological characteristics, yield and yield components of Canola, as a factorial experiment in a randomized complete blocks design with three replications at Sheshdeh region of Fasa, Iran (57°28′09″ E, 53°58′06″ N) in *2018-2019* and 2019-2020 years. Nitrogen fertilizer factor in 12 levels including a_1: urea (recommended) before planting and stem elongation, a_2: urea (recommended) before planting, stem elongation and heading, a_3: urea (recommended) in stem elongation and heading, a_4: urea (under recommended) before planting and stem elongation a_5: urea (under recommended) before planting, stem elongation and heading, a_6: urea (under recommended) in stem elongation and heading, a_7: ammonium sulfate (recommended) before planting and stem elongation, a_8: ammonium sulfate (recommended) before planting, stem elongation and heading, a_9: ammonium sulfate (recommended) in stem elongation and heading, a_{10}: ammonium sulfate (under recommended) before planting and stem elongation a_{11}: ammonium sulfate (under recommended) before planting, in stem elongation and heading, a_{12}: ammonium sulfate (under recommended) stemming and heading and density factor in three levels 50, 70 and 90 plants m^{-2}. Results indicated that The highest leaf area index (4.1) was obtained at a density of 50 plant.m^{-2} in 160 days after planting. The increasing slope of rapeseed growth rate at densities of 50 and 70 plants.$m^{-2}$was much higher than of 90 plants.m^{-2}density. Application of urea as recommended (F_2: 120kg ha^{-1} or120g $plot^{-1}$) in three stages as 40 g before planting, 40 g in stem elongation and 40 g in heading stages and the density of 90 plants m^{-2} caused the lowest number of racemes in main branches (15.83 racemes $mainbranches^{-1}$). The highest 1000-seed weight was recorded in ammonium sulfate as recommended (264 $kgha^{-1}$ or 264g $plot^{-1}$) in before planting and heading stages with 50 and 70 plant m^{-2} density in both experimental years (4.40,4.40,4.36 and 4.44g respectively). with increasing density, seed yield and oil yield decreased considerably and this decreasing was more in the first year than in the second year. 1000-seed weight was the most important component affecting seed yield (r = 0.65). According to the results of this study, to achieve the highest yield using ammonium sulfate as recommended (264 kg ha^{-1} or 264g $plot^{-1}$) in before planting and heading stages and density of 70 plants m^{-2} is recommended.

Keywords: Ammonium sulfate, Density, Rapeseed, Seed yield, Urea.

INTRODUCTION

Rapeseed (*Brassica napus* L.) is one of the most important oil crops in the world that with its special properties such as high oil content and suitable flexibility for cultivation in different climates, can largely compensate for the shortage of oil production. This has good branching ability and in low densities can compensate the lack of plants by increasing the number of sub-branches. Optimal plant density in Rapeseed, according to the climatic conditions and soil of the region, causes the plant use all environmental factors such as water, air, light and resources (Kimber and Groger, 1995). Angadi et al. (2003) reported that Rapeseed can regulate its yield over a wide range of densities. Although Rapeseed cannot fully compensate very low densities, environmental conditions play a significant role in compensatory ability. Gann (2003) reported that the optimal plant density of rapeseed varies depending on environmental conditions, and the longer the post-flowering period, the more critical the yield increasing. Liu et al. (2019) showed that with increasing density, single plant yield decreased but total yield increased.

Nutrition in rapeseed is a factors that affect on grain yield, oil content and grain quality. The use of nitrogen fertilizer depends on soil nitrogen availability and nitrogen losses. Different factors such as moisture limitation, nitrogen losses, low uptake, weed competition and improper use of fertilizers, affect nitrogen uptake (Taheri et al, 2005). Jackson (2000) observed that rapeseed grain and oil yield increased by application of 200 kg ha^{-1} N. Khan et al. (2011) showed that ammonium sulfate increased rapeseed yield more than urea. In alkaline soils, ammonium sulfate is effective in acidifying the root zone so improves the absorption of elements such as phosphorus, nitrogen and micro elements. Anjum et al. (2016) reported that the yield and yield components of rapeseed increased by application of ammonium sulfate fertilizer. Therefore, to improve rapeseed yield, the application of this fertilizer is preferable to other sources of nitrogen fertilizer. Nitrogen deficiency reduced plant population density at harvest stage, which decreased yield by 35.1% and 17.1% in non nitrogen application and 60 kg ha^{-1} N treatments respectively. In addition to nitrogen fertilizer application, optimal application time also has a beneficial effect on increasing grain and oil yield in rapeseed (Liu et al., 2019). Nitrogen rate is important in rapeseed. The amount and distribution of N had only minor effects on canola growth ($P < .05$) and no effects on yield or harvest index. Splitting fertilizer into two or three applications throughout the season resulted in more mineral N available in the soil later in the season (Becker et al., 2020). In a study it was shown that N-use efficiency was influenced more by N recovery and uptake efficiency, rather than physiological efficiency, which highlights the importance of soil moisture availability and the ability of the crop to exploit soil water and N reserves (Riar et al., 2020). Accordingly, this study was aimed to evaluate the effect of type, amount and application time of nitrogen fertilizer in different planting density on growth indices and yield of rapeseed.

MATERIALAND METHODS

Two field experiments were conducted at the Sheshdeh region, Shiraz, Iran (2018-2019 and 2019-2020). The field was located at the south of Iran; 57°28′09″ E, 53°58′06″ N, and an altitude of 1500 m above sea level. The region is characterized with a warm-temperate and semi-arid environment. The average annual (30 years) precipitation and temperature are 221 mm and 27°C, respectively. The monthly weather data logged during the experimental time in each year are provided in Table 1. The experiment was in a factorial based on randomized complete block design in three replicates. A factor was nitrogen fertilizer at twelve levels (described in Table 2) as F_1, F_2, …… F_{12} and B factor was density at three levels (50, 70 and 90 plant m^{-2}) as D_1, D_2 and D_3. Soil samples were gathered from the experimental zone at 0–30 cm depth to examine preliminary soil characteristics, and the results of the soil test are shown in Table 3.

The land was plowed, and then double disking was done perpendicular to each other for crushing lumps and softening the land. In each replication, 36 plots were created. Each plot had ten rows with 5-m length and 0.2-m distance between rows. Two unplanted rows were considered between two plots . Inter- replication planting space was 2 m. The seeds of *Brassica napus* L were sown according to the desired densities on Novamber 18 and 16 in two consecutive years of experiment, respectively. The used seed in this experiment was Hayola 50 cultivar that was prepared from the Seed and Plant Improvement Institute of Zarghan, Shiraz, Iran.

Table 1. Monthly weather data logged during the experimental time

Year/month		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
2018-2019	Average minimum temperature (°C)	14.4	9	3.2	1.6	2.7	3	9.4	12.3
	Average maximum temperature (°C)	31.3	22.9	19	16.9	15.6	16.6	21.4	28.8
	Precipitation (mm)	2	11.5	17	21.5	54.5	37	177.5	6
2019-2020	Average minimum temperature (°C)	15.3	7.9	3.9	1.7	0.7	3.8	7.4	11.6
	Average maximum temperature (°C)	32.5	22.9	16.1	14.3	15.5	20.6	21	29.6
	Precipitation (mm)	16	11	127	150.5	28	21	122	30.5

Table 2. Description of the treatment of fertilizers used in the experiment

A factor (fertilizer)	Description
F_1	Urea [recommended (120kgha^{-1} or120g $plot^{-1}$) as 60g before planting and 60 g in heading stage]
F_2	Urea [recommended (120kgha^{-1} or120g $plot^{-1}$) as 40 g before planting, 40 g in stem elongation and 40 g in heading stage]
F_3	Urea [recommended (120kgha^{-1} or120g $plot^{-1}$) as 60g in stem elongation and 60g in heading stage]

F_4	Urea [under recommended (90 kgha^{-1} or 90g plot^{-1}) as 45 g before planting and 45gr in heading stage]
F_5	Urea [under recommended (90 kgha^{-1} or 90g plot^{-1}) as 30 g before planting, 30g in stem elongation and 30gr in heading stage]
F_6	Urea [under recommended (90 kgha^{-1} or90 g plot^{-1}) as 30g in stem elongation and 30 g in heading stage]
F_7	Ammonium sulfate [recommended (264 kgha^{-1} or 264g plot^{-1}) as 132 g in before planting and 132 g in heading stage]
F_8	Ammonium sulfate [recommended (264 kgha^{-1} or 264g plot^{-1}) as 88 g in before planting, 88 g in stem elongation and 88 g in heading stage]
F_9	Ammonium sulfate [recommended (264 kgha^{-1} or 264g plot^{-1}) as 132 g in stem elongation and 132 g in heading stage]
F_{10}	Ammonium sulfate [under recommended (198 kgha^{-1} or 198g plot^{-1}) as 99 g in before planting and 99 g in heading stage]
F_{11}	Ammonium sulfate [under recommended (198 kgha^{-1} or 198g plot^{-1}) as 66 g in before planting, 66 g in stem elongation and 66 g in heading stage]
F_{12}	Ammonium sulfate [under recommended (198 kgha^{-1} or 198g plot^{-1}) as 99 g in stem elongation and 99 g in heading stage]

Table 3. The results of soil analysis at the experimental sites (soil depth 0–30 cm)

Year	Soil depth	Sand %	Silt %	Clay %	Soil texture	Organic carbon (%)	Organic matter (%)	Total nitrogen (%)	Available P (mg kg^{-1})	K (mg kg^{-1})	pH	EC
2018 - 2019	0-30	27	55	18	siltyloam	1.6	0.45	0.16	9.8	320	7.41	1.79
2019 - 2020	0-30	27	55	18	siltyloam	1.63	0.45	0.17	9.5	265	7.41	1.19

Traits measurement

Leaf area and plant dry weight were measured every 5 days in 5 stages of growth from the time of stem elongation to the seed filling in the pod stage. Leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) were measured using Equations (1), (2) and (3), respectively.

$$LAI = (LA2 + LA1)/2 \times (1/GA) \quad (1)$$

$$CGR = (1/GA) (W2 - W1) (T2 - T1) \quad (2)$$

$$NAR = (W2 - W1) (T2 - T1)\times (\ln LA2 - \ln LA1)(LA2 - LA1) \quad (3)$$

In harvesting stage, the sampling process was carried out from 1 m^2 area of each plot and traits such as plant height, number of sub-branches, number of silique per sub-branch, number of silique per main branch, number of silique per plant, silique length, number of seeds per silique, 1000-seed weight, biological yield, grain yield and harvest index were measured. A 100 g sample of seeds was taken from each plot to determine the oil percentage and oil yield.

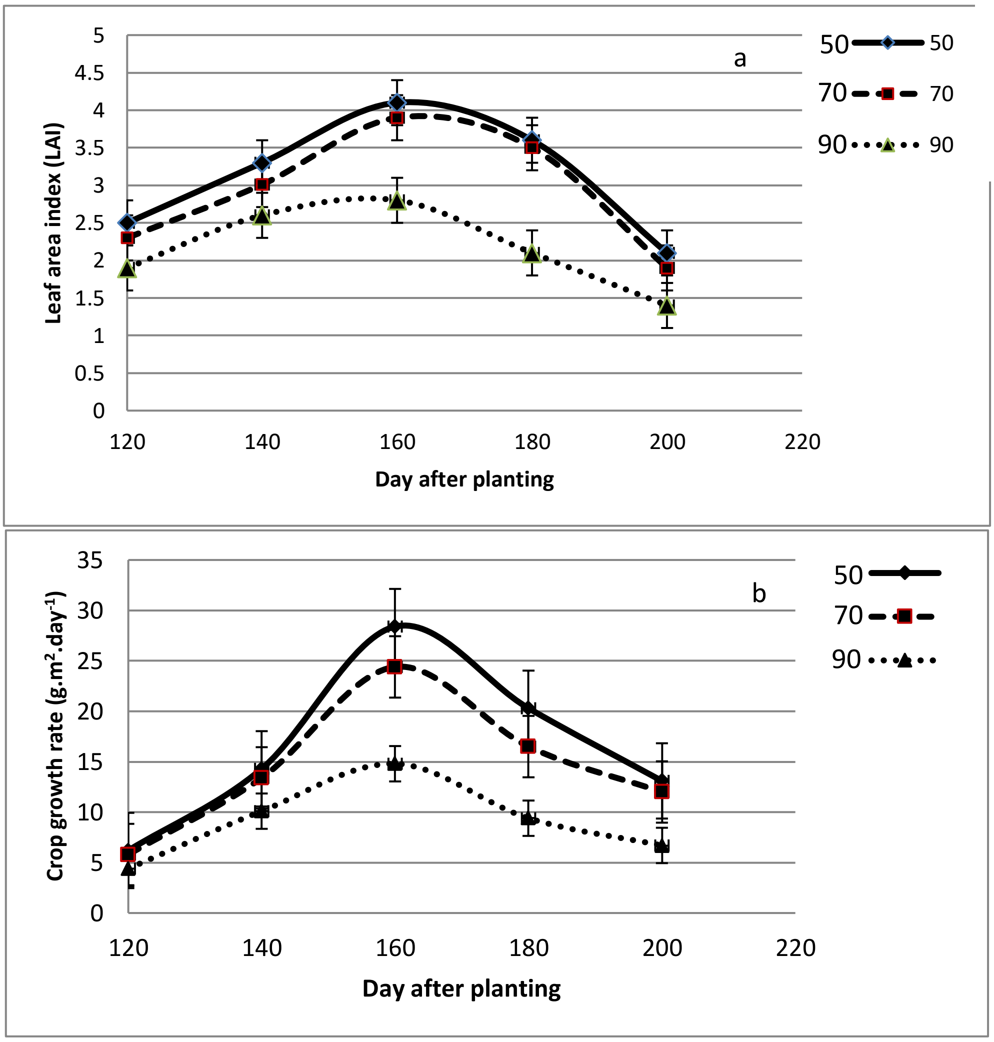
Experimental design and data analysis

A factorial analysis was applied in randomized complete blocks design in two years. Each treatment was repeated three times and wherever significant differences were obtained by the ANOVA, a comparative Duncan test ($P \leq 0.05$) was carried out. Bartlett test was applied to ensure the homogeneity of error variances. All of the traits were analyzed by combined analysis because of homogeneous error variances for two consecutive years. The obtained data were analyzed using SAS v 9.1 (SAS Institute Inc. USA).

RESULTS AND DISCUSSION

Leaf area index (LAI)

The differences in leaf area index among nitrogen fertilizer treatments was not significant while these differences was more evident in planting densities. The trend of changes in leaf area index showed that rapeseed leaf area index had a similar trend in all densities during the growth period (Figure 1 a). With the arrival of the fast growing period of the crop in stem elongation stage (the first stage of sampling) and the increase in the number of leaves, the leaf area index showed an increasing trend and in the flowering stage reached to its maximum value. After that due to shading of top leaves , yellowing and aging of lower leaves and transfer process of re-transferring of material to the reproductive organs, leaf area index decreased. During the growth period and different stages of sampling, the leaf area index in 50 and 70 plant m^{-2} densities did not differ much due to less inter competition between rapeseed. In the sampling stages, especially from the flowering stage, because of increasing inter-competition of rapeseed for resources, the difference between the leaf area index at the density levels of 50 and 70 plant.m^{-2} was more noticeable with a density of 90 plants .m^{-2}. Also, in the last stage of sampling (ripening), due to the aging and fall of leaves at the end of the growing season, the leaf area index diagrams almost coincided with each other. The highest leaf area index (4.1) was obtained at a density of 50 plant.m^{-2} in 160 days after planting, on the other hand at the time of emergence of pods and the beginning of seed formation in pods, while at the same stage, leaf area index at density of 90 plant.m^{-2} was 2.8 (Figure 1 a). It seems that despite the increasing in rapeseed leaf area index at the density of 90 plants.m^{-2}, this density caused the increase of rapeseed competition and negative effects on LAI. However, rapeseed at a density of 50 and 70 plants .m^{-2} had the more competitive ability compare to 90 plant.m^{-2} density.



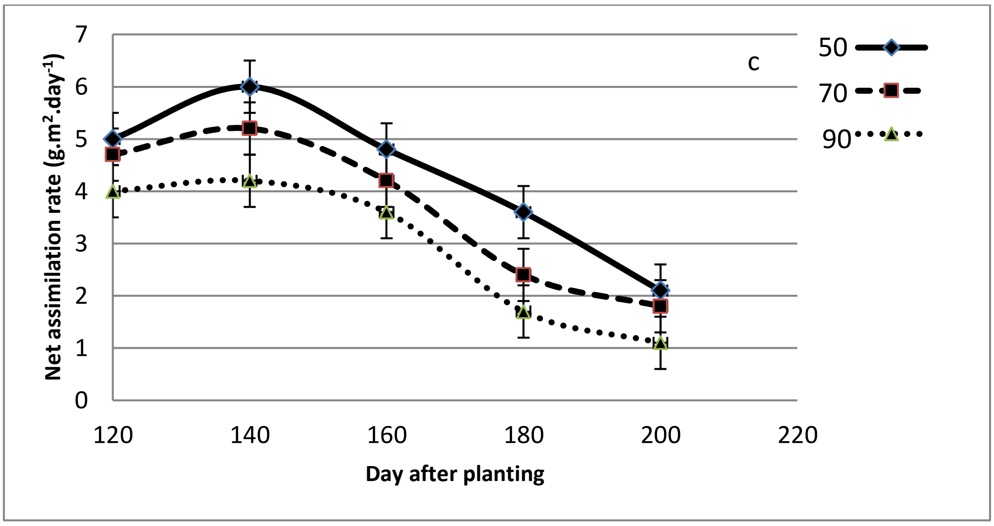


Figure 1. Changes in leaf area index (a), crop growth rate (b) and net assimilation rate (c) in Canola with different densities. Vertical bars represent the standard errors of the means

Crop growth rate (CGR)

The differences in crop growth rate among nitrogen fertilizer treatments was not significant while these differences was more evident in planting densities. Crop growth rate indicates the amount of dry matter accumulation over time per unit area of land. The growth rate pattern of rapeseed was relatively same in all densities. rapeseed growth rate increased slowly at the beginning of the season due to the small size of the plant and then due to the increase in leaf area, this increased to the late flowering and beginning of pod appearance stages. It reached to its maximum in pod appearance stage. After that, due to the allocation of photosynthetic materials to the seed, the reduction of leaf area (aging and leaf falling), CGR found a downward trend (Figure 1 b). The maximum growth rate of rapeseed achieved at a density of 50 plants. m^{-2} ($g.m^{-2}.day^{1}$) (Figure 1 b), which it showed a 50% increase compared to the density of 90 plants.m^{-2}at the same stage. Over time, rapeseed growth rate increased in all densities. The increasing slope of rapeseed growth rate at densities of 50 and 70 plants.$m^{-2}$was much higher than of 90 plants.m^{-2}density, while the decline in rapeseed growth rate at 90 plant.m^{-2} density was less than 50 and 70 plants.m^{-2}.

Net assimilation rate (NAR)

The differences in net assimilation rate among nitrogen fertilizer treatment was not significant while these differences was observed in planting densities treatment. The net assimilation rate is an estimate of the net photosynthesis of the leaf. The net assimilation rate is at its maximum when all the leaves are fully exposed to the sun. This value corresponds to when the plants are small in size and the leaves are so large that they do not shade each other. The shape of the NAR curve is descending and with increasing of plant age, the net photosynthesis of the leaves decreases due to the shading of the leaves on top of each other and the aging of the leaves. Researchers have shown that the type of vegetation pattern, even if the number of plants per unit area be constant, is effective on NAR and therefore the photosynthetic efficiency of the plant population is different in different patterns of planting. The curve of changes in net assimilation rate at different densities showed that in the early stages of plant growth, net assimilation rate was maximum due to low leaf area and lack of shading on each other and as a result of light competition, especially at a density of 50 plants. m^{-2} but as time went on and increasing leaf area and leaves shading on each other, the NAR curve decreased sharply and eventually as the leaves aged, the production efficiency per leaf decreased and the NAR decreased and reached the minimum value especially at 90 plant.m^{-2} density (Figure 1 c).

Yield component and yield

Sub-branch number

The analysis of variance results showed that the interaction effect of fertilizer and density on the number of sub-branches was significant (***$P \leq 0.01$***) (table 4). Results showed that application of ammonium sulfate as recommended (F_9: 264 kgha^{-1} or 264g plot^{-1}) in stem elongation and heading stages and the density of 70 plants m^{-2} caused the more increasing in number of sub-branches (6.16 sub-branch plant^{1}). Application of urea as recommended (F_2: 120kg ha^{-1} or120g plot^{-1}) as 40 g before planting, 40 g in stem elongation and 40 g in heading stages and the density of 90 plants m^{-2} caused the lowest number of sub-branches per plant (3.38 sub-branch plant^{-1}) (table 5). However, if the same amount of urea was consumed in two stages (F_3), it would further increase the number of sub-branches per plant. Therefore, nitrogen fertilization installments were important.

Table 4.Variance analysis effects of Year (Y) × Density (D) × Fertilizer (F) on yield component , grain and oil yield characteristics of rapeseed

S.o.v	df	Subbranches N.	Racemes/ subbranch	Racemes/ branch	Racemes/ plant	Racemes length	Seed number/ Racemes	Seed thousand weight	Biological yield	Seed yield	Oil%	Oil yield
Y	1	3.12ns	71576.9**	10154.4**	26400.6**	1.77**	214.0**	0.0004^{ns}	6591744^{ns}	1577678.0ns	1.18ns	1960125.0ns
Error	4	23.9	16744.2	2232.4	2199.1	4.65	36.0	0.09	334376814	21572216.0	36.96	4173875.7
F	11	1.42ns	563.7**	286.4**	**431.7	0.44*	11.40ns	0.26ns	19670233ns	409427.2**	20.4*	641320.1*
Y ×F	11	0.48ns	245.2	114.6ns	211.9ns	0.06ns	4.14ns	0.02ns	8010618ns	2528530.5*	0.82ns	265798.3ns
D	2	2.58ns	4363.5**	1515.4**	4788.3**	0.55ns	370.0**	0.71ns	626707836**	29179301.0**	5.28ns	8496519.6**
F×D	22	2.17*	289.06^{ns}	203.7*	320.8**	0.34*	8.41ns	0.40ns	16539010ns	1052298.6ns	9.50ns	401949.1ns
Y×D	2	0.47ns	4202.1**	2261.6**	3664.6**	0.13ns	409.4**	0.07*	7945ns	49996902.4**	0.17ns	93908.9ns
Y× F×D	22	0.58ns	496.4**	142.06ns	422.9**	0.08ns	8.90ns	0.05**	11681877ns	1439158.7ns	1.20ns	152402.9ns
Error	140	0.58	30822.4	115.5	138.2	0.21	7.72	0.19ns	12696690	1336534.7	10.54	327012.6
Coefficient of variation (%)		24.5	24.6	30.9	17.3	8.4	16.19	11.40ns	30.3	30.1	8.85	30.17

ns, * and ** show non significance, significant differences at 0.05, 0.01 probability level, respectively.

Table 5. Two-year mean values of several agronomic characteristics as affected by fertilizer and density interaction

Fertilizer	**Density**	**Subbranches no.**	**Racemes/ Sub-branch**	**Racemes/ plant**	**Racemes length (cm)**
F_1	**D1**	5.16 ^{bc}	30.66 ^{cd}	67.66 ^{d}	5.80 ^{a}
	D2	4.83 ^{c}	25.66 ^{d}	71.50 ^{c}	5.20 ^{b}

	D3	4.66 ^{cd}	28.50 ^{d}	63.33 ^{e}	5.33 ^{ab}
F_2	**D1**	4.83 ^{c}	17.66 ^{e}	55.83 ^{fg}	5.28 ^{b}
	D2	5.00 ^{bc}	34.16 ^{c}	73.50 ^{c}	5.31 ^{ab}
	D3	3.83 ^{e}	15.83 ^{e}	52.00 ^{g}	5.11 ^{b}
F_3	**D1**	4.50 ^{cd}	33.16 ^{c}	53.66 ^{fg}	5.68 ^{ab}
	D2	4.33 ^{c}	39.50 ^{b}	80.83 ^{b}	5.50 ^{ab}
	D3	5.83 ^{ab}	35.00 ^{bc}	57.50 ^{f}	5.13 ^{b}
F_4	**D1**	4.83 ^{c}	18.66 ^{e}	75.00 ^{c}	5.23 ^{b}
	D2	5.33 ^{abc}	23.00 ^{de}	61.00 ^{ef}	5.71 ^{a}
	D3	5.50 ^{ab}	26.50 ^{d}	51.50 ^{g}	5.41 ^{ab}
F_5	**D1**	4.33 ^{d}	34.66 ^{bc}	61.66 ^{e}	5.66 ^{ab}
	D2	5.66 ^{ab}	26.33 ^{d}	65.50 ^{de}	5.43 ^{ab}
	D3	5.50 ^{ab}	28.16 ^{d}	57.66 ^{f}	5.46 ^{ab}
F_6	**D1**	4.50 ^{cd}	26.66 ^{d}	60.83 ^{ef}	5.78 ^{a}
	D2	5.00 ^{bcd}	48.16 ^{a}	77.16 ^{c}	5.30 ^{ab}
	D3	4.16 ^{de}	28.16 ^{d}	62.16 ^{e}	5.23 ^{b}
F_7	**D1**	4.33 ^{cd}	28.33 ^{d}	68.33 ^{d}	5.98 ^{a}
	D2	4.83 ^{c}	42.00 ^{b}	82.50 ^{b}	5.96 ^{a}
	D3	5.83 ^{ab}	25.00 ^{de}	65.83 ^{de}	5.33 ^{ab}
F_8	**D1**	4.50 ^{c}	32.50 ^{cd}	69.50 ^{d}	5.13 ^{b}
	D2	5.50 ^{ab}	30.66 ^{cd}	71.50 ^{cd}	5.11 ^{b}
	D3	4.66 ^{c}	30.16 ^{cd}	75.50 ^{c}	5.41 ^{ab}
F_9	**D1**	5.66 ^{ab}	23.50 ^{de}	73.16 ^{c}	5.63 ^{ab}
	D2	6.16 ^{a}	34.66 ^{c}	82.50 ^{b}	5.06 ^{b}
	D3	4.66 ^{c}	22.83 ^{de}	60.00 ^{ef}	5.15 ^{b}
F_{10}	**D1**	5.00 ^{bcd}	26.50 ^{d}	70.16 ^{cd}	5.46 ^{ab}
	D2	5.16 ^{bc}	33.66 ^{c}	80.33 ^{b}	5.53 ^{ab}
	D3	4.66 ^{c}	26.50 ^{d}	56.50 ^{fg}	5.43 ^{ab}
F_{11}	**D1**	5.33 ^{abc}	25.16 ^{d}	68.66 ^{cd}	5.38 ^{ab}
	D2	5.83 ^{ab}	31.66 ^{cd}	81.00 ^{b}	5.88 ^{a}
	D3	4.50 ^{cd}	27.66 ^{d}	58.66 ^{f}	5.53 ^{ab}
F_{12}	**D1**	5.50 ^{ab}	17.00 ^{e}	61.16 ^{ef}	5.38 ^{ab}
	D2	4.50 ^{cd}	42.83 ^{b}	95.00 ^{a}	5.61 ^{ab}
	D3	4.16 ^{de}	25.33 ^{d}	72.00 ^{cd}	5.78 ^{a}
Means followed by same letter on the column do not differ significantly at 5% probability, by Duncan test.					

Racemes number in main-branch and plant

The analysis of variance results showed that the effect of fertilizer, density and their interaction on the number of racemes in the sub-branch and per plant was significant (***$P \leq 0.01$***) (table 4). Results showed that application of urea as under recommended (F_6: 90 kgha^{-1} or 90 g plot^{-1}) in stem elongation and heading stages and the density of 70 plants m^{-2} caused the more increasing in number of racemes in main branches (48.16 racemes mainbranches^{-1}). Application of urea as recommended (F_2: 120kg ha^{-1} or120g plot^{-1}) in three stages as 40 g before planting, 40 g in stem elongation and 40 g in heading stages and the density of 90 plants m^{-2} caused the lowest number of racemes in main branches (15.83 racemes mainbranches^{-1}) (table 5). Also results showed that application of ammonium sulfate as under recommended (F_{12}: 198 kg ha^{-1} or 198g plot^{-1}) in stem elongation and heading stages and the density of 70 plants m^{-2} caused the more increasing in number of racemes per plant (95.00 racemes plant^{-1}). Application of urea as under recommended (F_4: 90 kgha^{-1} or 90g plot^{-1}) in three stages as 45 g before planting and 45gr in heading stages and the density of 90 plants m^{-2} caused the lowest number of racemes per plant (51.50 racemes plant^{-1}) (table 5). Adequate nitrogen supply, especially during the stem elongation and heading stages, is effective in increasing the number of racemes per plant. The reason why the application of nitrogen fertilizer in three stages (before planting, stemming and budding) did not increase the number of racemes per plant, is probably due to the lack of sufficient nitrogen required in these stages. This is due to the effective role of nitrogen nutrient management in the distribution of assimilates and modulating the effects of intra-plant and extra-plant competition (Zangani, 2003). Nitrogen splitting in three stages may also caused the increasing in photosynthetic levels and vegetative growth, which ultimately leads to a delay in the reproductive phase. This will cause the coinciding of seed filling period with the hot weather and hot winds at the end of the season, reducing yields (Malek Ahmadi *et a*l., 2009). One of the reasons for the increase in the number of racemes per plant due to the use of nitrogen fertilizer less than recommended can be that increasing the use of nitrogen causes more longitudinal growth of the plant and one of the results of increasing longitudinal growth is reduced growth of lateral branches (Malek Ahmadi *et a*l., 2009). The results showed that in the first year of the experiment (2018-2019), the number of racemes per branch decreased significantly with increasing plant density to 90 plant m^{-2}, but in the second year of the experiment (2019-2020), the results showed that with increasing plant density, the number of racemes per branch increased (table 6 and 7). The difference in this result in the two years of the experiment is probably due to nutrition, because in the first year of the experiment, the land was not planted the previous year (fallow), but in the second year of the experiment, the number of racemes per branch increased due to proper nutrition in the first year. S0 the results showed that although rapeseed has good flexibility to compensate for the effects of reducing the density, but its compensatory power, especially at higher densities, is strongly affected by plant nutrition.

Table 6. Effect of density on several agronomic in two years

Year	Density	Racemes/ branch	Grain number/ Racemes	Grain yield Kg ha^{-1})(
2018-2019	D1	20.75c	16.77b	2251.02de
	D2	32.27b	20.47a	3721.55bc
	D3	13.61d	11.25c	1542.36e
2019-2020	D1	31.66b	18.50ab	4325.08b
	D2	36.44ab	17.83b	5209.61a
	D3	39.66a	18.13ab	3249.30c
Means followed by same letter on the column do not differ significantly at 5% probability, by Duncan test.				

Table 7. Two-year mean values of several agronomic characteristics as affected by fertilizer and density interaction

Fertilizer	Density	Racemes/ subbranch		Racemes/ plant		Seed thousand weight (g)	
		Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
F1	D1	34.66ef	93.33a	54.66de	80.66ab	3.86cd	3.83cd
	D2	72.66c	78.00bc	64.00c	79.00b	3.86cd	3.83cd
	D3	28.33f	62.33cd	49.00e	77.66b	3.93c	3.80cd
F2	D1	36.33ef	51.00d	56.00de	55.66cd	4.36a	3.76cd
	D2	50.00de	82.00b	65.00c	82.00ab	3.30e	3.66cde
	D3	22.00f	70.33c	44.00e	60.00cd	3.93c	3.86cd
F3	D1	45.66e	53.66d	55.33de	52.00de	3.93c	3.86cd
	D2	58.66cde	93.33a	71.33abc	90.33a	4.26ab	4.23ab
	D3	19.66f	89.66ab	25.66f	89.33a	3.86c	3.80cd
F4	D1	43.33e	64.00cd	85.33ab	64.66c	3.80cd	3.86cd
	D2	49.33de	69.33c	43.33e	78.66b	4.06bc	3.96c
	D3	24.00f	84.00ab	26.33f	76.66b	3.53de	3.80cd
F5	D1	38.33ef	81.66b	47.33de	76.00b	3.56d	3.63cde
	D2	56.00d	32.33ef	61.33cd	69.66bc	4.16b	4.00bc
	D3	21.00f	84.00ab	33.33ef	82.00ab	3.90c	3.83cd
F6	D1	43.33de	59.66cd	52.33de	69.33bc	3.86c	3.96c
	D2	58.00d	84.66ab	61.33cd	93.00a	4.13a	4.06bc
	D3	29.66f	70.33c	33.33ef	91.00a	3.13e	3.40e
F7	D1	47.66de	77.00bc	60.00cd	76.66b	4.40a	4.36a

	D2	65.33cd	96.33a	77.33abc	87.66ab	4.40a	4.44a
	D3	36.33ef	75.00bc	49.33de	82.33ab	3.60d	3.76cd
F8	**D1**	39.00ef	89.66ab	53.66d	85.33ab	4.06bc	4.23ab
	D2	43.33e	85.66ab	70.66bc	72.33bc	4.10bc	4.83cd
	D3	31.00ef	88.66ab	63.66c	87.33ab	3.83cd	4.06bc
F9	**D1**	40.33def	96.33a	49.66 de	96.66a	3.93c	4.03bc
	D2	66.33c	94.00a	80.00ab	85.00ab	4.03bc	4.10b
	D3	36.00ef	74.33bc	45.66de	74.33bc	3.46de	3.46e
F10	**D1**	37.33ef	85.00ab	62.33c	78.00b	4.16b	3.80cd
	D2	64.33cd	65.66c	81.66ab	79.00b	4.36a	4.23ab
	D3	25.66f	81.33b	35.66ef	77.33b	3.70d	3.93c
F11	**D1**	30.66ef	81.00b	55.00cd	82.33ab	4.03bc	4.03bc
	D2	43.33e	85.00ab	79.66b	82.33ab	4.30ab	4.06bc
	D3	22.66f	80.00b	39.33ef	78.00b	3.80cd	3.96c
F12	**D1**	53.33cde	78.66b	53.33cd	69.00bc	4.00bc	4.03bc
	D2	65.66cd	88.66ab	99.00a	91.00a	3.83cd	3.90c
	D3	30.66ef	94.66a	57.66cd	86.33ab	3.53d	3.80cd
Means followed by same letter on the column do not differ significantly at 5% probability, by Duncan test.							

Number of grains per racemes

The results indicate that the effect of nitrogen fertilizer on the number of grains per racemes was not significant but the effect of density was significant (*$P \le 0.01$*) (table 4). Data collected in the average of two study years indicate that the highest number of seeds per racemes (20.47) was observed in the first year of experiment at density of 70 plant m^{-2}. There were no significant differences for number of grains per racemes in the second year (2019-2020) (table 6). It seems that proper nutrition in two years compensated effects of density especially in the second year.

1000-seed weight

Results of this study for 1000-seed weight are presented in tables 4 and 7. The effect of nitrogen fertilizer and density was not significant but interaction of Y×D and Y×F×D was significant ($P \le 0.05$ and $P \le 0.01$ respectively). The data presented in table 7 show that in both year the highest 1000-seed weight was recorded in ammonium sulfate as recommended (264 $kgha^{-1}$ or 264g $plot^{-1}$) in before planting and heading stages with 50 and 70 plant m^{-2} density in both experimental years (4.40,4.40,4.36 and 4.44g respectively) (table 7) . In both experimental years in each of the fertilizer treatments, 1000-seed weight decreased with increasing plant density. 1000-seed weight is one of the important and determining components of grain yield and plays an important role in the yield potential of a cultivar. Yield components are affected by factors such as optimal use of light, nutrients, proper density, efficient photosynthesis and adequate assimilates to the plant, that all of them are effective in increasing grain yield. Increasing plant density creates intense intra-species competition and the distribution of assimilates to the seed is reduced, therefore, the 1000 seeds weight reduced (Ozer, 2003). This finding agrees with that of sedaghat et al. (2003) who reported that increased density in 4 fertilizer treatments reduced 1000-seed weight of rapeseed. The obtained result is also consistent with the results of Angadi et al. (2003) research.

Seed yield

The results of analysis of variance showed that density effect on seed yield was significant (*$P \le 0.01$*) but nitrogen fertilizer effect was not significant (table 4). The results presented in table 6 show that with increasing density, seed yield decreased considerably and this decreasing was more in the first year than in the second year. The higher yield at density of 70 than the other two densities is due to the more uniform distribution of plants, which in turn results in better distribution of solar radiation in the canopy and thus reduces intra-species competition and increases the number of racemes (Johnson and Hanson, 2003). Similarly Momoh and Zhou (2001) states that rapeseed seed yield decreased. Cultivation at optimal density promotes more balanced distribution of plants, improves nutrient uptake from the soil surface, increases light absorption and increases yield (Biljili et al, 2010). Higher yield at 70 plants m^{-2}density compared to other used densities is due to the higher number of racemes per m^{-2}. Also at this density, by creating more green cover, they are able to use solar radiation more efficiently in order to produce economic yield (Angadi et al, 2003).

Oil percentage and yield

Results of this study for oil percentage and yield are presented in tables 4 and 8. Nitrogen fertilizer had significant effect on oil percentage ($P \leq 0.05$). The highest oil percentage (38.5%) was obtained from urea in recommended (120kgha^{-1} or120g plot^{-1}) as 60g before planting and 60 g in heading stage (F_1) and the lowest oil percentage (34.61%) was obtained from ammonium sulfate [recommended (264 kgha^{-1} or 264g plot^{-1}) as 132 g in stem elongation and 132 g in heading stage (F_9) (table 8). Oil yield was also affected by nitrogen fertilizer ($P \leq 0.05$). The highest oil yield (1715.1 kg ha^{-1}) was obtained from ammonium sulfate [recommended (264 kgha^{-1} or 264g plot^{-1}) as 132 g in before planting and 132 g in heading stage (F_7) and the lowest oil yield (1096.2 kg ha^{-1}) was obtained from urea in recommended (120kgha^{-1} or120g plot^{-1}) as 40 g before planting, 40 g in stem elongation and 40 g in heading stage (F_2). Oil percentage did not considerably change in different used density. However, the variations observed in oil yield as affected by density were significant ($P \leq 0.05$). With increasing plant density, oil yield decreased and this is due to reduced grain yield due to increased density. This result is in agreement with Morrison's et al. (1990) finding that there were no consistent effects of density on oil percentage of summer rape.

Table 8. Means of main effects (fertilizer and density) on oil% and oil yield of rapeseed.

Fertilizer	Oil%	Oil yield
F1	38.50a	1365.4ab
F2	36.66abc	1096.2b
F3	36.61abc	1413.7ab
F4	37.44ab	1105.0b
F5	35.33bc	1301.8ab
F6	36.38abc	1334.9ab
F7	36.16abc	1715.1a
F8	36.16abc	1393.8ab
F9	34.61c	1281.3ab
F10	37.11ab	1466.3ab
F11	37.27ab	1140.8b
F12	37.83ab	1601.6a
Density		
D1	36.40a	990.01a
D2	36.94a	1390.19b
D3	36.68a	1673.75c
Means followed by same letter on the column do not differ significantly at 5% probability, by Duncan test.		

Correlation analysis results

Correlation coefficients between traits are given in table 9. As can be seen, seed yield had a positive and significant correlation with all studied traits, but the highest correlation with 1000-grain weight (r = 0.65), number of racemes per plant (r = 0.62) and number of racemes in the main branch (r =0.62), respectively. Grain yield showed the lowest correlation with pod length (r = 0.12) and number of pods in sub-branch (0.12). Seed yield also had a positive but lower correlation with biological yield (r = 0.14) (Table 9). Therefore, seed yield was more affected by 1000-seed weight and number of racemes per plant. The results showed that seed yield also had a positive and significant correlation with oil yield (r = 0.50). In the other words, the higher the seed yield, the higher the oil yield. Regarding the oil yield, the results of correlation coefficients indicated that the yield of correlation oil was positive and significant with the characteristics of racem length (r = 0.58), number of racemes per plant (r = 0.58), number of seeds per raceme (r = 0.54), seed yield (r = 0.50), 1000-seed weight (r = 0.42), and number of sub-branches (r = 0.38) but had a non-significant positive correlation with biological yield (r =

0.07) and a negative correlation with the number of racemes in the sub-branch (r = - 0.075) (table 9). Indeed, it can be said that positive and significant correlation between oil yield with traits such as raceme length, number of racemes and number of grains per raceme is related to the fact that more grains per raceme, which is affected by raceme length and number of racemes, increases grain weight indicating the transfer of larger volume of photosynthetic assimilates to the seed, which increases the oil content of grain.

Table 9. Correlation coefficient among traits of Canola

Parameters	1	2	3	4	5	6	7	8	9	10
(1)Subbranches N.	1									
(2)Racemes/ subbranch	-0.33**	1								
(3)Racemes/ branch	0.49**	0.011ns-	1							
(4)Racemes/ plant	0.45**	0.078ns-	0.88**	1						
(5)Racemes length	0.49**	-0.024ns	0.98**	0.91*	1					
(6)Seednumber/Racemes	-0.17**	0.24**	0.003 ns	0.012 ns	0.015 ns	1				
(7)Seed thousand weight	0.17*	-0.032ns	0.29**	0.34**	0.27**	0.12*	1			
(8)Biological yield	0.056 ns	0.14*-	0.007 ns	0.006 ns	0.008 ns	0.05ns-	0.11ns-	1		
(9)Seed yield	0.38**	0.12*	0.62**	0.62**	0.12**	0.14*	0.65*	0.14*	1	
(10) Oil yield	0.28**	-0.075ns	0.09ns	0.58**	0.58**	0.54**	0.42**	0.07 ns	0.50 **	1

ns,**,*: Non –significant, Significant at 5 and 1% probability level, respectively.

CONCLUSIONS

The results of this study indicated that the effect of fertilizer treatment on the number of racemes per subbranch, number of racemes per subbranch, number of racemes per branch, number of racemes per plant and seed yield was significant but on other measured was not significant . According to the results of this study, the optimal plant density is 70 plants m^{-2}. However, the density of 50 plants m^{-2} was not significantly different from the density of 70 plants m^{-2} meter in terms of some traits such as growth indices, 1000-seed weight and oil yield. Density of 90 plants m^{-2} caused a significant reduction in growth indices, followed by yield and yield components. This is due to the intense competition that occurs between rapeseed plants at this density. Due to the fact that the use of ammonium sulfate as recommended (264 $kgha^{-1}$ or 264g $plot^{-1}$) in before planting and heading stages with 70 plant m^{-2} density in both experimental years caused the highest 1000-seed weight, so according to the results of this study, to achieve the highest yield using this nitrogen source in before planting and heading stages and density of 70 plants m^{-2} is recommended. The results showed that 1000-seed weight was the most important component affecting seed yield and also raceme length, number of racemes per plant and number of seeds per racemes were important components affecting rapeseed oil yield.

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