

Response of Canola (*Brassica napus*) Cultivars to Rate and Split Application of Nitrogen Fertilizer

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Abstract: Canola (*Brassica napus* L.) was grown in field experiment at Research Farm, Faculty of Agriculture, Zanjan University, Iran to determine the response of canola cultivars to rate and split application of nitrogen fertilizer. The experiment was conducted as factorial-split design of randomized complete block design. Three canola cultivars that included V1=Okapi, V2= Opera and V3=Licord were applied. Nitrogen fertilizer rates included 50 and 100 kg ha^{-1} and nitrogen split application included T1 (100% of fertilizer was applied at pre-sowing), T2 (100% of fertilizer was used at 4-leaf stage) and T3 (50% of fertilizer was applied at pre sowing and another 50% of fertilizer was applied at 4-leaf stage). Results showed that 100 kg Nha^{-1} along with split application of nitrogen fertilizer (T3) resulted in higher seed yield and there was difference among canola cultivars in terms of nitrogen use efficiency. Licord cultivar (V3) along with 100 kg Nha^{-1} had the highest grain yield. Seed oil yield responses of canola cultivars to nitrogen fertilizer were like seed yield. Dry matter production responded positively to nitrogen rate. Harvest index was increased under pre-sowing or split application of nitrogen fertilizer and some canola cultivars such as Licord (V3) had higher harvest index that can be used in plant breeding programs. 100-seed weight was affected by canola cultivar, rate and split application of nitrogen fertilizer. For example in N2T3 (100 Kg Nha^{-1} as split application), Opera cultivar (V2) and Okapi Cultivar (V1) had the highest and lowest 100-seed weight respectively. Licord cultivar (V3) along with 50 kg Nha^{-1} and basal dressing of nitrogen fertilizer had the highest pod number per plant. This cultivar (V3) had a high yield under wide range of nitrogen rate and split application that can be selected due to sustainable yield.

Key words: Canola (*Brassica napus*), nitrogen fertilizer, seed oil yield, yield components, nitrogen split application.

INTRODUCTION

Canola (*Brassica napus* L.) is the main winter growing oilseed in Iran. Nowadays, canola cultivars are low in erucic acid and glucosinolates. Canola oil is considered healthy for human nutrition due to its lowest content of saturated fatty acids among vegetable oils and a moderate content of poly-unsaturated fatty acids (Starner *et al.*, 1999). Low level of the yield is due to mistakes in agrotechnical principles. There are 16 elements that are essential for the growth of the world's major crops. In estimating fertilizer requirements for canola, farmers use methods such as soil tests and plant field cropping history. Oil content of canola depends on many factors such as variety, growth environment, agrotechnics and fertilization. To produce seed of good quality, special attention must be paid to the rate, placement and timing of fertilizer application. Nitrogen is the most important fertilizer applied to canola in terms of cost to growers, and inadequate or untimely N applications often restrict yields. Nitrogen deficit canola plants have fewer and smaller leaves than N-sufficient plants (Mendham *et al.*, 1981).

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Bernurdi and Banks (1993) found that top dressing canola with 50 kgNha⁻¹ gave 10% higher seed yields than the same amount of N applied pre-sowing. It is shown that top dressing with N produced similar seed yields as an equivalent amount of N applied pre-sowing (Sykes and Mailer, 1989). Hocking *et al.* (1997) reported that the increase in pod number per plant with increasing N fertilizer was virtually the only factor responsible for the increased seed yield as seed number per pod and individual seed weight were comparatively constant over the range of N rates applied. Hocking and Stapper (2001) reported that N fertilizer had a little effect on seed oil percentage. The aim of this study was to determine yield and yield components response of canola cultivars to rate and split application of nitrogen fertilizer.

MATERIALS AND METHODS

The experiment was conducted in 2004-2005 at Research Farm, Faculty of Agriculture, Zanjan University, Iran. The soil texture at the experimental area was sand-loam and its pH was 7.5.

Design Characteristics and Cultural Practices:

the experiment was conducted as factorial-split design of randomized complete block design with three replications. Block length was 42 m and its wideness was 6 m. Block spacing was 6 m. Each block had 6 main plots and each main plot contained 3 sub-plots. Main plot spacing was 7.8 m. Experiment treatments were as following:

1-nitrogen fertilizer rates included 50 and 100 kgNha⁻¹

2-split application of nitrogen fertilizer included T1 (100% of fertilizer was consumed as pre-sowing), T2 (100% of fertilizer was used at 4-leaf stage) and T3 (50% of fertilizer was applied at sowing time and another 50% was applied at 4-leaf stage). Rate and split application of nitrogen fertilizer were arranged in main plots.

3- Winter canola (*Brassica napus L.*) cultivars included V1=Okapi, V2=Opera and V3=Licord were arranged in split plots. These cultivars were purchased from Plant and Seed Institute- Oil Seed Research Department. Nitrogen fertilizer was urea (46% N).

Soil preparation was done by mould board plowing and disk. Tereflan herbicide (2.5 lit ha⁻¹) was used for weed control before disking. Super phosphate triple fertilizer (185 kgha⁻¹) and potassium sulphate (240kgha⁻¹) were applied according to recommendation of soil test. Land leveler was used for leveling the land then furrower was used for creating furrow in 60 cm. In order to prevent run off, each block was surrounded by soil and runoff of each block was separately gone out.

Sowing time was September 22, 2004. Sowing was densely performed by hand then when the seedling was 3-4 leaf they were thinned with expected density. Plant spacing into row was 4 cm. Seeding depth was 2 cm. Irrigation interval was 10 days. Irrigation interval became shorter at flowering and emergence stage. Fertilization was performed by opening a 3cm furrow on two sides of each ridge. The most weeds observed in the field were Field Bindweed (*Convolvulus arvensis*), Foxtail Barley (*Hordeum jubatum*) and wild carrot (*Dacus carrota*). The weeds were chemically and mechanically controlled. The most insect pest was gray cabbage aphid (*Brevicoryne brassicae L.*). Aphids damage bulbs and flowers.

Plant Sampling and Statistical Analysis:

before harvesting, five plants were selected accidentally in order to evaluate yield components and some traits of canola. Plant height was measured from crown to end of main stem.

20 pods per main stem and 30 pods per secondary branch were selected in order to determine the length pod, and the number of seed per stem. In order to determine the number of pod per plant, five selected plants (as mentioned before) were used.

In order to determine economic yield, up to 50 cm of primer line and edge line were discarded and four planting rows were harvested then seeds were fractionated and grain yield was evaluated on 6 m². Harvest index was computed as the ratio of grain to above-ground dry matter at harvest.

In order to determine the oil content of canola, some seeds were grinded then 10 gr of each sample was used in NMR (nuclear magnetic resonance) instrument.

Analysis of variance (ANOVA) was used to determine significant differences. The Multiple Range Test of Duncan performed the separation of means when the *F*-test revealed the error probability to justify the difference minor. Correlation coefficients were calculated for the relationship between seed yield and several crop parameters. All statistics were performed with the program MSTATC (version 2.10) and SPSS (version 10.0).

RESULTS AND DISCUSSION

Grain Yield, Dry Matter and Harvest Index:

Grain Yield:

Results showed that interaction between nitrogen rate and nitrogen split application and interaction between

canola cultivar and nitrogen rate had significant effect on grain yield (table 1). Mean comparisons showed that N2T3 had the highest grain yield however its difference with N1T1 was not significant (figure 1). It means that split application of nitrogen results in efficient use because its availability increases and its leaching decreases. This contrasts with the other results which showed that topdressing with N produced similar yields as an equivalent amount of N applied pre-sowing (Sykes, 1988; Sykes and Mailer, 1989). However conflicting results have been reported for topdressing N in canola compared with equivalent amount applied pre-sowing, probably due to factors such as leaching of N applied pre-sowing for example Bernardi and Banks(1993) found that topdressing canola gave higher seed yields than the same amount of N applied pre-sowing.

Mean comparisons showed that N2V3 had the highest grain yield however its difference with N1V1 was not significant (figure 2). Some researchers found that N resulted in higher yield due to higher stem length, lateral branch, dry matter (Allen and Morgn, 1972), leaf area index and photosynthesis (Nuttall and Button, 1990). There was positively significant correlation between grain yield and oil percentage, oil yield, dry matter yield and harvest index.

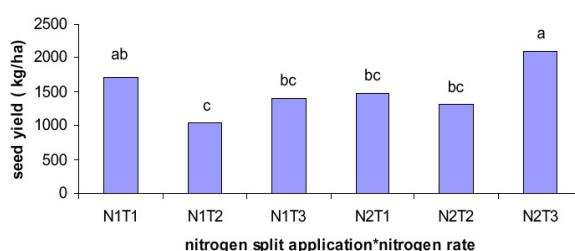


Fig. 1: Effect of interaction between nitrogen split application and nitrogen rate on seed yield (kg/ha) of canola. Means followed by the same letter are not significantly different at $P < 0.05$ as determined by the same letter are not significantly different at $P < 0.05$ as determined by duncan's Multiple Range Test.

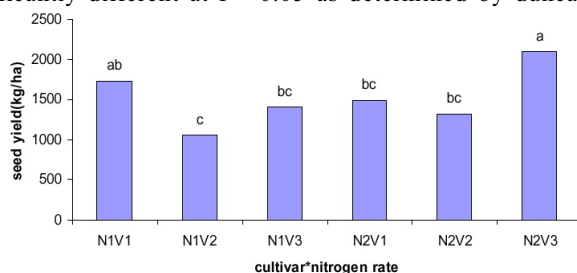


Fig. 2: Effect of interaction between cultivar and nitrogen rate on seed yield (kg/ha) of canola. Means followed by the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Multiple Range Test

Dry-matter:

results showed that interaction among nitrogen rate, nitrogen split application and canola cultivar on dry matter was significant (table 1). Mean comparisons (table 2) showed that N2T3V3 and N2T1V2 had the highest dry matter, it is common that there is positive relationship between N application and dry-matter (Allen and Morgn, 1972). This result showed that application of N at sowing stage (T1, T3) resulted in higher dry-matter because T2 (application of N only at 4-leaf stage) resulted in lower dry-matter. Ogilovy and Bastiman(1992) reported similar results. There was positively significant correlation between dry-matter yield and grain yield.

Harvest Index:

results showed that nitrogen split application, and interaction between canola cultivar and nitrogen rate had significant effect on harvest index (table 1). Mean comparison showed that T1, T3 had the highest harvest index (figure 3). Some researchers found that nitrogen rate had negligible effect on the harvest index (Hocking *et al.*, 1997; Hoccking and stapper, 2001). Lower harvest index of T2 may be explained by increased vegetative growth due to application of N at the 4-leaf stage while application of nitrogen at pre-sowing stage or half of N at 4-leaf stage did not have this effect. Comparisons for interaction between canola cultivar and nitrogen rate showed that N2V3 had the highest and N1V2 had the lowest harvest index. This result showed

that higher nitrogen application resulted in higher harvest index and some canola cultivars such as Licord (V3) had higher harvest index that can be used in plant breeding programs (figure4).

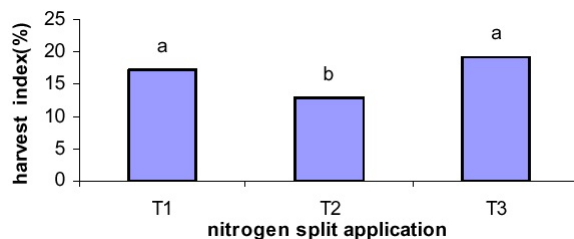


Fig. 3: Effect of nitrogen split application on harvest index (%) of canola. Means followed by the same letter are not significantly different at $P < 0.01$ as determined by Duncan's Multiple Range Test.

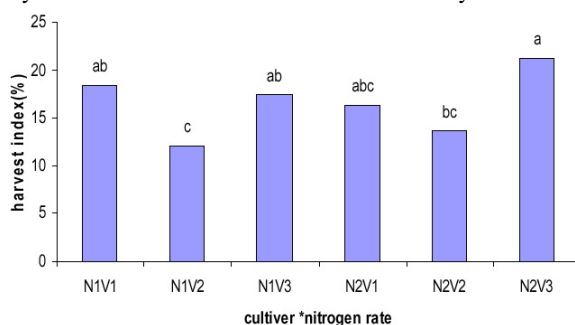


Fig. 4: Effect of interaction between cultivar and nitrogen rate on harvest index (%) of canola. Means followed by the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Multiple Range Test.

There was positively significant correlation between harvest index and grain yield, seed oil percentage, seed oil yield and 100-seed weight.

Plant Height:

Results showed that effect of interaction between nitrogen split application and nitrogen rate, interaction between cultivar and nitrogen split application and interaction between cultivar and nitrogen rate were significant (table 1).

Mean comparison for interaction between nitrogen rate and nitrogen split application showed that N1T1 (50 kgNha⁻¹ as basal dressing) and N2T3 (100kgNha⁻¹ along with 1/2 N pre-sowing and 1/2N at 4-leaf stage) had the highest plant height while N2T1 (100 kgNha⁻¹ as basal dressing) had the lowest plant height (figure 5). Mean comparison of interaction between cultivar and nitrogen rate showed that N1V3 and N2V3 had the highest plant height while N2V2 and N1V2 had the lowest plant height (figure 6). Mean comparison of interaction between cultivar and nitrogen split application showed that T2V3 and T3V3 had the highest plant height (figure 7). There was positively significant correlation between plant height and seed oil percentage, seed oil yield and the number of pod per plant.

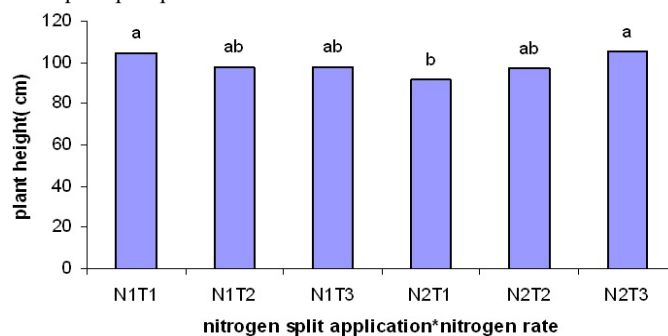


Fig. 5: Effect of interaction between nitrogen split application and nitrogen rate on plant height (cm) of canola. Means followed by the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Multiple Range Test.

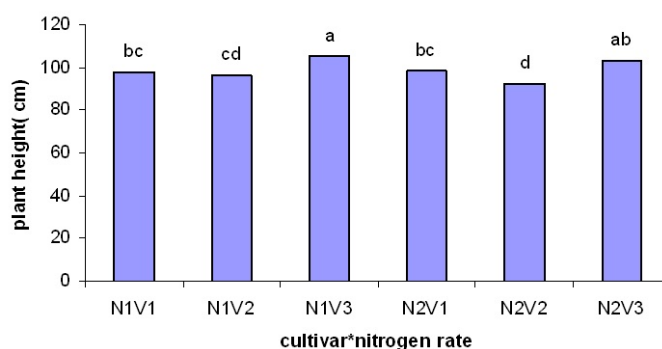


Fig. 6: Effect of interaction between cultivar and nitrogen rate on plant height (cm) of canola. Means followed by the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Multiple Range Test.

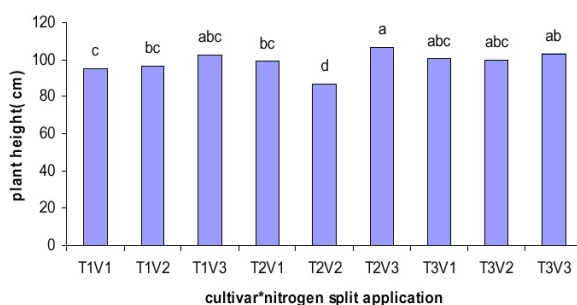


Fig. 7: Effect of interaction between cultivar and nitrogen split application on plant height (cm) of canola. Means followed by the same letter are not significantly different at $P < 0.01$ as determined by Duncan's Multiple Range Test.

Seed Oil Percentage and Seed Oil Yield:

Seed Oil Percentage:

Results showed that interaction among cultivar, nitrogen rate and nitrogen split application was significant (table 1). Mean comparison for this interaction showed that N2T3V3 had the highest seed oil percentage however its difference with N2T3V2, N2T1V3 and N1T3V3 was not significant (table 2). Overall, this results showed that Licord (V3) cultivar along with higher nitrogen rate when was applied as split application resulted in higher seed oil percentage. Although N fertilizer often reduces grain oil concentration through an inverse relationship between grain N (protein) and oil concentrations (Taylor *et al.*, 1991. Brennan *et al.*, 2000). This did not occur in our study. Hocking and Stapper (2001) reported similar results. The increase in seed oil percentage due to split application of nitrogen may be explained by efficient use of nitrogen due to reduced leaching and increased availability of nitrogen. There was positively significant correlation between seed oil percentage and seed yield, seed oil yield, harvest index, 100-seed weight and plant height.

Seed Oil Yield:

Results showed that interaction between nitrogen split application and nitrogen rate and interaction between canola cultivar and nitrogen rate on seed oil yield were significant (table 1). Mean comparisons for interaction between nitrogen rate and nitrogen split application showed that N2T3 and N1T1 had the highest seed oil yield (figure 8). The results emphasize that if nitrogen fertilizer rate is low (50 kgNha^{-1}), it should be applied as basal dressing while nitrogen fertilizer rate is high (100 kgNha^{-1}), it should be applied as split application. It is said that there are inverse relationship between seed oil concentration and seed protein content when higher rate of nitrogen is applied to canola (Taylor *et al.*, 1991. Zhao *et al.*, 1993). But seed yield increased due to increased N so seed oil yield is also increased and the low oil percentage is compensated. Mean comparisons for interaction between canola cultivar and nitrogen rate showed that N2V3 had the highest seed oil yield however its difference with N1V1 was not significant (figure 9). It is concluded that some cultivars such as Licord (V3) in high nitrogen rate application and other cultivars such as Okapi (V1) in low nitrogen rate had the high oil yield. There are positively significant correlation between seed oil yield and seed yield, seed oil percentage, harvest index, 100-seed weight and plant height.

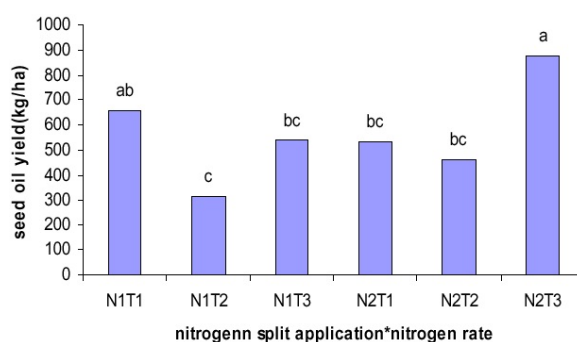


Fig. 8: Effect of interaction between nitrogen split application and nitrogen rate on seed oil yield (kg/ha) of canola. Means followed by the same letter are not significantly different at $P < 0.05$ as determined by Duncan's Multiple Range Test.

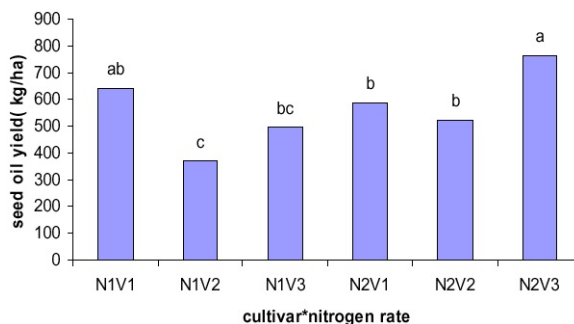


Fig. 9: Effect of interaction between cultivar and nitrogen rate on seed oil yield (kg/ha) of canola. Means followed by the same letter are not significantly different at $P < 0.01$ as determined by Duncan's Multiple Range Test

Yield Components:

100-seed Weight:

interaction among canola cultivars, nitrogen rate and nitrogen split application had significant effect on 100-seed weight of canola (table 1). Mean comparison for this interaction showed that N2T3V2 had the highest 100-seed weight (table 2). The results showed that N fertilizer essentially resulted in increased 100-seed weight. However there was difference among canola cultivars in terms of nitrogen use efficiency. For example in N2 T3 (100 kgNha⁻¹ as split application), Opera cultivar (V2) had the highest and Okapi (V1) cultivar had the lowest 100-seed weight. The results also showed that split application of nitrogen fertilizer, essentially resulted in higher 100-seed weight. There was positively significant correlation between 100-seed weight and seed oil percentage, seed oil yield and harvest index. This correlation showed that seed weight is one of the most factors for increasing seed oil yield of canola and this parameter can be used by plant breeders. Some researchers reported similar results (Barros *et al.*, 2004; Tuncturk and Tuncturk, 2006).

Pod Number per Plant:

interaction among canola cultivar, nitrogen rate and nitrogen split application had significant effect on pod number per plant (table 1). Mean comparison for this interaction showed that N1T1V3 had the highest pod number per plant (table 2). Licord cultivar (V3) had a high yield in wide range of nitrogen rate and split application and it can be selected due to sustainable yield. Overall, nitrogen split application (V3) resulted in higher pod number per plant. Other researchers found similar results (Wright *et al.*, 1988; Hocking *et al.*, 1997). There was positively significant correlation between pod number per plant and plant height.

Seed Number per Pod:

only canola cultivars had significant effect on seed number per pod (table 1). Mean comparison for this trait showed that Okapi (V1) and Licord (V3) cultivar had the highest seed number per pod (figure 10). As mentioned before, N1V1, N2V3 had the highest seed yield and seed oil yield, so one reason for this high yield is increased seed number per pod. Hocking *et al.*, (1997) reported similar results.

Table 1: Analysis variance of yield and yield components of canola as affected by nitrogen split application, nitrogen rate and canola cultivar.

Source of variation	df	mean of square									
		Seed yield	Dry-matter	harvest index	100-seed weight	seed oil percentage	seed oil yield	pod number per plant	seed number per pod	plant height	pod length
Replication	2	883.1128641*	763.182.795 ns	761.103*	0.135**	157.321*	322656.409*	140.269ns	12.667ns	23.659*	0.022ns
Nitrogen rate	1	346.806153 *	569.13500601**	873.14 ns	0.095*	101.764ns	195746.321ns	732.615ns	20.498ns	41.291ns	1.014**
Nitrogen Split application	1	188.1547816**	933.1004533 ns	770.195**	0.64**	297.513**	460641.070**	399.035ns	4.208ns	76.401ns	0.284*
Nitrogen Split application × nitrogen rate	2	905.994587*	539.3597135 ns	653.39 ns	0.045ns	37.456ns	239891.269*	628.505ns	27.335ns	456.623*	0.483**
Error	10	790.153917	963.1140923	13.2	0.003	30.137	48671.863	213.76	12.313	102.315	0.061
cultivar	2	236.887191**	460.1004684 ns	858.84**	0.1**	100.867**	189899.944**	1133.060**	171.275**	426.163**	1.110**
Nitrogen rate ×cultivar	2	296.378185*	719.263852 ns	416.58*	0.155**	41.293**	119274.056**	1167.660**	21.773ns	26.449*	0.084ns
cultivar × nitrogen split application	4	744.212086 ns	882.2740655**	975.18 ns	0.09**	33.719**	53687.660ns	244.015ns	8.767ns	136.803**	0.142ns
Nitrogen rate × nitrogen split application × cultivar	4	323.109891ns	61.3527722**	0885.0 ns	0.08**	55.057**	26537.037ns	524.210*	15.427ns	23.938 ns	0.224*
error	24	602.101452	931.52392	846.1	0.002	6.181	20354.927	158.15	7.396	29.691	0.065
total	53										

*,**, ns: significance at the 0.01, 0.05 level of probability, respectively; ns= not significant.

Table 2: Mean comparisons for the effect of interaction among nitrogen rate, nitrogen split application and canola cultivar on some traits of canola

treatment	dry- matter(kgha ⁻¹)	100-seed weight(gr)	seed oil percentage	pod number per plant	pod length(cm)
N1T1V1	8833 bcde	2.01 65 def	37.5 cdefg	76.3 ef	8.983 bcdef
N1T1V2	9667 ab	1.85 efg	33.91 fgh	96.8 bcdef	9.210 abcd
N1T1V3	9667 ab	1.9 efg	36.45 defg	126.6 a	9.37 ab
N1T2V1	9000 bcd	1.85 efg	30.1 hij	101.2 bcd	8.958 bcdef
N1T2V2	7833 de	1.71 65 fg	27.05 j	117.5 ab	9.577 a
N1T2V3	8667 bcde	1.4665 g	29.71 hji	104.4 abcd	9.4 ab
N1T3V1	8667 bcde	2.25 de	39.21 bcde	87.4 def	8.833 cdefg
N1T3V2	8000 cde	2.2 de	33.11 ghi	104.4 abcd	9.5 a
N1T3V3	7500 e	2.6665 bc	41.6 abc	100.4 bcde	8.99 bcdef
N2T1V1	10000 ab	1.5335 g	29.1 ij	82.8 def	8.37 g
N2T1V2	10670 a	1.75 fg	36.34 efg	83.4 def	8.957 bcdef
N2T1V3	7500 e	2.35 cd	41.15 abcd	89.4 def	8.64 efg
N2T2V1	10000 ab	1.85 efg	38.23 cdef	101.6 bcd	9.11 abcde
N2T2V2	9333 abc	1.8335 efg	27.81 j	73.6 f	9.12 abcde
N2T2V3	10000 ab	2 def	36.48 defg	106.9 abcd	8.55 fg
N2T3V1	10000 ab	1.8665 efg	37.23 cdefg	105.8 abcd	8.737 defg
N2T3V2	8833 bcde	3.5165 a	43.07 ab	90.4 cdef	9.593 a
N2T3V3	10500 a	2.9 b	43.94 a	114.8 abc	9.277abc

Means followed by the same letter within a column are not significantly different at P < 0.01 (P < 0.05 for pod number per plant) as determined by Duncan's Multiple Range Test.

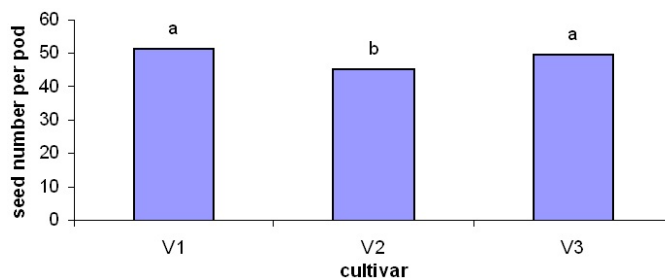


Fig. 10: Effect of cultivar on seed number per pod of canola. Means followed by the same letter are not significantly different at P < 0.01 as determined by Duncan's Multiple Range Test.

Pod length:

interaction among nitrogen rate, nitrogen split application and canola cultivar had significant effect on pod length (table 1). Mean comparison for this interaction showed that low nitrogen rate resulted in higher pod length (table 2). Some canola cultivars such as Opera (V2) especially along with split application of nitrogen fertilizer (T3) resulted in higher pod length. N1T2V2, N1T3V2 and N2T3V2 had the highest pod length.

Conclusion:

The study has shown that canola responded with increased grain yields to rates of N fertilizer up to 100 kgNha⁻¹ on soils of low to moderate N fertility. In this study, response of canola to nitrogen fertilizer depended on cultivars and split application of nitrogen for example 100 kgNha⁻¹ had the highest seed oil yield along with split application of nitrogen (T3) while 50 kgNha⁻¹ along with basal dressing (T1) of N had the highest seed oil yield. Among canola cultivars, Licord cultivar (V3) along with 100 kgNha⁻¹ had the highest seed oil yield, while Okapi cultivar (V1) along with 50 kgNha⁻¹ had the highest seed oil yield. Basal dressing (T1) or split application of nitrogen had a performance better than application of nitrogen at 4-leaf stage (T2) of canola. The results showed that some canola cultivars such as Licord (V3) had the higher harvest index that can be used in plant breeding programs. Positively significant correlation between 100-seed weight, seed oil yield and harvest index shows that seed weight is one of the most factors for increasing seed oil canola through plant breeding.

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