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Effects of Nitrogen and Seed Rates on Yield and Oil Content of Canola (*Brassica napus* L.)

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Abstracts: In order to investigate the effect of nitrogen and seed rates on yield and oil content of canola, the experimental design was split plot in randomized complete block design with four replicates at Neka (Iran) in 2009. The main plot was nitrogen rates included N_{92}, N_{115}, N_{138} and N_{161} kg N ha^{-1} and the sub plot was seed rates included S_6, S_8 and S_{10} kg seed ha^{-1} was in sub plot. Results indicated that there was significant difference in nitrogen rates on seed yield, oil yield and oil content ($P \leq 0.01$). N_{161} and N_{92} had the highest and lowest seed and oil yields with 5686 and 3385 and 2263 and 1604 kg ha^{-1}, while oil content was inversion, with 39.84 and 47.42%, respectively. S_6 and S_{10} had the highest and the lowest seed and oil yields with 5020 and 2168 kg ha^{-1}, respectively, while oil content was not significant difference. The highest and the lowest 1000-seed weight and number of pods per plant were obtained with N_{161} and N_{92}, respectively, while, number of seeds per pod and pod length was not significant difference. Nitrogen × seed rates interaction on number of pods per plant and number of pods per main branch was significant ($P \leq 0.01$). Interaction of $N_{161} \times S_6$ had the highest and $N_{92} \times S_{10}$ the lowest number of pods per plant. Interaction of $N_{161} \times S_6$ had the highest and $N_{115} \times S_{10}$ the lowest number of pods per main branch. There is positive correlation between seed yield and number of pods per plant, 1000-seed weight, number of pods per main branch and plant height. There is strong negative correlation between seed yield and number of sub branch. Therefore, high nitrogen and low seed rate increased seed yield and oil yield, whereas, oil content was consistent by increasing nitrogen and seeding rates.

Key words: Canola · Nitrogen · Seeding rates · Oil content · Seed yield

INTRODUCTION

High rain, clay soil and low temperature in the short sowing season of the north of Iran, canola has limited time to express potential plasticity compared with other regions of the world where the canola sowing season is longer. Canola is a relatively new oilseed crop and little information is available regarding the yield response of canola about the nitrogen fertilization rate and seeding rates.

Oilseed crops require adequate nitrogen supply for maximum productivity [1]. In the subhumid environments of western Canada, for example, canola crops respond to nitrogen fertilizer positively even when nitrogen fertilizer is applied at rates as high as 180 kg N ha^{-1} [2]. Gan *et al.* [3] showed that improving nitrogen use efficiency in oilseed production systems requires optimizing rates of nitrogen fertilizer which vary depending on environmental conditions, soil nitrogen supply and rainfall during the critical growth period of the oilseed crops play an important role in affecting nitrogen use efficiency. Kutcher *et al.* [4] indicated that crop response to fertilizer nitrogen in specific soil and climatic conditions is critical to improve crop production and reduce losses of nitrogen across the landscape units. Varying the amount of fertilizer at different landscape positions has been suggested as an appropriate technique to optimize the efficiency of inputs and crop production on a hummocky landscape [5]. Gan *et al.* [6] showed that for all oilseed species, the seed yield was highly responsive to N fertilizer rates from zero to about 100 kg N ha^{-1} and thereafter, the rate of yield responses declined. Structured physiological responses to growth resources limit the ability of crop plants to convert extra photosynthetic biomass associated with additional nitrogen fertilization into seed yield [7].

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Nitrogen accounts for the largest energy use and input expenses in oilseed production systems [8]. Also, amounts of nitrogen fertilizer required for maximum yield of oilseed species vary, depending on environmental conditions [6]. Gan *et al.* [6] indicated that under environments with low-yielding potential, the N fertilizer required for maximum seed yield was around 160 kg N ha^{-1} for mustard species and 120 kg N ha^{-1} for canola species. For example, Hocking *et al.* [9] demonstrated that extra kilograms of seed yield obtained from extra nitrogen application (relative to unfertilized checks) was greater for mustard than for canola at locations when low rates of nitrogen fertilizer were applied.

Optimum canola density is very difficult in the humid region in the north of Iran where low temperature in autumn decreasing germination percentage, high rain in winter damage seedling and clay soil result in poor seedbed conditions and inadequate density. Therefore, optimum plant population of canola is more critical in the similar regions of the world. Factors reported to reduce plant populations of canola include inadequate or excessive soil moisture, soil crusting, low temperature, seeding equipment, late spring frost and hail damage [10]. Angadi *et al.* [11] showed that canola adjusted seed yield across a wide range of plant populations, although it did not compensate completely for the decreasing populations.

Angadi *et al.* [11] indicated that environmental conditions played a significant role in the expression of plasticity of canola. For example, in first year, with slightly above-normal growing season precipitation, canola maintained similar yield levels across a wide range of populations (20 to 80 plants m^{-2}), while in second year, with well below normal precipitation, seed yield declined as populations dropped below 40 plants m^{-2}. Reducing plant population by half from 80 to 40 plants m^{-2} did not reduce seed yield when the reduced plant population was uniformly distributed, but reduced yield when the population was nonuniformly distributed [11]. The plasticity of a plant to compensate for suboptimal plant populations depends on the availability of resources such as light, water and nutrients [12]. In particular, the greater the availability of resources, the greater will be the expression of plasticity [11]. Morrison *et al.* [13], using seeding rates instead of actual populations, focused on above-optimum plant population range. Thus, under the generally good growing season moisture in southern Manitoba, lowest seeding rates of 1.5 to 3.0 kg ha^{-1} (35 to 70 plant m^{-2}) were enough to produce maximum grain yield.

Canola yield plasticity in that study varied widely indicating the importance of weather conditions in determination of the optimum population [11]. Because of this wide range of plasticity, a canola population of 80 to 180 plants m^{-2} has been recommended for canola production in the Canadian prairie [14]. Higher plant population has been recommended and adopted to ensure a competitive crop to check weeds in the early growth stages [13]. Increased variability in the stand was found to reduce seed yield in winter canola [15]. However, yield structure is very effective, correlate and variable across a seeding rate and N fertilization rates. The objectives of this study was to determine the effect of nitrogen rates and seeding rates on seed yield and yield components and oil content of canola under humid conditions.

MATERIALS AND METHODS

Study Site: Field experiment was located 50 km northeast of Neka (at 53°13'58" latitude and 36°46'33" longitude), Iran in 2009. The field study was consisted of silt clay soil selected soil properties are presented in Table 2.

The characteristics of the soil type and residual soil available N, P and K were determined for depth (0-30 cm) at the site, before seeding. The field study was consisted of SiC soil selected soil properties are presented in Table 2. Organic matter was determined by the colorimetric method. Soil pH was measured from a saturated paste. Phosphorus was determined by the method described by Olsen *et al*. [16]. Potassium was extracted with ammonium acetate and measured by atomic absorption spectroscopy.

Table 1: Weather condition in experiment site in corn growth stages at Neka in 2009

Variable	Oct.	No.	Dec.	Jan.	Feb.	March	April	May	June
Minimum tem.	17	10.0	6	2.0	5.0	7	7.0	13.0	18
Maximum tem.	25	18.0	15	11.0	13.0	15	16.0	22.0	27
Precipitation	93	63.9	127	41.5	105.5	22	105.5	22.5	4

Table 2: Selected soil properties for composite samples at experimental site in 2008

Soil texture	K ppm	P ppm	N %	OC %	OM %	pH	EC µmohs/cm	Depth cm
Silt clay	240	8	0.18	1.85	3.18	7.32	0.91	0-30

Experimental Design: The experimental design was split plot in randomized complete block design with four replicates. The main plot was nitrogen rates included 92, 115, 138 and 161 kg N ha^{-1} and the sub plot was seed rate included 6, 8 and 10 kg seed ha^{-1}. K and P fertilizer as potassium sulfate and triple superphosphate (46-46), respectively that applied broadcast during planting. Fertilizers were incorporated into soil 30 to 40 mm deep using a shallow rotary tillage before seeding. N fertilizer was applied during of growth period in the field with splitting 25% in sowing time, 50% in stem elongation and 25% in firs flower open. The amount of N from the blend fertilizer application was accounted in the nitrogen rate treatments. Weeds in the canola were controlled plots using the post-emergent herbicide was used in early January 2009 to desiccate the crops. A Hayola 401 canola cultivar was chosen for the study because of its early maturity. This cultivar was representative and was popular among growers in the north of Iran during the period of this study.

Sample Analysis: Plot area was six rows wide (30 cm row spacing) and 5 m long. The area of the plot (experimental unit) was between 5×2 m_2. Plots were seeded on 10 Oct. Plant population was determined by counting seedlings 10 to 14 d after initial seedling emergence in 0.5-1.0 m^2 per plot. Seed samples (four per replication) were harvested from 4 m^2 (1 by 4 m^2) plots. Seed samples were dried at 65°C for 3 d and weighed to determine seed yield. Seed yield were adjusted to 12% moisture content. Aboveground plant biomass was determined by harvesting one 4 m^2 area of each plot at maturity. The plant samples were oven dried at 65 to 70°C for 4 to 5 d and weighed. Seed samples were dried, weighed and analyzed for oil content. One sample per treatment was analyzed for oil content by near infrared spectroscopy (NIR). Results for oil content were expressed on an 8.5% moisture basis. Oil yield was calculated by multiplying seed yield by oil concentration.

Statistical Analysis: Data were subjected to an analysis of variance using SAS [17]. When *F* was significant, statistical differences among the means were determined using a DMRT (α= 0.05).

RESULTS AND DISCUSSION

There was significant difference in plant height, number of sub branch and number of pods per main branch in nitrogen rates ($P \leq 0.01$). Plant height of N_{161} and N_{115} had the highest and lowest with 147.9 and 133.7 cm, respectively. Thus, the plant height was increased with increasing nitrogen rate. In seeding rates, there was significant difference in number of sub branch ($P \leq 0.01$) (Table 3). Whereas, S_6 and S_{10} had the highest and the lowest number of sub branch. Nitrogen × seeding rates interaction was significant in number of sub branch ($P \leq 0.01$) (Table 3). The interaction $N_{161} \times S_6$ and $N_{92} \times S_{10}$ had the highest and the lowest number of sub branch, respectively (Table 4). Number of pods per main branch ranged from 50.28 to 62.42 pods per main branch. Angadi *et al.* [11] confirmed that the primary response of canola to lower plant population increased pods per plant through increased branching and increased pod retention at each node.

There was significant difference in number of pods per plant with nitrogen, seeding rates and interactions ($P \leq 0.01$) (Table 3). Application of N_{161} had the greatest number of pods per plant. S_6 and S_{10} had the greatest and the least number of pods per plant, respectively (Table 4). Angadi *et al.* [11] showed that the number of pods formed on primary and secondary branches was increased as population decreased. The number of pods per plant is the most responsive of all the yield components in canola [18] and is determined by the survival of branches, buds, flowers and young pods rather than by the potential number of flowers and pods [19]. The interaction $N_{161} \times S_6$ and $N_{92} \times S_{10}$ had the highest and the lowest number of pods per plant, respectively (Table 4). Thurling [20], Ozer *et al.* [21] and Ali *et al.* [22] have estimated strong direct effect of number of pods per plant on seed yield per plant. Tusar-Patra *et al.* [23] concluded that the strongest effect on seed yield was estimated for number of pods per plant followed by number of seeds per pod and 1000- seed weight. Also, Marjanovic-Jeromela *et al.* [24] indicated that the correlation between the number of pods per plant and seed yield per plant kept strong. Similar results were reported by Guo *et al.* [25], Behl *et al.* [26] and Ozer *et al.* [21]. Pospišil and Mustapiæ [27] indicated that a positive correlation between number of pods per plant and seed yield per plant.

Nitrogen rate had significant effect on 1000-seed weight ($P \leq 0.01$) (Table 3). Increase N rate increased 1000-seed weight. This was largely a result of consistent pod length and number of seeds per pod. Ali *et al.* [28] indicated that a negative correlation between number of pods per plant and 1000-seed weight. There is high correlation (0.65**) between 1000-seed weight and seed yield. The highest and lowest 1000-seed weight was obtained by N_{161} and N_{92} with 4.66 and 3.57 g,

Table 3: Mean squares of seed yield, oil yield and yield components in nitrogen and seeding rates levels

S.O.V.	df	Plant height	N. of sub branch	N. of pods per main branch	N. of pods in plants	N. of seed in pods	Pods length	1000-grain weight	Seed yield	Oil content	Oil yield
Replication	3	40.07^{ns}	0.64^{*}	15.85^{ns}	685.26^{ns}	1.02^{ns}	0.04^{ns}	0.05^{ns}	61917.47^{ns}	15.27^{ns}	55176.05^{ns}
Nitrogen (N)	3	594.04^{**}	12.30^{**}	375.97^{**}	10978.55^{**}	2.62^{ns}	0.03^{ns}	2.87^{**}	12502388.39^{**}	122.45^{**}	1188581.98^{**}
Error (a)	9	40.02	0.172	18.23	472.09	2.41	0.04	0.05	146753.38	7.71	49876.28
Seed rate (S)	2	57.50^{ns}	0.83^{**}	26.08^{ns}	8231.50^{**}	1.05^{ns}	0.01^{ns}	0.01^{ns}	1825219.65^{**}	0.23^{ns}	303241.58^{**}
N×S	6	13.01^{ns}	0.08^{**}	35.12^{ns}	954.34^{**}	2.35^{ns}	0.06^{ns}	0.07^{ns}	179758.62^{ns}	1.52^{ns}	448665.69^{*}
Error (b)	24	16.94	0.02	21.12	247.70	2.651	0.08	0.08^{ns}	83674.07	4.62	16577.40
C.V. (%)	-	2.94	3.02	8.28	5.41	6.52	5.82	7.05	6.22	4.90	6.39

* Significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$, ns, non significant

Table 4: Mean comparison of seed yield, oil yield and yield components in nitrogen and seeding rates levels.

Treatments N rate Kg ha^{-1}	Plant height cm	N. of sub branch	N. of pods per main branch	N. of pods per plant	N. of seeds per pod	Pods length cm	1000-grain weight g	Seed yield kg ha^{-1}	Oil content %	Oil yield kg ha^{-1}
92	134.2 b	3.48 c	51.83 c	260.9 c	24.75 a	6.77 a	3.57 d	3385 d	47.42 a	1604 c
115	133.7 b	3.82 c	50.28 c	282.9 b	25.44 a	6.75 a	3.80 c	4302 c	45.03 ab	1938 b
138	143.7 a	4.57 b	57.83 b	286.7 b	25.25 a	6.67 a	4.26 b	5226 b	43.24 b	2260 a
161	147.9 a	5.77 a	62.42 a	332.9 a	24.24 a	6.77 a	4.66 a	5686 a	39.84 c	2263 a
Seed rate Kg ha^{-1}										
6	139.2 a	4.66 a	57.06 a	313.5 a	25.23 a	6.72 a	4.08 a	5020 a	43.75 a	2168 a
8	138.4 a	4.34 ab	54.89 a	291.0 b	24.96 a	6.77 a	4.09 a	4359 b	43.97 a	1899 b
10	142.0 a	4.23 b	54.81 a	268.1 c	24.71 a	6.72 a	4.05 a	4570 b	43.93 a	1983 b

Values within a column followed by same letter are not significantly different at $P \leq 0.05$

respectively (Table 4). Many authors estimated significant positive correlation between 1000-seed weight and seed yield [20, 21, 28]. However, Pospišil and Mustapić [27] did not confirm such inferences. It probably would affect seed oil content since there is negative correlation (-0.51**) between 1000-seed weight and seed oil content. Pospišil and Mustapić [27] founded that no correlation between number of pods per plant and 1000-seed weight. Angadi *et al.* [11] indicated seeds per pod and seed weight were stable across populations.

There was significant difference in seed oil content with nitrogen rates ($P \leq 0.01$) (Table 3). Seed oil content ranged from 39.84 to 47.42%. Seed oil content was decreased with increasing nitrogen rate. This result confirm by Ghanbari-Malidarreh, [29] shows that a result of delayed maturity as indicated by differences in maturity dates among nitrogen rates; negative relationship exists between oil and nitrogen content because high temperature and nitrogen application in grain filling period. So, to consistent with previous reports [30, 31, 32]; this is probably due to nitrogen delaying plant maturity and increasing grain filling period. The highest and lowest oil content was obtained by N_{92} and N_{161} with 47.42 and 39.84%, respectively (Table 4). Because, there is negative relationship between oil content and nitrogen content in seed. Seeding rate had not significant effect on seed oil content (Table 3). Marjanovic-Jeromela *et al.* [24] estimated that correlations between the number of pods per plant and seed oil content as well as number of pods per plant and 1000-seed weight were not.

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 populations. Seed yield responded to nitrogen rates and seeding rates. There was significant difference in seed yield, but the interaction was non-significant (Table 3). In nitrogen rates, the difference between the lowest and highest was 2301 kg ha^{-1} for seed yield. Seed yield of N_{161} produced 68% more than N_{92}. Thus, application 69 kg N ha^{-1} had increased 68% seed yield. Among treatments, seed yield was the greatest for N_{161}, lowest for N_{92}. Ghanbari-Malidarreh, [29] indicated that the relationship between seed yield and nitrogen rates was linear. Also, Gan *et al.* [6] showed that the amount of N fertilizer required to achieve the maximum seed yield was 106 kg N ha^{-1} for rapa canola, 135 kg N ha^{-1} for alba mustard and *B. napus* canola and 162 kg N ha^{-1} for the two *juncea* spp. Optimal seed yield of 5686 kg ha^{-1} occurred in the 161 kg N ha^{-1}, consistent with previous data from Jackson *et al.* [30],

Table 5: Interaction of seed yield, oil yield and yield components in nitrogen and seeding rates levels.

N rate× Seed rate	Plant height cm	N. of sub branch	N. of pods per main branch	N. of pods per plant	N. of seeds per pod	Pods length cm	1000-grain weight g	Seed yield kg ha^{-1}	Oil content %	Oil yield kg ha^{-1}
$N_{92}S_6$	133.6 e	3.65 f	49.70 cd	268.4 def	25.20 a	6.76 a	3.71 cd	3629 ef	47.67 a	1732 de
$N_{92}S_8$	132.4 e	3.43 g	52.60 bcd	261.3 f	24.20 a	6.87 a	3.42 d	3321 f	47.05 ab	1553 ef
$N_{92}S_{10}$	136.7 cde	3.38 g	53.20 bcd	253.1 f	24.85 a	6.68 a	3.57 d	3206 f	47.55 a	1526 f
$N_{115}S_6$	135.3 de	4.05 e	56.17 abc	297.0 c	25.30 a	6.71 a	3.86 cd	4888 d	45.40 abc	2218 abc
$N_{115}S_8$	132.0 e	3.75 f	47.70 d	286.4 cde	25.73 a	6.79 a	3.79 cd	3977 e	45.48 abc	1808 d
$N_{115}S_{10}$	133.8 e	3.65 f	46.95 d	265.3 ef	25.30 a	6.74 a	3.74 cd	4041 e	44.25 abc	1787 d
$N_{138}S_6$	142.9 bc	5.05 c	59.85 ab	310.0 bc	25.25 a	6.79 a	4.10 bc	5477b c	42.67 cde	2337 ab
$N_{138}S_8$	141.1 bcd	4.43 d	57.03 abc	292.0 cd	24.80 a	6.54 a	4.39 ab	4966 d	43.60 bcd	2171 bc
$N_{138}S_{10}$	146.8 ab	4.23 e	56.63 abc	258.1 f	25.70 a	6.69 a	4.31 ab	5234 cd	43.45 cd	2273 ab
$N_{161}S_6$	144.8 ab	5.90 a	62.52 a	378.5 a	25.15 a	6.69 a	4.66 a	6087 a	39.25 f	2384 a
$N_{161}S_8$	147.9 ab	5.75 ab	62.25 a	324.3 b	25.10 a	6.89 a	4.76 a	5171 cd	39.80 ef	2062 c
$N_{161}S_{10}$	150.8 a	5.65 b	62.47 a	295.9 c	23.00 a	6.79 a	4.57 a	5800 ab	40.47 def	2345 ab

Values within a column followed by same letter are not significantly different at P $\leq$ 0.05

Table 6: Correlation between of seed yield, oil yield and yield components in nitrogen and seeding rates levels

Correlation	Plant height	N. of sub branch	N. of pods per main branch	N. of pods per plant	N. of seeds per pod	Pods length	1000-grain weight	Seed yield	Oil content	Oil yield
Plant height	1									
N. of sub branch	0.69**	1								
N. of pods per main branch	0.58**	0.72**	1							
N. of pods per plant	0.38**	0.70**	0.43**	1						
N. of seeds per pod	-0.07	-0.10	-0.13	-0.02	1					
Pods length	-0.05	0.01	-0.09	-0.12	0.34*	1				
1000-grain weight	0.61**	0.79**	0.60**	0.56**	-0.09	-0.20	1			
Seed yield	0.66**	-0.76**	0.54**	0.60**	-0.11	-0.03	0.65**	1		
Oil content	-0.54**	-.70**	0.48**	-0.50**	0.09	0.03	-0.51**	-.067**	1	
Oil yield	0.55**	0.59**	0.43**	0.48**	-0.06	0.003	0.57**	0.92**	0.92**	1

* Significant at P $\leq$ 0.05, ** Significant at P $\leq$ 0.01, ns, non significant

Popove [31] and Grant and Bailey [32]. Seed yield at S_6 and S_8 was the highest and lowest with 5020 and 4359 kg ha^{-1}, respectively (Table 4). Optimal seed yield of 5020 kg ha^{-1} occurred in the S_6. Ogrodowczyk and Wawrzyniak [33] found that flowering duration has the strongest direct effect on seed yield.

There was significant difference in oil yield at nitrogen and seeding rates ($P \leq 0.01$) (Table 3). The maximum oil yield was obtained by application of 161 kg N ha^{-1}, even though a negative relationship exists between oil content and increasing nitrogen. Thus, low oil content due to higher oil yield when canola is fertilized at N rates exceeding 161 kg ha^{-1}. Oil yield under N_{161} produced 41% more than N_{92} (Table 4). Ozer *et al.* [21] showed that a significant correlation between seed oil content and seed yield per plant. Marjanovic-Jeromela *et al.* [24] showed that a significant positive correlation estimated between seed oil content and seed yield per plant (0.609**) leads to the conclusion that simultaneous selection regarding oil content and seed yield per plant is possible to be done. The highest and the lowest seed oil yield were obtained by S_6 and S_8, respectively. The interaction $N_{161}\times S_6$ and $N_{92}\times S_{10}$ had the highest and the lowest seed oil yield, respectively (Table 5).

CONCLUSION

Increasing application of nitrogen in canola fields is a benefit alternative to decreasing for nitrogen management. In this study, as the rate of applied N increased, plant height, number of sub branch, number of pods per main branch, number of pods per plant, 1000-grain weight, seed yield and oil yield tended to increase while seed oil content tended to decline. Pods length and number of seeds per pod were not consistently affected by changes in N rate. Oil yield of canola had increased, while seed oil content was consistent, because seed yield had increase, so suggesting that nitrogen application rates can be increased when soil nitrogen was low or high moisture content and the weather was rainy.

Although, it seen that, nitrogen splitting in better time perhaps duo to nitrogen application decrease and reduction in nitrogen losses following optimum seeding rate and other nutrition especially P, K and S. Therefore, the impact seeding rate on seed yield was important because the number of pods per plant had increase. Although in yield components, the number of pods per plant had strong (0.60^{**}) correlation with seed yield and affected by seeding rate and nitrogen rate. Ghanbari-Malidarreh, [29] indicated that relationships between yield components in canola was complex and also, were affected by nitrogen rate, nitrogen splitting and plant density.

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