ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 5 (4): 577-582, 2006
ISSN 1812-5379

Effect of Potassium and Sulphur Fertilizers on Yield, Yield Components and Seed Quality of Spring Canola (*Brassica napus* L.) Seed

M. Govahi and M. Saffari
Department of Agronomy, College of Agriculture,
Shahid Bahonar University of Kerman, Iran

Abstract: An experiment was conducted during 2004 to study effects of potassium and sulphur fertilizers on yield, yield components and seed quality in canola (*Brassica napus* L.) CV, Hayola 401 at experimental farm in research station of agricultural college of Shahid Bahonar University of Kerman. The experimental was conducted on a tree-replicated split-plot design with K treatment as the main plot and S treatment as the sub plot. The levels of potassium were (0, 60, 90 and120 kg ha^{-1}) and sulphur were (0, 40, 80 and 120 kg ha^{-1}). Dry-matter accumulation of plant increased with increasing levels of applied S, but showed no significant effect with increasing levels of applied K. Number of primary and secondary branches increased with increasing S application(117 and 32.4%), but unaffected with K application. Average seeds/pod increased with increasing levels of S application. Although the differences were not significant with increasing levels of application (13.5%), but it was not influence with K application, 1000 seed weight increased with increasing levels of S application (37.59%) and levels of applied K (1.14%). The increase of 3.89 and 6.0% in seed oil content was respectively realized with increasing the rate of 0 to 40 and 40 to 80 kg S ha^{-1}, but the increased of application S from 80 to 120 kg S ha^{-1} showed no significant increased in oil content, seed oil content was insignificantly affected by increasing the levels of K. Seed protein content of canola was unaffected by K and S application. Seed yield was, respectively realized with increasing of applied S from 0 to 40 and 40 to 80 kg ha^{-1} and 80 to 120 kg ha^{-1}, but the increased of applied K from 60 to 90 kg ha^{-1} and 90 to 120 kg ha^{-1} showed no significant increase in seed yield. The increase of 3.81% in oil yield was realized with increasing the rate of 0 t 60 kg K ha^{-1}, but the increased of application K from 60 to 90 kg K ha^{-1} and 90 to 120 kg K ha^{-1} showed no significant increased in oil yield/ha. While significant increased (51.41%) was observed with higher input of S (120 kg ha^{-1}). Protein yield ha^{-1} was insignificantly affected by increasing the levels of K application, but significant increase (32.80%) was observed with higher input of S (120 kg ha^{-1}). Total S uptake in seed significantly increased with application S (0 to 120 kg ha^{-1}), but was unaffected with K application.

Key words: Fertilizer, canola, potassium, sulphur

INTRODUCTION

In the Iranian prairies, canola (*Brassica napus* L.) is cultivated on approximately 300,000 ha. Canola is an edible oil crop with the meal utilized as a high-protein feed supplement. Balanced and effective fertilizer management is critical to optimize crop yield and profitability, to ensure crop quality and to sustain soil productivity (Grant and Bailey, 1993). Canola has a relatively high nutrient requirement andmost soil under cultivation of the crop in Iran are deficient in one more nutrients for optimum seed yield; oil and protein concentration.

Potassium plays a major role in the physiological activities of plant and is required in large amounts for adequate crop production (Grant and Bailey, 1993). A healthy, high-yielding crop contains between 150 and 300 kg ha^{-1} (Holmes 1980).

Sulphur is the fourth major nutrient in crop production. Sulphur is especially critical in canola production and S deficiencies frequently restrict canola yield (Grant and Bailey, 1993). Rape requires about 1.5 kg of S to grow 100 kg ha^{-1} of seed (Nyborg *et al*., 1974), so a 2000 kg ha^{-1} crop would require approximately 30 kg S ha^{-1}. Nuttal *et al.* (1987) observed increased canola yields in Saskatchewan of up to 1.06 t ha^{-1}, with the application up to 50 kg S ha^{-1}. In order to obtain optimum yield of high-quality canola seed, S needs to be on integral part of balanced fertilization with other nutrients (Bullock and Sawyer, 1991; Asar and Scarisbrick, 1995; Ahmad *et al*., 1999, 2000; Jackson, 2000; Malhi and Gill, 2002). The present investigation was carried out to study the effect of K and S fertilizers on yield and seed quality.

Corresponding Author: M. Govahi, Department of Agronomy, College of Agriculture,
Shahid Bahonar University of Kerman, P.O. Box 76135-666, Iran Fax: 0098 341 322 2043

Table 1: Some characteristics of soils (0-30 cm) at the experimental sit

Texture	Clay (%)	Silt (%)	Sand (%)	Kava (mg kg^{-1})	Pava (mg kg^{-1})	Ntot (%)	SO_4S (mg L^{-1})	pH	ECS (ds m^{-1})
Sandy loam	14	13	73	209	6.56	0.023	164	7.9	2.11

MATERIALS AND METHODS

This study was carried out during the year 2004 at research station, college of agric, Shahid Bahonar University of Kerman, Kerman, Iran (30° 20′ N, 57° 10′ E). Soil characteristics and nutrient levels are shown in Table 1. Fertilizer S treatments were arranged within the K treatment in a tree-replicate split-plot design with K treatment as the main plot and S treatment as the subplot. Each plot was 8 m long and 5 m wide. All the plots received urea (180 kg ha^{-1}) and triple super phosphate (180 kg ha^{-1}). Spring canola (*B. napus* Hayola 401) was seeded with a double-disc press drill at 40 cm row spacing at a seed rate of 27.9 kg ha^{-1}. The K fertilizer (potassium chloride) was applied at seeding in levels 0, 60, 90, 120 kg ha^{-1}. The S fertilizer (Ammonium sulphate) was applied at seeding in levels 0, 40, 80, 120 kg ha^{-1}. Method of application was surface broadcast and incorporation in soil. Conventional crop management was used during the growing period (Zhou, 2001). Seed yield was determined by hand-harvest in a 1 m^2 quadrate with a plot combin. The number of plants was recorded and a random sub-sample of 10 plants was removed in order to assess the number of primary and secondary branches and pods per plant. All plants from each quadrate were dried in a forced air oven at 80°C for 48 h. Weight per seed was determined from a dry, 10 g sub-sample.

Seed samples were analyzed for oil and protein content and total S Total oil content was obtained by the soxhlet extraction method, using diethyl ether, as reported AOAC methods 920.39 (AOAC 1980). Protein was determined by the Kjeldahl procedure, AOAC method 920; the factor N.6.25 was used to convert nitrogen in to crud protein.

Data analyses were done with use of SPSS statistical package for Windows version 12.0. Where the F-test showed significant differences among means, Duncan's multiple range test was performed at the 0.05 level of probability to separate means. For each ANOVA, standard error of the mean (SEM) and significant are reported.

RESULTS AND DISCUSSION

Yield components and seed yield: Increasing S application from 0 to 120 kg ha^{-1} increased the dry weights of individual plant part, especially in the root and secondary branches (Table 2). The increased were, however, not significant expect for roots, shells and primary branches. Increasing K application from 0 to 120 kg ha^{-1} made no significant increase in dry weight. The combined effect of K and S application increased the dry weights/plant. The plant height was not consistently influence by increasing K and S application (Table 4).

Table 2: Effect of levels of potassium and sulphur on dry weight (g)/plant in spring canola at harvest

Treatment	Root	Stem	Primary branches	Secondary branches	Shell
Potassium (kg ha^{-1})					
0	5.25^{ns}	25.04^{ns}	16.37^{ns}	16.95^{ns}	2.81^{ns}
60	5.26	25.65	16.48	16.71	2.81
90	5.95	26.35	17.06	16.84	2.85
120	5.90	26.19	17.15	17.02	2.84
df (SE)	6(0.29)	6(0.50)	6(0.29)	6(0.59)	6(0.03)
Sulphur (kg ha^{-1})					
0	4.72^{c}	25.10^{ns}	16.42^{ns}	15.97^{ns}	1.49^{d}
40	5.12^{b}	25.26	16.43	16.23	2.52^{c}
80	5.92^{ab}	26.20	17.02	17.53	3.55^{b}
120	6.60^{a}	26.68	17.19	17.78	3.74^{a}
df (SE)	24(0.29)	24(0.50)	24(0.29)	24(0.59)	24(0.03)

Means within a column followed by the same letter are not significantly different at the 0.05 level of probability. ns; indicating not significant at p = 0.05, df; Degree of freedom within groups, SEM; refers to Standard Error of Means

Table 3: Effect of levels of potassium and sulphur on components of yield in canola

	Seed/pod				
Treatment	Primary pod	Secondary pod	Terminal raceme	Average seed No.	1000 seed weight (g)
Potassium (kg ha^{-1})					
0 (K_1)	26.4^{ns}	25.7^{ns}	24.7^{ns}	25.6^{ns}	3.50^{ns}
60 (K_2)	24.10	25.2	24.6	25.3	3.50
90 (K_3)	26.2	25.4	24.8	25.5	3.52
120 (K_4)	26.3	25.5	24.8	25.5	3.54
df (SE)	6(0.26)	6(0.33)	6 (0.35)	6(0.19)	6(0.27)
Sulphur (kg ha^{-1})					
0 (S_1)	24.1^{c}	23.9^{c}	23.1^{b}	23.7^{d}	2.90^{d}
40 (S_2)	26.0^{b}	25.1^{b}	24.0^{b}	25.1^{c}	3.34^{c}
80 (S_3)	27.2^{a}	26.1^{ab}	25.5^{a}	26.3^{b}	3.73^{b}
120 (S_4)	27.7^{a}	26.7^{a}	26.3$_{a}$	26.9^{a}	3.99^{a}
df (SE)	24(0.26)	24(0.33)	24(0.35)	24 (0.19)	24(0.27)
Interaction					
$K_1 * S_1$	25.1^{de}	24.0^{cd}	23.6^{c-e}	24.2^{d-f}	2.96^{d}
$K_1 * S_2$	25.8^{cd}	25.2^{a-d}	23.6^{c-e}	24.9^{c-e}	3.35^{c}
$K_1 * S_3$	27.2^{a-c}	26.7^{ab}	25.8^{a-c}	26.6^{ab}	3.70^{b}
$K_1 * S_4$	27.6^{ab}	27.0^{a}	26.0^{ab}	26.9^{a}	3.99^{a}
$K_2 * S_1$	23.5^{e}	23.7^{d}	22.5^{e}	23.2^{f}	2.94^{d}
$K_2 * S_2$	26.5^{a-d}	25.5^{a-d}	24.0^{b-e}	25.4^{b-d}	3.34^{c}
$K_2 * S_3$	27.4^{abc}	25.3^{abcd}	25.6^{abc}	26.1^{abc}	3.74^{b}
$K_2 * S_4$	27.0^{abc}	26.2^{abc}	26.2^{ab}	26.4^{ab}	3.97^{a}
$K_3 * S_1$	23.8^{e}	23.8^{d}	22.8^{de}	23.5^{f}	2.99^{d}
$K_3 * S_2$	25.8^{cd}	24.7^{b-d}	24.3^{a-e}	24.9^{c-e}	3.35^{c}
$K_3 * S_3$	27.4^{a-c}	26.4^{ab}	25.4^{a-c}	26.4^{ab}	3.71^{b}
$K_3 * S_4$	28.0^{a}	26.6^{ab}	26.5^{a}	27.0^{a}	4.01^{a}
$K_4 * S_1$	23.9^{e}	23.9^{d}	23.6^{c-e}	23.8^{ef}	3.06^{d}
$K_4 * S_2$	26.0^{b-d}	25.1^{a-d}	24.0^{b-e}	25.0^{c-e}	3.33^{c}
$K_4 * S_3$	26.9^{a-c}	25.9^{a-d}	25.1^{a-d}	26.0^{a-c}	3.78^{b}
$K_4 * S_4$	28.2^{a}	26.9^{a}	26.3^{ab}	27.2^{a}	4.00^{a}

Means within a column followed by the same letter are not significantly different at the 0.05 level of probability. ns; indicating not significant at p = 0.05, df; Degree of freedom within groups, SEM: refers to Standard Error of Means

The number primary and secondary branch/plant increased with the increasing S application (117 and 32.4%; Table 4), but was unaffected with K application. The total pods/plant were evidently shown in the number of pods per individual branches. Whereas this increase was not significant with increasing level of S application had a significant increasing effect (Table 4). Number of pods on the primary and secondary branches and terminal racem increased with increasing K application. In combining levels of K and S application, number of branches and total pods/plant were generally increased with increasing K and S application. The seed yield showed increasing responses to levels of S application as reflected in the average number of seeds/pod (13.5%), but it was not significant with increasing K application (Table 3). One thousand seed weight significantly increased with increasing S application (37.59%), but it was not consistently influence by increasing K application (Table 3).

Seed yield of canola increased with increasing S application. Seed yield respectively increased by 14.54, 8.49, 7.76% S application from 0 to 40 kg ha^{-1} and from 40 to 80 kg ha^{-1} and 80 to 120 kg ha^{-1}. For the rate of S application, the liner and quadratic contrast were significant. Application of S significantly enhanced the seed yield in canola (Nuttal *et al*., 1987; Malhi and Gill, 2002; Grant *et al*., 2003, 2004). Seed yield increased 2.51% with application of K from 0 to 60 kg ha^{-1}, but the increased were not significant with increasing application of K beyond 60 kg ha^{-1} (Table 2). Minimal seed yield response of spring and winter rape observed with application of K (Weter *et al*., 1970; Stabbetorf, 1973; IPI 1974; Holmes and Ainsely, 1977, 1978; Sheppard and Bates, 1980). These observation indicated a small response of K application on seed yield. Higher seed yields were realized with application 120 kg ha^{-1} S, with the maximum seed yield of 1130 kg ha^{-1} when 60 kg ha^{-1} was applied. But this combined with the highest K input did not give any significant increased in seed yield. This indicated that increasing the level of applied K to 120 kg ha^{-1} only increased production cost rather than yield potential.

Oil content: Oil content of canola seed was generally increased with increasing S application. Oil content respectively increase 3.89 and 6.0% with increasing S application from 0 to 40 kg ha^{-1} and from 40 to 80 kg ha^{-1}, but these increases were not significant with increasing application of S beyond 80 kg ha^{-1} (Table 5). Liner and quadratic contrasts for the rates of S were significant. The

Table 4: Effect of levels of potassium and sulphur on components of yield in canola

		Branches/plant (No.)		Pods/plant			
Treatment	Plant height (cm)	Primary branch	Secondary branch	Primary branch	Secondary branch	Teminal raceme	Total pod
Potassium (kg ha^{-1})							
0 (K_1)	100.2^{ns}	6.5^{ns}	18.3^{ns}	102.8^{ns}	112.8^{ns}	12.6^{ns}	228.1^{ns}
60 (K_2)	98	6.9	18.6	101.4	112.8	11.7	225.8
90 (K_3)	98.9	7.2	18.8	106.0	115.9	12.0	233.9
120 (K_4)	98.2	7.2	19.1	104.4	115.5	11.8	231.8
df (SE)	6(1.29)	6(0.28)	6(0.69)	6(3.43)	6(3.10)	6(0.79)	6(4.76)
Sulphur (kg ha^{-1})							
0 (S_1)	97.4^{ns}	4.1^{b}	15.7^{c}	93.0^{c}	105.3^{b}	8.2^{c}	206.4^{d}
40 (S_2)	97.3	6.4^{b}	18.5^{b}	97.9^{bc}	112.0^{ab}	10.9^{b}	220.8^{c}
80 (S_3)	99.7	8.4^{a}	19.8^{ab}	105.3^{b}	118.2^{a}	13.8^{a}	237.3^{b}
120 (S_4)	101.1	8.9^{a}	20.8^{a}	118.3^{a}	121.5^{a}	15.2^{a}	255.0^{a}
df (SE)	24(1.29)	24(0.28)	24(0.69)	24(3.43)	24(3.10)	24(0.79)	24(4.76)
Interaction							
$K_1 * S_1$	98.7^{ab}	3.9^{f}	15.3^{d}	91.7^{c}	96.0^{c}	8.7^{c}	196.3^{g}
$K_1 * S_2$	99.3^{ab}	5.7^{de}	18.2^{a-d}	97.3^{a-c}	114.3^{a-c}	12.0^{a-c}	$223.^{b-g}$
$K_1 * S_3$	98.8^{ab}	7.5^{a-c}	19.3^{a-d}	105.7^{a-c}	115.0^{a-c}	14.7^{ab}	235.3^{a-f}
$K_1 * S_4$	103.9^{a}	8.9^{a}	20.2^{a-c}	116.3^{ab}	125.7^{a}	15.0^{ab}	257.0^{a}
$K_2 * S_1$	96.8^{ab}	3.8^{f}	14.9^{d}	90.0^{c}	111.7^{a-c}	8.3^{e}	210.0^{fg}
$K_2 * S_2$	96.2^{ab}	6.5^{b-d}	18.2^{a-d}	99.3^{a-c}	108.7^{a-c}	11.3^{a-e}	219.3^{d-g}
$K_2 * S_3$	98.6^{ab}	8.2^{ab}	20.0^{a-d}	98.0^{a-c}	112.3^{a-c}	11.3^{a-c}	221.7^{c-g}
$K_2 * S_4$	100.5^{ab}	9.0^{a}	21.2^{a}	118.3^{ab}	118.3^{ab}	15.7^{a}	252.3^{a-c}
$K_3 * S_1$	98.5^{ab}	4.6^{ef}	16.4^{b-d}	97.7^{a-c}	109.3^{a-c}	7.7^{c}	214.7^{a}
$K_3 * S_2$	99.4^{ab}	6.4^{cd}	18.7^{a-d}	99.7^{a-c}	110.3^{a-c}	10.3^{bc}	220.3^{d-g}
$K_3 * S_3$	97.4^{ab}	8.9^{a}	19.2^{a-d}	107.3^{a-c}	121.7^{ab}	15.0^{ab}	244.0^{a-e}
$K_3 * S_4$	100.4^{ab}	8.9^{a}	20.9^{ab}	119.3^{a}	122.3^{ab}	15.0^{ab}	256.7^{a}
$K_4 * S_1$	95.5^{ab}	4.1^{ef}	16.2^{cd}	92.7^{e}	104.0^{bc}	8.0^{c}	204.7^{fg}
$K_4 * S_2$	94.2^{b}	6.7^{b-d}	18.6^{a-d}	95.3^{bc}	114.7^{a-c}	10.0^{be}	220.0^{d-g}
$K_4 * S_3$	103.8^{a}	9.1^{a}	20.6^{a-c}	$110.3.9^{a-c}$	123.7^{ab}	14.3^{ab}	248.3^{a-d}
$K_4 * S_4$	99.4^{ab}	8.9^{a}	21.1^{a}	119.3^{a}	119.7^{ab}	15.0^{ab}	254.0^{ab}

Means within a column followed by the same letter (s) are not significantly different at the 0.05 level of probability. ns; indicating not significant at p = 0.05, df; Degree of freedom within groups, SEM; refers to standard error of means

Table 5: Effect of levels of potassium and sulphur on seed yield, oil and protein content, oil and protein yield, total S uptake in seed

Treatment	Seed yield (kg ha^{-1})	Oil content (%)	Protein content (%)	Oil yield (kg ha^{-1})	Protein yield (kg ha^{-1})	Total S uptake in seed (%)
Potassium (kg ha^{-1})						
0 (K_1)	974.51^{b}	36.58^{ns}	23.40^{ns}	355.67^{b}	227.73^{ns}	0.765^{ns}
60 (K_2)	998.95^{a}	36.77	22.75	369.23^{a}	227.83	0.764
90 (K_3)	999.20^{a}	37.04	22.04	372.03^{a}	230.26	0.766
120 (K_4)	999.51^{a}	37.44	22.83	374.85^{a}	227.63	0.766
df (SE)	6(15.44)	6(0.27)	6(0.20)	6(8.31)	6(3.92)	6(0.03)
Linear	ns	ns	ns	ns	ns	ns
Quadratic	ns	ns	ns	ns	ns	ns
Sulphur (kg ha^{-1})						
0 (S_1)	840.31^{d}	34.66^{c}	23.07n.s	288.99^{d}	193.67^{d}	0.488^{d}
40 (S_2)	962.51^{c}	36.01^{b}	23.08	346.69^{c}	221.53^{c}	0.693^{c}
80 (S_3)	1044.18^{b}	38.17^{a}	23.02	398.54^{b}	241.07^{b}	0.884^{b}
120 (S_4)	1125.16^{a}	38.88^{a}	22.86	437.55^{a}	257.20^{a}	0.998^{a}
df (SE)	24(15.44)	24(0.27)	24(0.20)	24(8.31)	24(3.92)	24(0.03)
Linear	***	***	ns	***	***	***
Quadratic	***	***	ns	***	***	***
Interaction						
$K_1 * S_1$	821.91h	34.60^{de}	$23.59^{n.s}$	275.38^{f}	193.87^{d}	0.488^{e}
$K_1 * S_2$	940.68f	35.70^{cde}	23.23	335.83^{d}	217.42^{c}	0.691^{d}
$K_1 * S_3$	1024.86d	38^{ab}	23.48	389.45^{c}	240.67^{abc}	0.844^{c}
$K_1 * S_4$	1110.59b	38^{ab}	23.31	422.03^{b}	258.59^{a}	0.997^{a}
$K_2 * S_1$	846.89g	34.17^{e}	22.76	289.37^{ef}	192.70^{d}	0.488^{e}
$K_2 * S_2$	969.18e	35.73^{cde}	22.98	346.33^{d}	223.12^{bc}	0.691^{b}
$K_2 * S_3$	1050.11c	38.30^{a}	22.65	402.19^{c}	240.02^{abc}	0.882^{b}
$K_2 * S_4$	1129.62a	38.87^{a}	22.89	439.05^{ab}	255.51^{a}	0.997^{a}
$K_3 * S_1$	845.97g	34.47^{e}	23.04	291.58^{ef}	193.61^{d}	0.489^{e}
$K_3 * S_2$	970.02e	36.20^{cd}	23.15	351.15^{d}	223.47^{bc}	0.694^{d}
$K_3 * S_3$	1050.57c	38.37^{a}	23.07	403.15^{c}	243.23^{ab}	0.884^{b}
$K_3 * S_4$	1130.05a	39.13^{a}	23.04	442.23^{a}	260.75^{a}	0.998^{a}
$K_4 * S_1$	846.47g	35.40^{cde}	23.07	299.65^{e}	194.49^{d}	0.488^{e}
$K_4 * S_2$	970.18e	36.43^{bc}	22.77	353.47^{d}	222.11^{bc}	0.693^{d}
$K_4 * S_3$	1050.98c	38^{ab}	22.43	399.38^{e}	240.34^{abc}	0.884^{b}
$K_4 * S_4$	1130.39a	39.53^{a}	22.83	446.88^{a}	253.59^{a}	0.998^{a}

Means within a column followed by the same letter are not significantly different at the 0.05 level of probability. ns; indicating not significant at $p = 0.05$, ***; 0.001 significant at probability. df; Degree of freedom within groups, SEM; refers to Standard Error of Means

effect of S fertilization on oil content of canola has been found to very from an increase (Ridley, 1972; Nuttall *et al*., 1987; Ahmad and Abdin, 2000; Ahmad *et al*., 2000; Jackson, 2000; Malhi and Gill, 2002; Grante *et al*., 2003) to a decline (Wetter *et al*. 1970) and unchanged (Ridley, 1973). This observations indicated a beneficial influence of S application on oil content in seed. Oil content of canola seed was not consistently influenced by increasing K application (Table 5). Potassium has generally shown no significant effect on oil content of spring or winter rape (Wetter *et al*., 1970; Stabbetorp, 1973; Holms and Ainsley, 1977, 1978; Sheppard and Bates, 1980). Application of S and K fertilizer increased significantly oil yield (Table 5), although there was no significant in the oil content with increasing levels of K (120 kg ha^{-1}). The total oil yield ha^{-1} increased because of the increasing effects on seed yield.

Protein content: Protein content of canola seed was not consistently influence by increasing K and S application (Table 5). Potassium has generally shown no significant effect on protein content of spring or winter rape (Wetter *et al*., 1970; Stabbetorp, 1973; Holmes and Ainsley, 1977; 1978; Sheppard and Bates, 1980). Sulphur fertilization can increase protein content in canola seed (Nuttal *et al*., 1987; Ahmad and Abdin, 2000) although in other studies, S did not influence protein content (Asar and Scarisbuick, 1995). Protein yield, respectively increased 14.36, 8.82, 6.69%, with increasing S application from 0 to 40 kg S ha^{-1} and 40 to 80 kg S ha^{-1} and 80 to 120 kg ha^{-1}, but there was no significant in the protein yield with increasing levels of K (120 kg ha^{-1}). Although there was not consistently influence in the protein content with increasing levels of S (120 kg ha^{-1}), the total protein yield ha^{-1} increased because the increasing effect on seed yield (Table 5).

Seed sulphur concentration: Total S uptake in seed significantly increased with increasing S application. Total S uptake in seed respectively increased by 41.79, 27.63 and 12.89% S application from 0 to 40 kg ha^{-1} and 40 to 80 kg ha^{-1} and 80 to 120 kg ha^{-1}. For the rate of S application the liner and quadratic contrast were significant. A consistent enhancement of S uptake in aboveground parts of canola plant has been found to increase with increasing S rate in previous study

(Janzenand Bettany, 1984). Application of S to canola increased S concentration, uptake in seed and strow (Malhi and Gill, 2002). Total S uptake in seed was not consistently influenced by increasing K application (Table 5).

CONCLUSIONS

From this observation, it can be concluded that the increased in oil content, seed yield and total S uptake associated with increasing application of S fertilizer, while protein content in seed showed no consistent effect of S application. Application of K fertilizer generally shown no significant effect oil content, protein content and total S uptake in canola seed but application of 90 kg K ha^{-1} increased seed yield.

ACKNOWLEDGEMENTS

We thanks the farmers and managers of Research Farms of the Department of Agiculture for the use of land, land preparation and harvesting of the crop. We also thank Mr. M.R. Sabetpey and Dr. S.M.J. Arvin for technical assistance sample preparation and the Agriculture Research Center of Kerman for seed analyses.

REFERENCES

Ahmad, A., G. Abraham and M.Z. Abdin, 1999. Physiological investigation of the impact of nitrogen and sulpfur application on seed and oil yield of rape seed (*Brassica compestris* L.) and mustard (*Brassica juncea* L. Czern and Coss) genotypes. J. Agron. Crop Sci., 183: 19-25.

Ahmad, A., I. Khan and M.Z. Abdin, 2000. Effect of sulphure fertilization on oil accumulation, acetyl-CoA Ccarboxylase activity in the developing seeds of rapeseed (*Brassica compestris* L.). Aust. J. Agric. Res., 51: 1023-1029.

Ahmad, A. and M.Z. Abdin, 2000. Interactive effect of sulphur and nitrogen on the oil and protein contents and on the fatty acid profiles of oil in the seeds of rapeseed (*Brassica compestris* L.) and mustard (*Brassica juncea* L. Czern and Coss). J. Agron. Crop Sci., 185: 49-54.

Asare, E. and D.H. Scarisbrick, 1995. Rate of nitrogen and sulphur fertilizers on yield, yield components and seed quality of oil seed rape (*Brassica napus* L.) Field Crops Res., 44: 41-46.

AOAC, 1980. Association of Analytical Chemists. 13th Edn., pp: 7021-7024.

Bullock, D.G. and J.E. Sawyer, 1991. Nitrogen, potassium and boron fertilization of canola. J. Prod. Agric., 4: 550-555.

Glass, A.D.M. and M.Y. Siddiqi, 1984.The Control of Nutrient Uptake Rate S in Relation to the Inorganic Composition of Plants. In Tinker, P.B. and A. Lauchli Eds. Advances in Plant Nutrition. Vol. 1. Prageger Publishers, New York, pp: 103-147.

Grant, C.A. and L.D. Bailey, 1993. Fertility management in canola production. Can. J. Plant Sci., 73: 651-670.

Grant, C.A., G.W. Clayton and Johnston, 2003. Sulphur fertilizer and tillage effect on canola seed quality in the Black soil zone of Western Canada. Can. J. Plant Sci., 83: 745-758.

Grant, C.A., A.M. Johnston and G.W. Clayton, 2004. Sulphur fertilizer and tillage management of canola and wheat in Western Canada. Can. J. Plant Sci., 84: 453-462.

Holmes, M.R.J. and A.M. Ainsley, 1977. Fertilizer requirements of spring oilseed rape. J. Sci. Food Agric., 28: 301-311.

Holmes, M.R.J. and A.M. Ainsley, 1978. Seedbed fertilizer requirements of winter oilseed rape. J. Sci. Food Agric., 29: 657-666.

Holmes, M.R.J., 1980. Nutrition of the oilseed rape crop. Applied Science Publishers, Barking. Essex, UK.

International Potash Institute, 1974. Summary of the results of N*k interaction experiments. Rotash Rev. Subject 16, 67th Suite, No. 819-1974. IPI, Bern, Switzerland, pp: 5-6.

Jackson, G.D., 2000. Effect of nitrogen and sulfur on canola yield and nutrient uptake. Agron. J., 92: 644-649.

Janzen and Bettany, 1984. Sulfur nutrition of rapeseed: Influence of fertilizer nitrogen and sulfur rates. Soil Sci. Soc. Am. J., 48: 100-107.

Malhi, S.S. and K.S. Gill, 2002. Effectiveness of sulphate-S fertilization and different growth stages for yield, seed quality and S uptake of canola. Can. J. Plant Sci., 82: 665-674.

Nuttall, W.F., H. Ukrainetz, J.W.B. Stewart and D.T. Spurr, 1987. The effect of nitrogen, sulfur and boron on yield and quality of rapeseed (*Brassica napus* L. and *B. compestris* L.). Can. J. Soil Sci., 67: 545-559.

Nyborg, M., C.F. Bentley and P.B. Hoyt, 1974. Effect of sulphur deficiency on seed yield of turnip rape. Sulphur Inst. J., 10: 14-15.

Ridley, A.O., 1972. Effect of nitrogen and sulfur fertilizers on yield and quality of rapeseed. Papers presented at the 16th Annual Manitoba soil science Meeting, University of Manitoba, Winnipeg and MB., pp: 149-155.

Ridley, A.O., 1973. Effect of nitrogen and sulfur fertilizers on yield and quality of rapeseed. Papers presented at the 17th Annual Manitoba soil science Meeting, University of Manitoba, Winnipeg and MB., pp: 182-187.

Sheppards, S.C. and T.E. Bates, 1980. Yield and chemical composition of rape in response to nitrogen, phosphorus and potassium. Can. J. Soil Sci., 60: 153-162.

Stabbetorp, P., 1973. Experiments with nitrogen, phosphorus, potassium and limit o n rape (*Brassica napus*) and turnip rape (*Brassica compestris*). Forsk. Fors. Landbruket, 24: 699-713.

Wetter, L.R, H. Ukrainetz and R.K. Downey, 1970. Effect of chemical fertilizers on the content of oil, protein and glucosinolates in *Brassica* including rapeseed. Intl. Conf. on the Sci., Technology and Marketing of Rapeseed and Rapeseed products. St. Adele, Quebec. Canada. Canola Council of Canada. Winnpeg. MB.

Zhou, W.J., 2001. Oilseed rape. (In) Cultivation of Crops, Zhang, G.P. and W.J. Zhou (Eds). Zhejiang University Press, Hangzhou, China, pp: 153-178.