OIL YIELDS OF CANOLA AS AFFECTED BY N AND S LEVELS AND METHODS OF APPLICATION UNDER RAINFED CONDITIONS

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ABSTRACT

Field experiments were conducted at Cereal Crops Research Institute Pirsabak Nowshera, Pakistan, for two years (2003-04 and 2004-05) to evaluate the effect of nitrogen and sulfur levels, and methods of nitrogen application on canola (*Brassica napus* L. cv. Bulbul-98) under rainfed conditions. In the experiments four levels of S (0, 10, 20, and 30 kg ha^{-1}) and three levels of N (40, 60, and 80 kg ha^{-1}) and a control treatment with both nutrients at zero level were included. Sulfur levels were applied at sowing while N levels were applied by three methods (100 % basal, 90 % basal + 10 % foliar, and 80 % basal + 20 % foliar). The experiments were laid out in RCB design with factorial arrangement having four replications. Results indicated that biological yield and HI were increased significantly with the application of up to 10 kg S ha^{-1} but no significant increase in these parameters were recorded when S level was increased beyond 10 kg ha^{-1}. Oil yields were enhanced up to 20 kg S ha^{-1}. Plots with highest N level of 80 kg ha^{-1} had highest values for biological yield (7.37 t ha^{-1}) and oil yield (685 kg ha^{-1}). Nitrogen levels did not affect harvest index. No significant influence of the methods of N application was recorded on any parameter under study. Higher biological and oil yields were recorded during 2004-05 as compared to 2003-04.

Keywords: Canola, Rainfed, Sulfur, Nitrogen, Methods of application, Oil yield

INTRODUCTION

Canola has the lowest saturated fat content among the vegetable oils. Today there is an increasing demand for this oil by diet- conscious consumers. (Grombacher and Nelson, 1992). Rapeseed grows best under relatively cool temperatures up to flowering. After flowering it can tolerate high temperature but heat and drought stress may result in a reduction of seed size, crop yield and oil contents. (Rehman et al., 1987). Its average yield in Pakistan is 839 kg ha^{-1} (MINFAL, 2005), which is very low as compared to other agriculturally advanced countries of the world. The European countries have a yield level of 3500 kg ha^{-1}, Canada 3200 kg ha^{-1} and Australia 2000 kg ha^{-1} (Reddy, 2004).Rainfed agriculture represent 25% of the total cropped area in Pakistan and 60% in NWFP (MINFAL, 2005). Increased production from the rainfed area is critical if Pakistan is going to meet the increasing needs of the country for food and other agricultural products. Current management by the rainfed farmers is at very basic levels of technology so the opportunities for increased productivity with improved management practices are substantial.

Nitrogen is required about 25% more by canola when compared with wheat (Hocking et al., 1997). To reduce the losses of N, trend for the split application has gained importance. Higher efficiency of split application (50% + 50%) has been reported by Barlog and Grzebisz (2004). While Ali and Ullah (1995) reported that 50 - 75 % nitrogen applied as basal dose and the rest as foliar is the best method of N application for rapeseed. Holmes (1980) concluded that choosing the correct rate and timing of nitrogen fertilizer application is one of the most important aspects of successful oilseed rape production.

In addition to N, sulfur is an important soil fertility factor to consider when growing canola (Ghosh et al., 2000) because of high requirement of S by Cruciferae family (Scherer, 2001). Sulfur is so important for canola that at high soil sulfur levels, (10-20 kg S ha^{-1}) is still recommended (Franzen, 1997). Refinement of N and S fertilizer recommendations for canola are needed to ensure optimum productivity, economic vitality and environmental stewardship (Jackson, 2000). Keeping in view the importance of N and S in canola production, the present experiments were designed with objectives:

i. To study the response of oil yield of canola to N and S application under rainfed conditions.
ii. To study the biological yield of canola in response to N and S application under rainfed conditions.

MATERIALS AND METHODS

Experimental Site

Field experiments were conducted at Cereal Crops Research Institute Pirsabak, Nowshera, Pakistan. Nowshera is located about 1600 km north of Indian

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Ocean at 34°N latitude, 72°E longitude and an altitude of 288 meters above sea level and thus have a continental climate. The study was conducted over two years period (2003-04 and 2004-05). The soil of the experimental field was sandy loam, moderately calcareous, low in nitrogen (0.014%), low in organic matter (0.31%), low in available sulfur (8.27 mg kg^{-1}) and alkaline in reaction having a pH of 7.7.

Mean monthly minimum temperature ranged from 6.21°C in January to 18°C in April and the maximum temperature ranged from 16.8°C to 33.2°C in April during 2003-04. While the temperature was cooler in 2004-05 because the mean monthly minimum temperature ranged from 3.8°C to 14.9°C and the maximum temperature ranged from 17.0°C to 30.9°C. Total seasonal rainfall was 227 mm in 2003-04 and 508 mm in 2004-05 (Tables I, II and III); the rainfall was much higher in 2004-05 than the 10 years average rainfall of 259 mm.

Experimental Procedure

Seed of improved canola cultivar Bulbul-98 were sown on 18 October 2003 and 19 October 2004 at CCRI Pirsabak. A uniform seed rate of 5 kg ha^{-1} was planted in all the plots through hand hoe in straight rows. The experiments were laid out in randomized complete block design having 4 replications and the size of sub plot was 5 m by 3 m. In each sub plot there were 6 rows 5 m long and 50 cm apart. Basic dose of PK at the rate of 60-60 kg ha^{-1} was applied in the form of triple super phosphate and murate of potash prior to sowing with seedbed preparation. Nitrogen was applied in the form of urea while sulfur was applied in the form of ammonium sulfate. Detail of the experimental treatments is given and Table IV. The nitrogen levels were applied by placement at the time of sowing and foliar spray at stem elongation stage. For foliar application, first water was sprayed on a plot to find out the volume of water required for a plot. The calculated amount of urea was dissolved in the required volume of water and then the diluted solution was sprayed on the crop through hand operated sprayer. Pure water was sprayed on those plots, which did not receive foliar application. After the completion of germination, seedlings were hand thinned to maintain a uniform plant to plant distance of 5 cm. Weeds were controlled manually. All cultural practices were applied uniformly to all the plots. The experiments were harvested in the month of April during both years.

The following factors and their levels were studied in the experiments.

FACTOR A. Sulfur levels (kg ha^{-1}):

	0	(S1)
	10	(S2)
	20	(S3)
	30	(S4)

FACTOR B. Nitrogen levels (kg ha^{-1}):

	40	(N1)
	60	(N2)
	80	(N3)

One treatment of both N and S at zero level was kept as check.

FACTOR C. Methods of Nitrogen Application

Placement at Sowing	Foliar at stem elongation (Stage 4)	
100%	0%	(M1)
90%	10%	(M2)
80%	20%	(M3)

List of data recorded:

a. Biological yield
b. Oil yield
c. Harvest index

Supporting data

a. Temperature
b. Rainfall

Procedure for data recording

For total biomass yield, four central rows in each sub plot were harvested, dried and weighed. In order to determine grain yield bundles from the same central four rows were threshed and the seed was weighed and the data were converted to kg ha^{-1}. To calculate harvest index, the grain yield was divided by biological yield and multiplied by 100 to express the data as percentage. Oil yield was calculated from seed yield and percentage of oil in the seed.

Random seed samples from each plot were collected and analyzed for percent oil by FOSS Routine Near Measurement System (35RP-3752F) TR-3657-C Model 6500, at oilseed laboratory, Nuclear Institute for Food and Agriculture, Peshawar. Near infrared reflectance spectroscopy is a rapid, non-destructive whole seed scanning technique, which does not require any sample preparation or chemicals (Daun et al., 1994).

Statistical analysis

Data recorded were analyzed statistically combined over years using analysis of variance techniques appropriate for randomized complete block design. For analysis excel worksheet was programmed. Main and interaction effects were compared using LSD test at 0.05 level of probability, when the F-values were significant. One single degree of freedom contrast was used to compare control with the rest of main plot treatments (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Biological yield

Data concerning biological yield (Table V) showed that N and S levels had a significant effect, while N application methods had no significant influence on the biological yield of canola. No significant interaction effects among different treatments were detected for biological yield. Lower biological yield of 4.08 t ha^{-1} was produced by control plots with no S and N application as compared to biological yield of 6.52 t ha^{-1} produced by plots which received different rates of N and S. Mean values of two years data revealed that biological yield increased with increasing N rate and the maximum biological yield of 7.37 t ha^{-1} was produced by the plots which received the highest rate of 80 kg N ha^{-1}. Sulfur application had also significantly enhanced biological yield. Higher biological yield was produced by the plots, to which S was applied as compared to the plots without S application. The differences among different doses of S were not significant, indicating biological yield remained almost constant irrespective of S levels. Comparison between the two growing seasons revealed that more biological yield of 5.316 t ha^{-1} was noted during 2004-05 as compared to 5.285 t ha^{-1} recorded during 2003-04. The increase in biological yield with the increasing rates of N may be due to the fact that N increases vegetative growth resulting in more photosynthesis and hence photosynthates, which increases the growth and development of crop and thus resulted in the increased biological yield. These results are in conformity with those reported by Uddin (1992) and Kutcher et al. (2005) who stated that biological yield increased with increasing rates of nitrogen. The increase in biological yield with the application of S shows the positive response of canola to applied sulfur. Sharma and Gupta, (1991) reported that the increase in biomass yield with the increase in S application may be due to the fact that S promotes vegetative growth, starch and grain formation.

Oil yield

Data regarding oil yields given in Tables VI showed that N, S and interaction between N and S had significantly influenced oil yields of canola under rainfed conditions. Higher oil yield of 617 kg ha^{-1} was recorded for the treatments that included N and S as compared to 379 kg ha^{-1} for control. Mean comparison for S levels showed that different levels of S had significant influence on oil yield. Higher oil yields were observed for the treatments which had 20 to 30 kg S ha^{-1}. Comparing different N levels, it was found that oil yield was enhanced with increasing N levels. The maximum yields were observed in the plots that received the highest dose of 80 kg N ha^{-1}. Combinations of N x S revealed that the impact of N in increasing oil yield was enhanced with combined application of S. Higher oil yields were produced by the plots that received 80 kg N in combination with 20 to 30 kg S ha^{-1}. Comparing results of the two growing seasons, it was found that higher oil yields (510 kg ha^{-1}) were produced during 2004-05 compared to those recorded during 2003-04 (486 kg ha^{-1}).

Increasing N level decreased oil concentration but the total oil yields increased because of the higher seed yield and maximum oil yields were observed in the plots that received 80 kg N ha^{-1}. These results are in agreement with the findings of Fismes et al. (2000) and Jackson (2000) who reported that increasing N rate decreased oil concentration in seed of canola but the over all oil yield increases because of the higher seed yield. Comparison of results of the two growing seasons indicated that oil yields were higher during 2004-05 compared to those of 2003-04. Such differences in oil yield could be due to differences in the rainfall between the two growing seasons (Table1), indicating that higher rainfall and lower temperatures are favourable for higher oil yields of canola. These results are in agreement with Ramsey and Callinan (1994) who reported that oil yields were lower in drier years than those in wet years.

Harvest index

Mean values of the two years data presented in Table VII showed that harvest index of canola had a significant response to S rates and N x S interaction. While N rates and application methods had no significant influence on harvest index of canola. Lower value of the harvest index (21.3 %) was recorded for control plots as compared to the mean value (22.4 %) noted from the rest of the plots. Application of different S levels exhibited significantly higher harvest index as compared to the plots receiving no S while harvest index recorded from different S levels was at par with each other. Significant N x S interaction indicated that the highest rate of N used in the study slightly depressed harvest index in plots where no S had been applied but in combination with 10 to 30 kg S ha^{-1}, application of 80 kg N ha^{-1} increased harvest index.

Comparing data for two years as a source of variation, revealed that no significant differences were found for the HI of canola. The findings of these experiments regarding harvest index are in agreement with Munir and MecNeily (1987) who found that N levels had no significant effect on harvest index. But these results are not in line with the findings of Shukla and Kumar (1997) who reported that harvest index was increased with increasing N rate.

CONCLUSION AND RECOMMENDATIONS

From the results of the experiments the following conclusions were made:

Higher values for biological yield, and harvest index, were obtained with the application of 10 kg S ha^{-1}. Enhanced oil yields were found in the plots that received 20 kg S ha^{-1}.

Nitrogen levels had no significant impact on harvest index. Increasing levels of N had progressively enhanced biological yield and oil yield up to the highest level of 80 kg N ha^{-1}.

No significant impact of N application methods was found on any parameter under study.

In light of the conclusion the following recommendations are made:

1. A combination of 80 kg N ha^{-1} + 20 kg S ha^{-1} resulted in enhanced oil yield of canola under rainfed conditions and is recommended.
2. In rainfed conditions application of N and S in a single dose at the time of sowing is recommended.
3. Further research work is needed to find out the optimum levels of N and S and their methods of application under rainfed conditions under different agro-ecological conditions.

Table I. ***Average air temperature and rainfall, at CCRI Pirsabak, Nowshera during the crop growing season 2003-04 and 2004-05***

Month	Min T (°C)	Max T (°C)	Average T (°C)	Total Rainfall (mm)	Ten years average Rainfall(mm)*
October	15.4(14.7)	30.9(28.0)	23.2(21.7)	14.0(106.2)	32.1
November	17.7(9.0)	24.4(26.8)	21.1(17.9)	41.0(19.7)	12.8
December	07.0(7.2)	19.7(20.1)	13.4(13.6)	43.0(104.1)	23.0
January	06.2(3.8)	16.8(17.0)	11.5(10.8)	70.5(36.0)	50.3
February	06.8(6.8)	21.6(16.3)	14.2(11.5)	58.5(114.0)	63.6
March	13.4(12.4)	30.1(24.9)	21.8(18.7)	0.00(127.7)	52.7
April	18.0(14.9)	33.2(30.9)	25.6(22.9)	65.8(17.5)	24.5
Total rainfall during the growing season				227.0(508.2)	259.0

Without parenthesis = for crop season 2003-04.
With parenthesis = for crop season 2004-05.
* 10 years = 1995-96 to 2004-05

Table II. ***Monthly air temperature and rainfall recorded during the crop growing season 2003-04.***

Month	Temperature (°C)			Rainfall (mm)		
	Average*	Normal**	DFN***	Total****	Normal**	DFN***
October	23.2	23.6	-0.4	14.0	32.1	-18.1
November	21.1	17.9	+3.2	41.0	12.8	+28.2
December	13.4	12.6	+0.8	43.0	23.0	+20.0
January	11.5	10.8	+0.7	70.5	50.3	+20.2
February	14.2	13.3	+0.9	58.5	63.6	-5.1
March	21.8	18.7	+3.1	0.0	52.7	-52.7
April	25.6	24.3	+1.3	65.8	34.0	+31.8

Table III ***Monthly air temperature and rainfall recorded during the growing season 2004-05.***

Month	Temperature (°C)			Rainfall (mm)		
	Average*	Normal**	DFN***	Total****	Normal**	DFN***
October	21.4	23.6	-2.2	106.2	32.1	+74.1
November	17.9	17.9	0.0	19.8	12.8	+7.0
December	13.6	12.6	+1.0	104.1	23.0	+81.1
January	10.4	10.8	-0.4	36.0	50.3	-14.3
February	11.6	13.3	-1.7	114.1	63.6	+50.5
March	18.7	18.7	0.0	127.8	52.7	+75.1
April	22.9	24.3	-1.4	17.5	34.0	-16.5

* Monthly mean of the daily maximum and minimum temperature.
** Normal was the mean temperature or total rainfall over a long period for a particular month.
*** DFN is the departure from normal which is the difference between the mean temperature and the normal of each parameter.
**** Total is the sum of rainfall received during the month.

Table IV. ***The treatment combinations in each replication were as follows***

	Treatment	Sulfur ($kg\ ha^{-1}$)	Nitrogen application ($kg\ ha^{-1}$)	
		Placement	Placement	Foliar
1.	Control	0	0	0
2.	S1N1M1	0	40	0
3.	S1N1M2	0	36	4
4.	S1N1M3	0	32	8
5.	S1N2M1	0	60	0
6.	S1N2M2	0	54	6
7.	S1N2M3	0	48	12
8.	S1N3M1	0	80	0
9.	S1N3M2	0	72	8
10.	S1N3M3	0	64	16
11.	S2N1M1	10	40	0
12.	S2N1M2	10	36	4
13.	S2N1M3	10	32	8
14.	S2N2M1	10	60	0
15.	S2N2M2	10	54	6
16.	S2N2M3	10	48	12
17.	S2N3M1	10	80	0
18.	S2N3M2	10	72	8
19.	S2N3M3	10	64	16
20.	S3N1M1	20	40	0
21.	S3N1M2	20	36	4
22.	S3N1M3	20	32	8
23.	S3N2M1	20	60	0
24.	S3N2M2	20	54	6
25.	S3N2M3	20	48	12
26.	S3N3M1	20	80	0
27.	S3N3M2	20	72	8
28.	S3N3M3	20	64	16
29.	S4N1M1	30	40	0
30.	S4N1M2	30	36	4
31.	S4N1M3	30	32	8
32.	S4N2M1	30	60	0
33.	S4N2M2	30	54	6
34.	S4N2M3	30	48	12
35.	S4N3M1	30	80	0
36.	S4N3M2	30	72	8
37.	S4N3M3	30	64	16

N = Nitrogen, S = Sulfur, M = Method of application

Table V ***Biological yield (t ha^{-1}) of canola as affected by S and N levels and its methods of application under rainfed conditions***

Sulfur	Nitrogen	Methods			Mean
--------kg ha^{-1}--------		M-1	M-2	M-3	
			S x N x M		S x N
0	40	5.762	5.737	5.583	5.694
0	60	6.221	6.379	6.509	6.370
0	80	7.083	7.016	7.342	7.147
10	40	5.749	5.657	5.821	5.742
10	60	6.277	6.432	6.436	6.382
10	80	7.347	7.602	7.461	7.470
20	40	5.624	5.730	5.690	5.681
20	60	6.510	6.563	6.631	6.568
20	80	7.583	7.466	7.413	7.487
30	40	5.851	5.888	5.784	5.841
30	60	6.478	6.488	6.492	6.486
30	80	7.307	7.472	7.358	7.379
			S x M		
0		6.355	6.377	6.478	6.403 b
10		6.458	6.564	6.573	6.531 a
20		6.572	6.586	6.578	6.579 a
30		6.545	6.616	6.544	6.568 a
			N x M		
	40	5.746	5.753	5.720	5.740 c
	60	6.371	6.465	6.517	6.451 b
	80	7.330	7.389	7.393	7.371 a
Methods Mean		6.483	6.536	6.543	
Control mean		4.080 b		Year-1	5.285 b
Rest mean		6.521 a		Year-2	5.315 a

Means of the same category followed by different letters are significantly different from one another using LSD test at 5% level of probability.

N = Nitrogen S = Sulfur M = Methods.

Table VI. ***Oil yield (kg ha^{-1}) of canola as affected by S and N levels and its methods of application under rainfed conditions***

Sulfur	Nitrogen	Methods			Mean
--------kg ha^{-1}--------		M-1	M-2	M-3	
			S x N x M		S x N
0	40	538	546	538	541 g
0	60	589	595	598	594 e
0	80	630	615	624	623 cd
10	40	554	553	563	557 f
10	60	613	612	624	616 d
10	80	683	692	685	686 b
20	40	553	558	555	556 f
20	60	629	631	633	631 c
20	80	717	710	716	715 a
30	40	556	554	555	555 f
30	60	611	621	624	619 cd
30	80	728	717	706	717 a
			S x M		
0		586	585	587	586 c
10		617	619	624	620 b
20		633	633	635	634 a
30		631	631	628	630 a
			N x M		
	40	551	553	553	552 c
	60	610	615	620	615 b
	80	689	683	683	685 a
Methods Mean		617	617	619	
Control mean		379 b		Year-1	486 b
Rest mean		617 a		Year-2	510 a

Means of the same category followed by different letters are significantly different from one another using LSD test at 5% level of probability.

N = Nitrogen S = Sulfur M = Methods.

Table VII. ***Harvest index (%) of canola as affected by S and N levels and its methods of application under rainfed conditions***

Sulfur	Nitrogen	Methods			Mean
--------kg ha^{-1}--------		M-1	M-2	M-3	
			S x N x M		S x N
0	40	21.8	22.2	22.5	22.1 de
0	60	22.4	22.1	22.0	22.2 cde
0	80	21.9	21.6	21.0	21.5 f
10	40	22.3	22.7	22.4	22.5 bcde
10	60	22.9	22.5	23.0	22.8 ab
10	80	22.3	21.8	22.1	22.1 de
20	40	22.7	22.5	22.5	22.6 bcd
20	60	22.6	22.5	22.3	22.5 bcde
20	80	22.5	22.6	23.0	22.7 bc
30	40	22.0	21.8	22.1	22.0 ef
30	60	22.1	22.4	22.5	22.3 bcde
30	80	23.9	23.0	23.1	23.3 a
			S x M		
0		22.0	21.9	21.8	21.9 b
10		22.5	22.3	22.5	22.4 a
20		22.6	22.5	22.6	22.6 a
30		22.6	22.4	22.6	22.5 a
			N x M		
	40	22.2	22.3	22.4	22.3
	60	22.5	22.4	22.4	22.4
	80	22.6	22.2	22.3	22.4
Methods Mean		22.4	22.3	22.4	
Control mean		21.3 b		Year-1	21.6
Rest mean		22.4 a		Year-2	22.1

Means of the same category followed by different letters are significantly different from one another using LSD test at 5% level of probability.

N = Nitrogen S = Sulfur M = Methods.

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