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The impact of nitrogen and organic matter on winter canola seed yield and yield components

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Abstract

Canola is becoming an important oilseed crop grown in rotation with wheat in Iran. This study was carried out to evaluate the effect of N fertilization and additive materials including wheat residue and compost on growth, yield and yield components of canola. The experiment was conducted at the Experimental Farm of College of Agriculture, Shiraz University, Shiraz, Iran, located at Badjgah in 2006-2007 and 2007-2008 growing seasons. The experimental design was split plot with three replications. Seed yield responded to the application of both compost and wheat straw and the maximum seed yield was recorded at 50 ton ha^{-1} of compost treatment. Increasing N caused a significant increase in seed yield. Seed yield showed a significant increase by increasing N from 0 to 100 kg ha^{-1} at 50 ton ha^{-1} compost treatment; however increasing N beyond 100 kg ha^{-1} had no significant effect on canola seed yield. Application of 100 kg ha^{-1} of N fertilizer at 50 ton ha^{-1} compost was adequate for optimum seed yield. Results of stepwise regression analysis showed that contribution of yield component of canola varies with change in N fertilizer and organic matter application rates. Soil organic carbon was also shown to increase following application of different types of organic matter.

Keywords: Winter oil seed rape, Stepwise regression, Compost, Organic carbon, Additive materials

Introduction

Canola is a new oilseed crop in Iran and its area under cultivation has been steadily growing. Application of N fertilizers was shown to increase canola seed yield even under a variety of diverse challenging conditions (Šidlauskas and Tarakanovas, 2004). The crop requirement for N fertilizers can vary a lot depending on soil type, climate, management practices, timing of N application, crop cultivars and etc. (Kalkafi et al., 1998). Canola is very responsive to N (Lewis et al., 1987) and several studies have shown that N is a critical limiting factor for canola production (Jackson, 2000). Characteristics of canola such as plant height, number of branches per plant, number of pods per plant, seed yield and oil content are positively correlated with soil N level (Ahmadi and Bahrani, 2009). Canola yield is also indirectly affected by N as a result of increased stem length, higher number of flowering branches, total plant weight, seeds per pod, and number and weight of pods and seeds per plant (Taylor et al., 1991). The significance of higher soil nutrient and particularly nitrogen availability in determining the yield quantity and quality of winter oil seed rape has been underlined by other workers (Rathke et al., 2005; Colnenne et al., 1998). In another study it was shown that among N fertilization, previous crop in rotation, and type of fertilizer as well as their interactions winter oilseed rape was most responsive to N fertilization rate (Rathke et al., 2005). Application of compost to agriculture soils has become a common practice especially in soils which have been depleted of organic matter as a consequence of continuous cropping. In comparison to chemical fertilizers, compost is considered a poor resource of nitrogen, phosphorus, and potassium; however the total available organic matter it supplies over time is greater than the directly available amount. Soil organic matter content is determined by both compost and crop C inputs (Carter et al., 2004). Soil properties are also affected by time of compost application and crop developmental stage. Addition of compost improves soil fertility by increasing both the quantity and the quality of soil organic matter (Rivero et al., 2004). Application of organic materials has caused increased wheat yield and improved aggregate stability and infiltration rate, better water retention at less than –100 kPa, and significant reduction in soil bulk density (Barzegar et al., 2002). Increased root mass and sugar yield over control as a result of application of compost, animal manure and chemical fertilizer has also been evidenced (Davarinejad et al., 2002). Canola yield under chemical fertilizer alone treatment and application of 40 Mg ha^{-1} compost was comparable to 50 percent chemical fertilizer treatment suggesting that 50 percent of the required fertilizer might be replaced by compost (Kazemeini et al., 2008). The objective of this experiment was to determine the effect of nitrogen and organic materials on canola yield and yield components.

Materials and methods

Field experiments were carried out in a silty clay loam soil at the Experimental Research Center (Badjgah), Shiraz University (52º 46 E, 29º 50 N and 1810m) in two growing seasons (2006-2008). The experimental design was split plot with three replications. The treatments consisted of N fertilizer in four levels (0, 50, 100, and 150 kg N ha^{-1}) as main plots, and additive materials including wheat residue in

Table 1. Monthly average temperature and rainfall values during the years of experiment and 30-year means at Agricultural Research Center (Badjgah), Shiraz. Iran

	Rainfall (mm)			Temperature(ºC)		
	2006-2007	2007-2008	1975-2005	2006-2007	2007-2008	1975-2005
Sep-Oct	0.00	0.00	1.80	16.70	15.70	15.30
Oct-Nov	0.00	0.00	25.90	12.30	11.30	9.90
Nov-Dec	82.00	18.00	82.00	2.60	6.60	5.80
Dec-Jan	50.50	76.00	98.30	0.38	1.40	3.40
Jan-Feb	82.50	29.50	87.50	4.50	3.70	3.50
Feb- Mar	35.00	0.00	66.70	7.40	8.90	6.90
Mar-Apr	138.50	3.50	43.90	11.50	14.00	10.90
Apr-May	3.00	0.00	13.60	17.30	17.90	15.70
May-Jun	0.00	0.00	0.80	22.00	22.40	20.20
Jun- Jul	2.50	0.00	0.30	25.10	25.80	23.76
Jul-Aug	0.00	0.00	0.50	24.10	24.70	23.72
Aug-Sep	0.00	0.00	0.40	21.20	21.00	20.40
Total	394.00	127.00	421.70	-	-	-

two levels (1500-3000 kg ha^{-1}), compost in two levels (35-50 ton ha^{-1}) and control (non additive material) as sub plots. Data on monthly average temperature and rainfall for two years of study and 30-years means of the region as well as some properties of soil are shown in Tables 1 and 2. Land preparation practices included plowing, disking and ridging plots (sized 3 by 3 m). In the first year, additive materials were mixed into the 30 cm depth of soil by moldboard plow. Nitrogen was supplied from urea and added to plots in two periods (½ at planting time and ½ at stem elongation stage). Compost was supplied from compost factory in Isfahan. Weeds were controlled by Triflouralin (2 liter ha^{-1}) that was applied prior to planting and incorporated into soil by disking. The seeds of canola CV. Talayeh (purchased from Iranian Plant and Seed Institute-Oil Seed Research Department) were sown in plots by Pneumatic grain drill (model Accord, Germany) on October 8th in both years. Some traits such as seed yield, biomass, harvest index (%), pod number per plant, seed number per pod, Mean kernel weight and branch number were measured by randomly selecting ten plants in each plot. The experimental data were analyzed using the SAS (version 9.1) system (SAS, 1996). Where analysis of variance showed significant treatment effect, LSD Test was used to compare the means at $P<0.05$.

Results and discussion

Seed yield

N fertilizer had a significant effect on canola seed yield. Increasing N fertilizer rate from 0 to 50 kg ha^{-1} and from 50 to 100 kg ha^{-1} increased the seed yield; however no significant increase in the seed yield was observed when the rate was increased from 100 to 150 kg ha^{-1} (Table 3). Similar studies reported increase in canola seed yield as a result of higher N fertilizer application rates (Ahmadi and Bahrani, 2009; Buttar et al., 2006; Cheema et al., 2001). Comparison of N-requirement of canola and cereals including wheat crop has also been investigated and the results showed that genotypes of canola required higher level of N fertilizers to maintain their seed yield (Balint and Rengel, 2008; Svecˇnjak and Rengel, 2006; Hocking and Stapper, 2001). Buttar et al. (2006) reported a significant increase in seed yield between 100 and 150 kg ha^{-1} which did not agree with our findings (Table 3), however results of the effect of N fertilization on growth and yield components from other studies were in line with our results (Ahmadi and Bahrani, 2009; Cheema et al., 2001). Soil amendment with organic matter significantly enhanced the seed yield at all levels of N fertilizer.

Table 2. Some properties of compost and soil of experiment site

Property	Soil	Compost
PH	7.83	7.1
Ec (ds/m)	0.21	16.7
N (%)	0.089	1.8
P (ppm)	22.3	60.75
K (ppm)	491	1918
Fe (ppm)	6.4	149.2
Zn (ppm)	2.27	288.2
Mn (ppm)	6.75	49.4
Cu (ppm)	2.35	87.3
O.M (%)	0.78	18.4
Sand (%)	21.28	-
Silt (%)	60.72	-
Clay (%)	18	-
Bulk density (g cm^{-3})	1.49	-

Application of 1.5 and 3 ton ha^{-1} of wheat straw and 35 and 50 ton ha^{-1} of compost respectively resulted in 15.5, 16, 40.7, and 46.4% increase in canola seed yield with the maximum seed yield at 50 ton ha^{-1} of compost (Table 4). There was a significant interaction between soil N fertilizer and organic matter. Application of compost at a rate of 50 ton ha^{-1} with 100 kg ha^{-1} of N fertilizer caused maximum seed yield (469 g m^{-2}) while minimum seed yield was observed at control levels of both organic matter and N fertilizer treatments (120 g m^{-2}) (Table 5). The analysis of N sources influencing yield in rapeseed has shown that canola responds to all forms of mineral N in inorganic fertilizers, N mineralized from organic fertilizers, and N mineralized from residue of the previous crop (Diepenbrock, 2000). The percent of seed yield increase in soils amended with organic matter showed a negative correlation with N fertilizer rate and the positive effect of organic matter on the seed yield was diminished at higher N fertilizer rates. Canola seed yield in soil amended with organic matter at 0, 50, 100, and 150 kg ha^{-1} levels of N fertilizer respectively recorded 54.1, 36.5, 34.3, and 13.7% increase over control (no organic matter) (Table 5). These findings suggest that application of organic matter can not only increase canola seed yield but simultaneously reduce canola N requirement, possibly through improvement of soil physical, chemical and biological characteristics which may be considered a step toward sustainable agriculture. Recent studies on wheat residue management showed that the return of rice and wheat residues could facilitate recycling a considerable amount of the N absorbed by the crop (Singh and Sherma, 2000). Barzegar et al. (2002) in their study on

Table 3. Effects of nitrogen on growth, yield and yield components of canola (mean two years data)

Nitrogen (kg ha^{-1})	Biomass (g m^{-2})	Seed yield (g m^{-2})	H.I.	SP	TPP	TSP	MKW	BN
N0	951.2	171.9	18.0	8.9	84.8	848.8	3.9	4.4
N1	1225.0	284.3	20.0	10.0	127.7	1333.8	4.7	6.0
N2	1314.3	366.5	27.8	10.5	146.8	1514.0	5.1	6.8
N3	1412.0	382.8	27.1	10.6	151.4	1536.0	5.3	6.8
LSD (5%)	80.92	23.23	1.97	0.34	6.03	60.55	0.31	0.77

N0=0 kg N ha^{-1}, N1=50 kg N ha^{-1}, N2=100 kg N ha^{-1}, N3=150 kg N ha^{-1}, H.I.=Harvest Index, SP= seed number per pod, TPP=total pod number per plant, TSP= total seed number per plant, MKW= 1000 seed weight, BN=Branch number

the effect of various organic amendments including 0, 5, 10, and 15 ton per hectare wheat straw, composted sugarcane bagasse residue and farmyard manure showed that application of organic materials increased wheat yield, aggregate stability, and soil infiltration rate. The effectiveness of different organic materials on improving the soil physical properties did not show any difference.

Biomass

N-fertilizer had a significant effect on biomass of canola per unit area with an optimal level of 150 kg N ha^{-1} (Table 3). Application of organic matter generally increased the biomass over control at all levels of N-fertilizer, however the magnitude of increase of biomass was higher at lower levels of N-fertilizer. For instance the highest increase in biomass over control ratio was 26.2% observed at 0 kg N ha^{-1} whereas the minimum increase (8.04%) was observed at 150 kg ha^{-1}. The highest increase in biomass occurred at 50 ton ha^{-1} level of compost and 100 kg N ha^{-1} rate that was not significantly different from 35 ton ha^{-1} of compost at 150 kg N ha^{-1} level (Table 5). Svecˇnjak and Rengel (2006) found a 46 percent significant reduction in plant dry weight at the low-N treatment compared with the high-N treatment. They also reported 46 percent reduction of plant N concentration in the low-N treatment (18.1 g kg^{-1}) than in the high-N treatment (33.8g kg^{-1}). In another study it was shown that application of 50 ton ha $^{-1}$ organic matter increased the wheat and barley yield by 1.7 and by 2.7 respectively (Zhang et al., 2000).

Harvest index (HI)

Harvest index (HI) of canola was significantly affected by N application. Increasing N application rate resulted in increased HI, however beyond the 100 kg ha^{-1} rate the increase was not significant (Table 3). Increasing the rate of fertilizer application was shown to increase the HI in other studies (Faramarzi et al., 2009; Cheema et al., 2001), but some studies reported negligible effect of N application rate on the HI (Hocking and Stapper, 2001; Hocking et al., 1997). The HI reached its peak at 50 ton ha^{-1} of compost and 100 kg ha^{-1} of N fertilizer treatment and was lowest at control (no organic matter, no N-fertilizer). Both compost and wheat straw increased the HI; however compost caused 20% HI increase over control while wheat straw caused 10% HI increase over control (Table 4). The HI increase pattern was consistent across organic material treatments at all levels of N fertilizer and across N-fertilizer at all levels of organic matter (Table 5).

Seeds number per pod (SP)

Increasing N fertilizer application rate up to 100 kg ha^{-1} increased seeds number per pod significantly but the increase was not statistically significant thereafter(Table 3). A positive correlation has been reported between the number of seeds per pod and the application rates of N-fertilizers (Chauhan et al. 1995; Morgan 1972). Other studies suggested a negative correlation between N application rate and the number of seeds per pod which is not in accordance with our findings (Cheema et al., 2001; Vullioud, 1974). The maximum SP was found at 50 ton ha^{-1} compost showing a significant difference with wheat straw regardless of the rate applied. Generally compost had a better effect on the SP and the percent of increase in SP over control was 18.5% at 35 ton ha^{-1} compost while it was 6.5% at 3 ton ha^{-1} wheat straw (Table 5). The optimal SP was recorded at 50 ton compost ha^{-1} and 100 kg N ha^{-1} however it was lowest at no-organic matter and no N-fertilizer treatment (Table 5). A negative correlation was found between the SP and N-fertilizer rate when organic matter was applied and percentage increase in SP was gradually reduced from 0 to 150 kg N ha^{-1} highlighting the importance of organic matter in substituting N-fertilizer (Table 5).

Total pod number per plant (TPP)

The total number of pods per plant (TPP) peaked at 150 kg ha^{-1} N fertilizer and was lowest at 0 kg ha^{-1} of N-fertilizer while the difference between TPP at 100 and 150 kg ha^{-1} levels of N-fertilizer was not significant (Table 3). Several workers have also reported positive response of the canola TPP to increased level of N fertilization (Ozer, 2003; Cheema et al., 2001; Allen and Morgan, 1972) which is in accordance with our findings. The TPP reached its peak at 50 ton ha^{-1} compost that did not show a significant difference with 35 tons ha^{-1} compost (Table 4). Application of organic matter increased the TPP over control at all levels of N. Interestingly the promoting effect of organic matter on the amount of increase of the TPP had a negative correlation with the rate of N application. TPP Increasing trend was decreased with application of N-fertilizer at all levels of organic matter, which indicates a negative correlation between organic matters at higher levels of N-fertilizer (Table 5).

Total seed number per plant (TSP)

The total number of seeds per plant (TSP) responded to both N-fertilizer and organic matter (Tables 3 and 4). The maximum TSP was found at 50 ton ha^{-1} compost which was significantly higher than wheat straw at all levels of the application rate (Table 4). The optimal TSP occurred at 50 ton ha^{-1} compost and 100 kg N ha^{-1}. Compared to wheat straw application of compost had a better effect on the TSP. Increasing trend of TSP over control at 50 ton ha^{-1} compost was 44.5% but only 24% at 3 ton ha^{-1} wheat straw (Table 4).

Table 4. Effect of additive organic matters on growth, yield and yield components of canola (mean two years data)

Treatments	Biomass (g m^{-2})	Seed yield (g m^{-2})	H.I.	SP	TPP	TSP	MKW	BN
Cont.	1098.3	243.5	22.1	9.2	105.1	1026.0	4.3	5.2
S1	1166.2	281.4	24.1	9.6	124.2	1261.5	4.6	5.7
S2	1187.1	282.7	23.8	9.8	125.5	1273.7	4.7	5.7
C1	1328.7	342.7	25.7	10.4	140.7	1483.7	5.0	6.5
C2	1347.8	356.6	26.4	10.9	143.0	1485.5	5.1	6.9
LSD (5%)	48.64	15.8	1.67	0.285	5.01	63.35	0.281	0.47

Cont.= Control, S1=1.5 ton wheat stubble ha^{-1}, S2=3 ton wheat stubble ha^{-1}, C1=35 ton compost ha^{-1}, C2=50 ton compost ha^{-1}, H.I.=Harvest Index, SP= seed number per pod, TPP=total pod number per plant, TSP= total seed number per plant, MKW= 1000 seed weight, BN=Branch number

Table 5. Interaction effects of nitrogen and plant density on growth, yield and yield components of canola (mean two years data)

Treatments		Biomass (g m^{-2})	Seed yield (g m^{-2})	H.I.	SP	TPP	TSP	MKW	BN
N0	Cont.	786	120	15.27	7.2	64.5	513	3.5	3.4
	S1	941	160	17.34	8.8	83.7	825	3.9	4.0
	S2	855	150	17.57	8.1	79.9	723	3.7	3.6
	C1	1061	208	19.63	9.5	91	996	4.3	5.0
	C2	1111	221	20.13	10.6	105	1147	4.4	5.8
N1	Cont.	1096	220	20.06	9.4	105	1102	4.3	5.0
	S1	1200	260	21.89	9.7	122	1285	4.6	5.9
	S2	1110	246	22.24	9.5	117	1234	4.3	5.4
	C1	1341	340	25.44	10.5	147	1584	5.0	6.3
	C2	1376	355	25.80	10.7	147	1464	5.2	6.9
N2	Cont.	1183	289	24.43	9.9	119	1171	4.4	6.0
	S1	1231	346	28.14	10.3	139	1397	5.1	6.4
	S2	1250	350	23.03	10.4	147	1578	5.3	6.8
	C1	1383	387	28.10	10.5	152	1664	5.2	7.0
	C2	1528	469	30.18	11.5	177	1760	5.6	8.0
N3	Cont.	1326	345	26.05	10.3	132	1318	5.1	6.0
	S1	1375	365	26.55	10.3	152	1540	5.1	6.5
	S2	1450	379	26.15	10.5	158	1560	5.3	6.8
	C1	1523	435	28.48	11.1	172	1698	5.4	7.4
	C2	1380	390	28.27	10.5	143	1564	5.2	7.1
LSD (5%)		97.3	29.4	3.35	0.5711	10.03	126.7	0.5625	0.95

N0=0 kg N ha^{-1}, N1=50 kg N ha^{-1}, N2=100 kg N ha^{-1}, N3=150 kg N ha^{-1},Cont.= Control, S1=1.5 ton wheat stubble ha^{-1}, S2=3 ton wheat stubble ha^{-1}, C1=35 ton compost ha^{-1}, C2=50 ton compost ha^{-1}, H.I.=Harvest Index, SP= seed number per pod, TPP=total pod number per plant, TSP= total seed number per plant, , MKW= 1000 seed weight, BN=Branch number

Mean Kernel weight (MKW)

N-fertilizer and organic matter had positive effects on the MKW and the optimal levels of both treatments yielding the maximum MKW were 50 ton ha^{-1} compost and 100 kg N ha^{-1} (Table 6). An increase in the MKW was observed with increase in N-fertilizer however at higher rates of N-fertilizer this effect was not significant (Table 3). Ahmadi and Bahrani, (2009) reported no significant effect for increased N levels on 1000-seed weight. Application of compost also caused a significant increase in the MKW over both wheat straw and control (Table 4). The discrepancies in the results of different studies might be due to high biological variation of the mean seed weight that might be in turn related to the importance of availability of nutrient supply in the short period of time between anthesis and maturity. Some researchers suggest that at this short time window, the supply of assimilates to the pod and eventually to the seed has a crucial role in the seed development (Allen and Morgan, 1975; Scott et al., 1973). As a consequence, plants with more nutrient supplies may have advantage over others.

Branch number

The number of branches of canola was increased significantly following increase in N fertilizer application rate and the maximum number of branches was observed at 100 kg N ha^{-1} and 50 ton ha^{-1} compost with a minimum at control levels of both treatments (Table 5). Several other studies have also reported positive effect of the rate of N-fertilization on the number of branches in canola, which is not far from expectation as N fertilizers stimulate better plant growth and development (Buttar et al., 2006; Ozer, 2003; Allen and Morgan, 1972). Among the organic materials, compost user caused a 29% increase in the branch number over control, while the increase was only 9.6 % for wheat straw (Table 4).

Stepwise selection of yield components

Results showed that contribution of yield components of canola varied with change in N-fertilizer and organic matter application rates. The mean kernel weight explained 97.8% of the variations in seed yield when no N-fertilizer applied.

Table 6. Summary of Stepwise Selection for nitrogen treatments (mean two years data)

Nitrogen (kg ha^{-})^{1}	Variable entered	Partial R-Square	Model R-Square	F Value	Pr >F
N0	*Mean kernel weight*	0.978	0.978	365.93	<0.0001
	Pod no. per plant	0.016	0.994	23.27	0.0019
	Seed no. per plant	0.004	0.999	35.37	0.0010
N1	*Seed no. per pod*	0.985	0.985	554.64	<0.0001
	Mean kernel weight	0.012	0.997	31.94	0.0008
	Seed no. per plant	0.003	1.0000	1190.68	<0.0001
N2	*Pod no. per plant*	0.976	0.976	333.40	<0.0001
N3	*Branch no.*	0.931	0.931	109.5	<0.0001
	Seed no. per pod	0.063	0.994	88.77	<0.0001
	Seed no. per plant	0.005	0.999	101.92	<0.0001

N0=0 kg N ha^{-1}, N1=50 kg N ha^{-1}, N2=100 kg N ha^{-1}, N3=150 kg N ha^{-1}

Table 7. Summary of Stepwise Selection for density treatments (mean two years data)

Organic Matter (ton ha^{-1})	Variable entered	Partial R-Square	Model R-Square	F Value	Pr >F
Cont.	Pod no. per plant	0.972	0.972	211.88	<0.0001
	Seed no. per pod	0.026	0.998	91.97	0.0002
S1	Pod no. per plant	0.979	0.979	291.27	<0.0001
	Branch no.	0.020	1.0000	2030.49	<0.0001
S2	Pod no. per plant	0.996	0.996	1515.25	<0.0001
	Mean kernel weight	0.004	1.0000	52.44	0.0122
C1	Mean kernel weight	0.979	0.979	291.78	<0.0001
	Seed no. per plant	0.015	0.994	16.17	0.0101
C2	Seed no. per plant	0.997	0.997	2370.39	<0.0001
	Mean kernel weight	0.003	1.0000	223.65	<0.0001

Cont.= Control, S1=1.5 ton wheat stubble ha^{-1}, S2=3 ton wheat stubble ha^{-1}, C1=35 ton compost ha^{-1}, C2=50 ton compost ha^{-1}

Nitrogen deficiency causes a reduction in vegetative growth and accumulation of non structural carbohydrates in stem tissues of the plant. It appears that remobilization of assimilates is impaired in vegetative growth stage but recommences in final stages of seed development and contributes in seed weight through re-translocation of non structural sugars making MKW a critical component of seed yield under poor nitrogen condition (Table 6). Increasing rate of N-fertilizer to 50 kg ha^{-1} changed the role of the number of seeds per pod as the main contributing component in seed yield (partial R-square=0.985) and diminished the contribution of mean kernel weight (Table 6). Canola is an indeterminate plant and its reproductive growth is also followed by any flash of vegetative growth, so an increase in N-fertilizing rate proceeds with increased vegetative growth and consequently with higher number of pods per plant. This may explain why application of 100 kg ha^{-1} nitrogen increased the contribution of the number of pods per plant in seed yield up to 97.6 % (Table 6). Increasing the rate of N-fertilizer to 150 kg ha^{-1} caused a significant increase in the number of secondary branches and improved the contribution of this component in seed yield to 93.1% (Table 6). With increasing nitrogen application rate as a vegetative growth stimulant, the number of secondary branches and accordingly the number of pods per plant increased. The number of pods per plant is one of the most important seed yield components of canola (Mottalebipour and Bahrani, 2006) and it has shown to have the highest positive correlation with canola seed yield (Ahmadi and Bahrani, 2009; Buttar et al., 2006). Billisborrow et al. (1999) reported that the application of sufficiently high rates of N fertilizer increased the potential of production of the number of pods per plant and the number of fertile pods of canola per unit area. When no organic matter was applied, the number of pods per plant explained 97.2% of variation in seed yield and the proportion of explained variance approached 99.6% after adding wheat straw to soil (Table 7). Most of the nutrient content of wheat straw might be converted into a readily available form for plant nutrition not before several years of residue decomposition in soil. Therefore application of plant residue to soil will not possibly have a significant advantage to the crop planted immediately in the next season. This may give an explanation why no significant difference between organic matter treatment and control (no organic matter) was found. Municipal waste compost on the other hand contains more available minerals and organic matter, thus application of 35 ton ha^{-1} compost improved the contribution of MKW in seed yield (partial R-square 97.9 %) (Table 7). As the rate of application of compost was increased to 50 ton ha^{-1}, the contribution of number of seeds per plant in seed yield replaced the MKW and became the most important component with a partial R-square of 99.7 %. Application of more compost led to a nutritional surplus in soil which improved utilization of soil nutrient by roots and enabled producing more seeds per pod.

Soil characteristics

Electro-conductivity and *pH*

Application of N-fertilizer increased soil electro-conductivity (EC) (Table 8). Neither compost nor wheat straw caused

Table 8. Effects of nitrogen on some soil nutrient concentration (mean two years data)

Nitrogen (kg ha^{-1})	K *(ppm)*	P *(ppm)*	N *(%)*	OC *(%)*	EC *(dS/m)*	pH
N0	589	13.9	0.058	0.561	0.345	7.86
N1	575	13.8	0.058	0.573	0.346	7.81
N2	573	13.4	0.062	0.577	0.395	7.81
N3	569	13.2	0.066	0.581	0.401	7.80
LSD (5%)	23	0.75	0.009	0.23	0.065	0.052

N0=0 kg N ha^{-1}, N1=50 kg N ha^{-1}, N2=100 kg N ha^{-1}, N3=150 kg N ha^{-1}

Table 9. Effects of additive organic matters on some soil nutrient concentration (mean two years data)

Treatments	K *(ppm)*	P *(ppm)*	N *(%)*	OC *(%)*	EC *(dS/m)*	pH
Cont.	550	13.5	0.059	0.55	0.415	7.88
S1	560	13.4	0.061	0.61	0.418	7.86
S2	557	14.0	0.063	0.64	0.412	7.88
C1	560	13.6	0.062	0.60	0.444	7.87
C2	580	14.0	0.069	0.69	0.468	7.86
LSD (5%)	32	0.65	0.002	0.165	0.058	0.03

Cont.= Control, S1=1.5 ton wheat stubble ha^{-1}, S2=3 ton wheat stubble ha^{-1}, C1=35 ton compost ha^{-1}, C2=50 ton compost ha^{-1}

significant changes in EC over control. Although an increase in EC was observed at compost treatments, however this increase did not show a significant difference with control which may be owing to the effect of higher EC of the compost used (Table 9). Similar effect of compost or manure on soil EC was also reported by Eghbal et al. (2004). Application of N fertilizer resulted in a decrease of pH, though the decrease was only significant between 150 and 0 kg N ha^{-1} treatments (Table 8). Biological nitrification of N sources that are mainly in the form of urea may cause reduction in soil pH. Amending of soil with organic matter did not cause any significant change in pH (Table 9).

Potassium and phosphorus

Neither N fertilizer nor organic matter caused a significant change in soil potassium level; however compared to control and wheat straw, application of compost increased soil potassium level significantly (Tables 8 and 9). Other results showed that use of sludge compost as soil amendment increased seed dry weight and also the amount of potassium and phosphorus absorbed by the plant over control (Bar-Tal et al., 2004). Available phosphorus in soil responded to the application of organic matter. The soil phosphorus was increased after adding compost (50 ton ha^{-1}) or wheat residue (3 ton ha^{-1}) to the soil but the increase was not significant (Table 9). Similar studies reported significant increase of available phosphorus in soil after application of animal manure and compost (Eghball, 2002).

Nitrogen content

Application of N-fertilizers had no significant effect on total soil nitrogen content (Table 8). Organic matter in the form of compost increased the total nitrogen content of soil significantly (Table 9). Increased available phosphorus and soil nitrogen contents after adding compost or animal manure to the soil has also been reported (Eghball et al., 2004). In another study Beraud et al. (2005) found that cropping condition may change mineral nitrogen uptake and carbon and nitrogen mobilization in soil through its effects on soil temperature and liberation of organic carbon from root seepage. Since mineralization rate of wheat is slower than compost, it can be concluded that in long term wheat left over has a residual effect on soil fertility and nitrogen availability.

Organic carbon

Application of nitrogen to soil caused an indirect increase in soil organic carbon by increasing crop residue (Table 8). Halvorson et al. (2002) found that regardless of increasing of plant residue after applying nitrogen to soil, this treatment did not cause any significant change in organic carbon content of the soil. Soil organic carbon was increased due to application of organic matters but not significantly (Table 9).

Conclusion

Our results showed a beneficial effect of compost application on the reduction of application rate of N-fertilizer. The optimal rate of application to guarantee the maximum canola seed yield is 100 kg ha^{-1} with 50 ton compost ha^{-1}. It appears that 50% of the required N-fertilizer could be replaced by compost application, but application of 150 kg N ha^{-1} with wheat straw increased the seed yield substantially. With high levels of application for all organic matter treatments, the canola seed yield increased rate over control was more than expected, and the maximum seed yield (356.6 g m^{-2}) was obtained by applying 50 ton ha^{-1} compost. Stepwise regression results showed that contribution of yield components of canola varies with change in N-fertilizer and organic matter application rates. Among different organic matter treatments, 50 ton ha^{-1} compost application increased soil EC significantly. Compared to the control (no additive materials), application of different organic matters had no effect on the soil pH. Between organic matters, application of 50 ton ha^{-1} compost increased total soil nitrogen. Increasing nitrogen levels had no significant effect on soil organic carbon. Different types of organic matter increased soil organic carbon, even though this increase was not significant.

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