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Sulphur fertilizer effects on grain yield and the sum of physiological indices of canola (*Brassica napus* L.)

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ABSTRACT

In order to evaluation of influence of sulphur fertilizer on grain yield and the some of physiological indices of canola, an split plot experiment based on randomized complete block design was conducted in Research Farm Islamic Azad University, Ardabil branch in 2007. Factors were: sulfur fertilizer at four levels (0 as control, 25, 50 and 75 kg S/ha) in the main plots and canola cultivars at three levels (Fornax, Opera and Slmo) in the sub plots. The results showed that various levels of sulfur fertilizer affected yield and yield components of canola. Means comparisons in compound of treatment cultivar× levels of sulfur showed that maximum grain yield was obtained by the plots which was applied 75 kg sulfur/ ha with opera cultivar. Similar results were obtained in grain per pod, pod per plant and thousand kernel weights. Investigation of variances of dry matter accumulation indicated that in all of treatment compounds, it increased slowly until 212 days after sowing with increasing of sulphur fertilizer and then increased rapidly till 296 days after sowing. From 296 days after sowing till harvest time, it decreased due to increasing aging of leaves and decreasing of leaf area index. Increase in S levels also significantly increased the crop growth rate and the maximum of it was observed by the plots that received 75 kg S/ha with opera cultivar. In addition, in all of treatment compounds, CGR increased slowly until 240 days after sowing and then decreased slowly till 254 days after sowing. From 254 days after sowing till harvest time, it decreased due to increasing aging of leaves and decreasing of leaf area index. Thus, it can be suggested that in order to increasing of grain yield, dry matter accumulation, crop growth rate and the other of physiological indices should be applied opera cultivar with 75 kg S ha^{-1} in conditions of Ardabil Plain.

Key words: Canola, Growth indices, Sulphur, Yield

INTRODUCTION

Canola (*Brassica napus* L.) is an important source of protein and oil for human and animal consumption. Most vegetative oils are edible and have been used in food preparation to make it more palatable and nutritious. Vegetable oils are preferred over the solid animal fats because of health benefits (Khalil and Rahman, 1999). Extraction of seed oil is high, with average oil content of 42% and a protein content of approximately 21% (Declercq and Daun, 1999). Canola has the lowest saturated fat content of any vegetative oil. To day there is an increasing demand for this oil by diet-conscious consumers (Grombacher and Nelson, 1992). Sulfur requirements for canola are higher than most crops. Recently observed lower sulphur emission to the atmosphere decreased the amount of sulphur in soil and caused worse sulphur nutrition of crop plants. The higher protein content of these cultivars compared with cereals, combined with Brassica's higher proportion of cysteine and methionine contribute to the larger sulphure requirement (Durrani and Khalil, 1990). Therefore sulphur nutrition must be seriously considered in a canola fertility program. The current S soil test tends to overestimate available sulfate-S, as field variability is huge. Therefore, at medium to low sulphur soil test levels, 25-35 kg ha^{-1} S is recommended. At high soil sulphur levels, 10-20 kg S ha^{-1} is still recommended (Franzen, 1997). Average rapeseed demand for sulphur is above 50 kg per hectare which is much more than that of crops from families fabaceae and chenopodiaceae 20-50 kg S per ha or cereals and potato (20 kg per ha) (Weiss, 1993). This fertilizer also helps in accelerating the photosynthesis activity (Chonogo and McVetty, 2001) and increase dry matter production in Indian mustard (Diepenbrock, 2000). Mohan and Sharma (1992) also reported that application of S increased the seed yield of Indian mustard. Haneklaus *et al*., (1999) reported an 88% rise in the canola yield by applying S–fertilizer (gypsum) alone. Jayan *et al*., (1997) reported an increase of 33% over the control, in the yield of Indian mustard by applying sulphur (50 kg ha^{-1}). Shekhawat *et al*., (1996) have been reported that increasing levels of sulphur from 0 kg /ha to 40 kg /ha increased total dry matter in some genotypes of Brassica napus and Brassica juncea. Shukla *et al*., (2002) reported that using sulphur as supplementary nutrient resulted in 20.5 and 23 % increase in crop growth rate in Indian mustard. Similar observation was also reported by Mathur and Wattal (1996). Shukla *et al*., (2002) reported that using sulphur increased relative growth rate in initially stages and decreased in the final stage. Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological processes in plant development. The aim of this study was to evaluate the influence of sulphur fertilization on grain yield and the some of physiological indices of canola in conditions of Ardabil Plain in Iran.

MATERIALS AND METHODS

A split plot experiment based on randomized complete block design with three replications was conducted in 2008 at the Research Farm of Islamic Azad University, Branch of Ardabil, (lat 38̊ 15´ N; long 48̊ 15´ E; Alt 1350m). Climatically, the area placed in the semi-arid temperate zone with cold winter and hot summer. Average rainfall is about 368 mm that most rainfall concentrated between winter and spring. The soil was loamy salty with pH about 8.2. The table 1 shows physical and chemical properties of farm soil used in the experiment. Mean temperatures and rainfall for the 2007 canola growing season (October –June), is presented in Figure 1. The field was prepated well before sowing by plowing twice with tractor followed planking to make a fine seed bed. Treatments were arranged in a split plot design with three replicates. Sulphur fertilizer in four levels (0, 25, 50 and 75 kg S /ha) as granolea in the main plots (control = 0 kg S/ha), while canola cultivars in three levels (Fornax, Opera and Slmo) were allocated at random in the sub-plots. Row spacing was 25cm, respectively. In each sub plot there were 6 rows 5m long. Plots and blocks were separated by 1m unplanted distances. Canola seeds were planted in the second week of September. Malhi and Leach (2000) and Malhi and Gill (2002) reported that sole application of S at sowing to canola gave better result than spilit application. Hence total of sulphur fertilizer was given at the time of sowing in autumn. Fertilizer basic dose of N. P. K at the rate of 120-75-70 kg ha^{-1} were applied in the form of urea, triple super phosphate and nitrate potassium. All of phosphor and potassium were applied at the time of sowing. Nitrogen fertilize was applied as 1/3th at sowing, 1/3 th at leaf rosette and 1/3 at flowering. Seeds were sown with density of 8 kg ha^{-1}.The field was immediately irrigated after planting. Weeds were controlled manually. All other agronomic operations except those under study were kept normal and uniform for all treatments. For estimation of growth analysis, 0.3 m^2 in each plot was sampled randomly in each treatments and average for recording the change in dry weight in shoots (above ground), interval at different stages of the canola growth 212, 226, 240, 254, 268, 282, 298 and 310 days after sowing. For dry weight determination, samples were oven dried at 70̊ C to constant weight. Leaf area index was determined by dividing leaf area over ground area and was estimated with equation 4. The variances of total dry matter (TDM), crop growth rate (CGR) and relative growth rate (RGR) were determined with using 1-3 equations (Acuqaah, 2002; Gupta and Gupta, 2005).

$$\mathrm{TDM} = e^{a+bt+ct^2+dt^3} \quad (1)$$

$$RGR = b + 2ct + 3dt^2 \quad (2)$$

$$CGR = (b + 2ct + 3dt^2) \times e^{(a+bt+ct^2+dt^3)} \quad (3)$$

$$\mathrm{LAI} = e^{(a+bt+ct^2)} \quad (4)$$

In these equations, t is the intervals of sampling or in the other hand, the beginning and end of the interval sampling and a, b and c are coefficient of equations.

Grain yield obtained from 1 m^2 long from the three middle rows in each sub plot. In order to measurement of yield components such as pod per plant and grain per pod, ten plants were selected randomly from 3 m long from the three middle rows of sub plots and then their average was calculated. Analysis of variance and regression were performed using SAS computer software packages.

RESULTS AND DISCUSSION

Grain yield and yield attribute**:** The grain yield, thousand grain weight, pod per plant and grain per pod were influenced significantly by sulphur levels, cultivar and interaction of sulphur levels ×canola cultivar.

Maximum number of pod per plant was recorded at application of 75 kg S ha^{-1} (92.04) and minimum of it was recorded at 0 kg S ha^{-1} (82) (Table 2). Of course, application of 50 and 75 kg S ha^{-1} had no significant impact on number pod per plant (Table 2). Means comparison in treatment compound of canola cultivar×various levels of sulfur indicated that the maximum (97.4) number of pod per plant was recorded for opera cultivar in application of 75 kg S ha^{-1} and minimum of it was recorded for Fornax cultivar (77.4) in zero kg S ha^{-1} (Table 3). Kumar et al., (2001) reported that number of pod per plant in some genotypes of *Brassica napus* and *Brassica juncea* increased with higher rate of S, which is also observed at the present study.

Maximum number of grain per pod was recorded at application of 75 kg S ha^{-1} (22.5) and minimum of it was recorded at 0 kg S ha^{-1} (14.3) (Table 2). Means comparison indicated that maximum grain per pod (23.57) was observed for opera cultivar in application of 75 kg S/ha, while minimum (8.87) of it was recorded for Fornax cultivar in application of zero kg S/ha (Table 2). Shekhawat *et al*., (1996) have been reported that increasing levels of sulphur from 0 kg /ha to 40 kg /ha increased grains per pod.

1000-grain weight: maximum 1000-grain weight was recorded at application of 75 kg S ha^{-1} (3.61) and minimum of it was recorded at 0 kg S ha^{-1} (2.49) (Table 2). Means comparison indicated that maximum 1000-grain weight (3.8) was observed for opera cultivar in application of 75 kg S/ha, while minimum (2.3) of it was recorded for Fornax cultivar in application of zero kg S/ha (Table 3). Shekhawat *et al*., (1996) have been reported that increasing levels of sulphur increased thousand grain weights.

Grain yield is the main target of crop production. The grain yield was significantly affected by both canola cultivars and various levels of sulphur fertilizer. Sulphur fertilizer significantly increased the grain yield. The grain yield varied between .81 ton/ha in zero level of sulphur fertilizer and 1.067 ton/ha in 75 kg S ha^{-1} (Table 2). Means comparison in treatment compound of canola cultivar×various levels of sulfur indicated that the maximum (1.165) grain yield was recorded for opera cultivar in application of 75 kg S ha^{-1} and minimum of it was recorded for Fornax cultivar (.88) in zero kg S ha^{-1} (Table 3). This might be related to the favorable response of canola cultivars to sulphur fertilizer. Haneklaus *et al*., (1999) reported an 88% rise in the canola yield by application of sulphur fertilizer. The results obtained in the present study are reported by Santonoceto *et al*., (2002) suggesting that increase in the rate of S resulted in a higher seed yield. Our findings are in agreement with observations made by Zhaohui and Shengxiu (2004).

Total Dry matter: study of trend of variances total dry matter in treatment compounds canola cultivars×various levels of sulfur fertilizer in figure 2 showed that in all of cultivars, total dry matter increased during plant growth with increasing sulfur fertilizer and reached to a maximum level at 282-296 days after planting, then showed a declining trend at maturity (296-310 DAS). Wysocki *et al*., (2005) have also reported such a decline in dry matter after reaching a climax in full bloom. The increase in total dry matter with the increasing rate of sulphur fertilizer indicates the favorable response of canola cultivars to sulphur fertilizer. It is perhaps related to activity photosynthesizing tissues which grow during this period of growth. Similar observations were also made by Clarck and Simpson (1978), Singh and Singh (1983). Subhani *et al*., (2003) found that total dry matter was increased with S application and the maximum of it was recorded in plots where 30 to 50 kg S ha^{-1} was applied. Study of total dry matter trends of opera cultivar in various levels of sulfur fertilizer shows that dry matter increased slowly until 212 days after sowing and then increased rapidly till 296 days after sowing. From 296 days after sowing till harvest time, accumulated dry matter decreased due to increasing aging of leaves, decreasing of leaf area rate (figure 5). On the other hand, total dry matter in unit of area increased with increasing levels of sulfur fertilizer, as the maximum and the minimum biomass in unit of area obtained from 0 and 75 kg $ha-^{1}$, respectively (Figure 2). Study the total dry matter in other cultivars (Fornax and Slmo) indicated that in all of cultivars increased with increasing of sulphur fertilizer and trend of variances were similar to dry matter remobilization in opera cultivar (Figure 2).

Crop growth rate: study of trend of variances crop growth rate in treatment compounds canola cultivars×various levels of sulfur fertilizer in Figure 3 showed that in all of cultivars, the crop growth rate was low in the beginning, increased thereafter considerably up to 242 days after planting with a peak during 240-245 days after planting (Figure 3), then showed a declining trend at 254-310 days after planting. The increase in CGR with the increasing rate of S may be due to the positive response of canola to S fertilizer. Similar results were also reported by Holmes (1980) and Fimes *et al*., (2000). The decrease in crop growth rate towards maturity is due to senescence of lower leaves and decrease of leaf area index (Figure 5). Similar results were reported by Kumar *et al*., (1999). Shukla *et al*., (2002) reported that application of sulphur increased 23% in CGR value of Indian mustard.

Relative growth rate: In the initial stages of the plant growth the ratio between alive and dead tissues is high and almost the entire cells of productive organs are activity engaged in vegetative matter production. In conclusion, the relative growth rate of plant crops is high. In all of treatment compounds, RGR decreased during plant growth with decreasing sulfur fertilizer and reached to a minimum level at 282-286 days after planting, then showed a negative value at maturity (296-310 DAS) (Figure 4). The reason of such negative value in RGR at the final stage can be related to increasing of the dead and woody tissues comparing to the alive and active texture. Similar observations have been reported by Shukla *et al*., (2002) in Indian mustard.

Leaf area index: study of variances trend of leaf area index in Figure 5 showed that in all of cultivars, Leaf area index increased during plant growth with increasing sulfur fertilizer and reached to a maximum level at 268 days after planting. From 268 days after sowing till harvest time, leaf area index decreased due to increasing aging of leaves, shading and competition between plants for light and other resources. Photosynthetic efficiency and growth in the crop plants are strongly related to the effect of canopy architecture on the vertical distribution of light within the canopy (Williams *et al*., 1968). Increasing leaf area index is one of the ways of increasing the capture of solar radiation within the canopy and production of dry matter. Hence, the efficiency of the conversion of intercepted solar radiation in to dry matter decreases with decreasing of leaf area index. In the present study, trend of variances leaf area index in treatment compounds of canola cultivars× various levels of sulfur fertilizer was according to crop growth rate. These results are in agreement with trend of variances total dry matter. Similar results have also been reported by Shulka *et al*., (2002).

Table 1- Soil physico-chemical properties at depth of 0-30 cm

K available (mg/kg)	P available (mg/kg)	N total (%)	O.C (%)	Texture	Sand (%)	Loam (%)	Clay (%)	Caco3 (%)	(%) SP	pH	Depth of sampling (cm)
385	16	.16	.78	Silty-loam	24	70	5	18.3	46	8.2	0-30

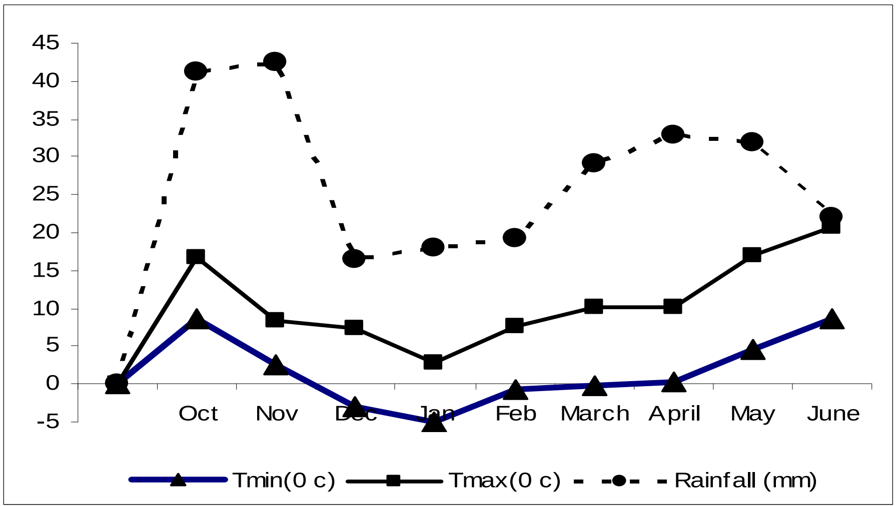

Fig 1-Minimum and maximum temperature and rainfall recorded during the period of canola growth (October –June) in 2007 .

Table 2-Effects of various levels of sulphur fertilizer on grain yield and the some of characteristics of canola

Characteristic		Grain yield (ton/ha)	1000 grain weights	Number of pod per plant	Number of grain per pod
Canola cultivars	Fornax	.83 b	2.83 c	83.19 c	19.65 b
	Slmo	.9 c	3.1 b	86.91 b	17.87 c
	Opera	1.09 a	3.31 a	92.62 a	21.42 a
Sulphur levels (kg/ha)	صفر	.81 d	2.49 c	82.11 c	14.3 c
	25	.96 c	2.75 b	89.06 b	19.39 b
	50	1.017 b	3.47 a	91.3 a	22.7 a
	75	1.067 a	3.61 a	92.04 a	22.5 a

Means with similar letters in each column are not significantly different

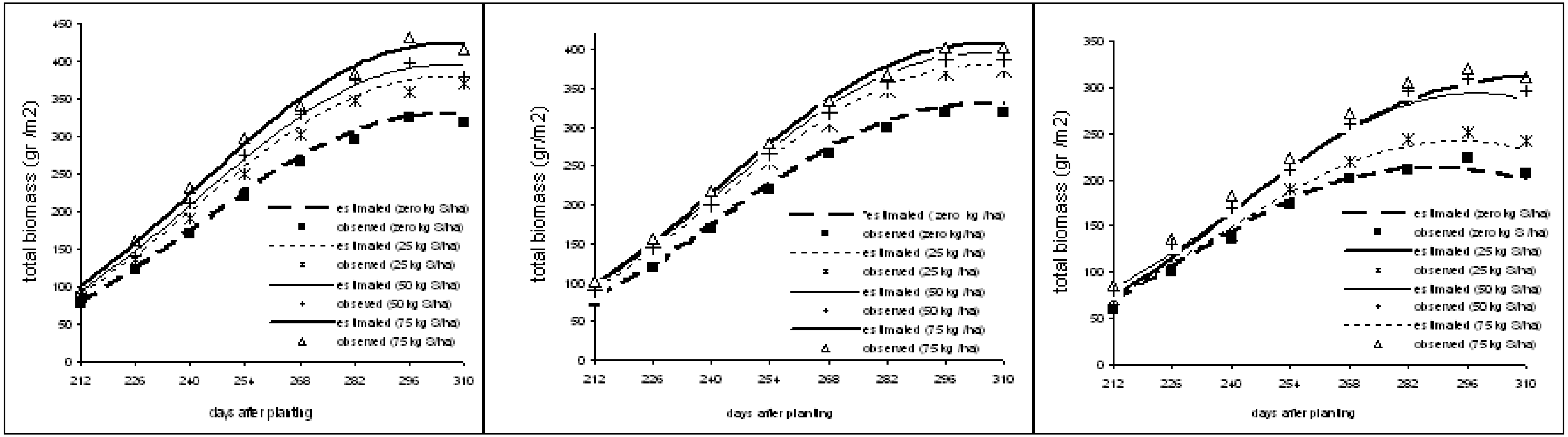

Fig 2- variances of total dry matter Opera (left), Fornax (center) and Slmo (right) cultivars in various levels of sulfur fertilizer

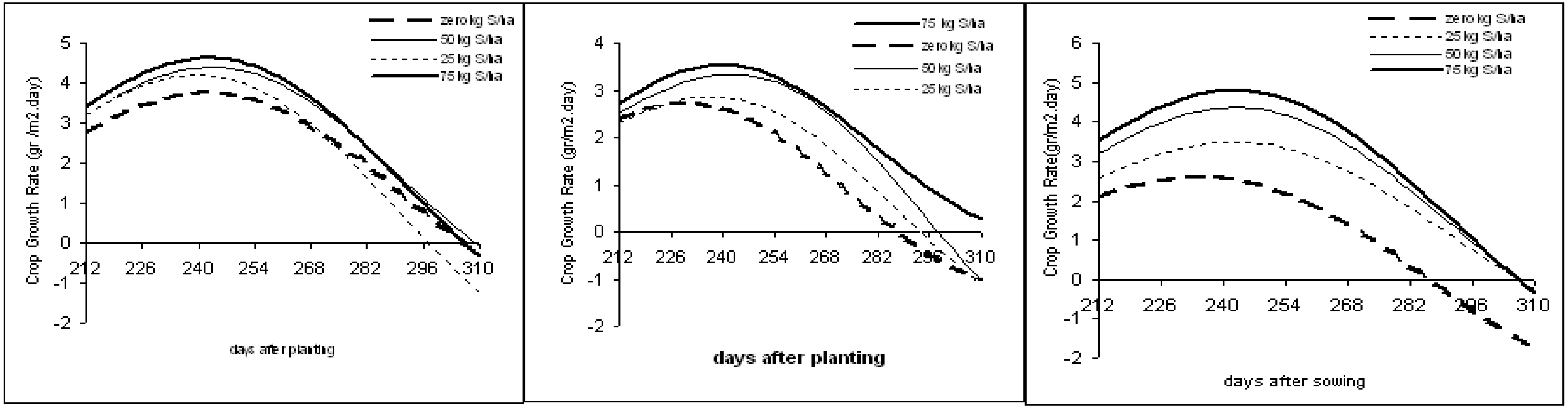

Fig 3- variances of crop growth rate Opera (left), Fornax (center) and Slmo (right) cultivars in various levels of sulfur fertilizer

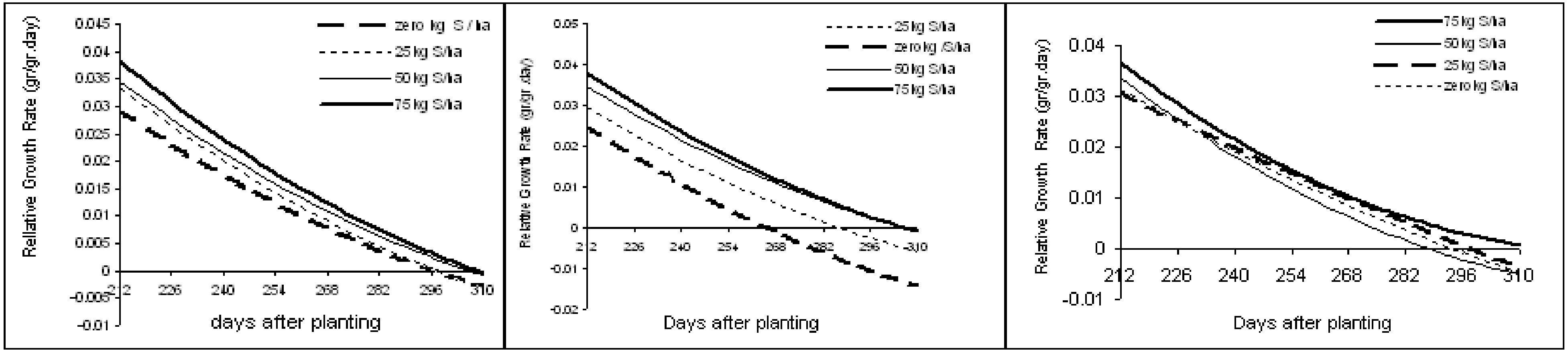

Fig 4- variances of relative growth rate Opera (left), Fornax (center) and Slmo (right) cultivars in various levels of sulfur fertilizer

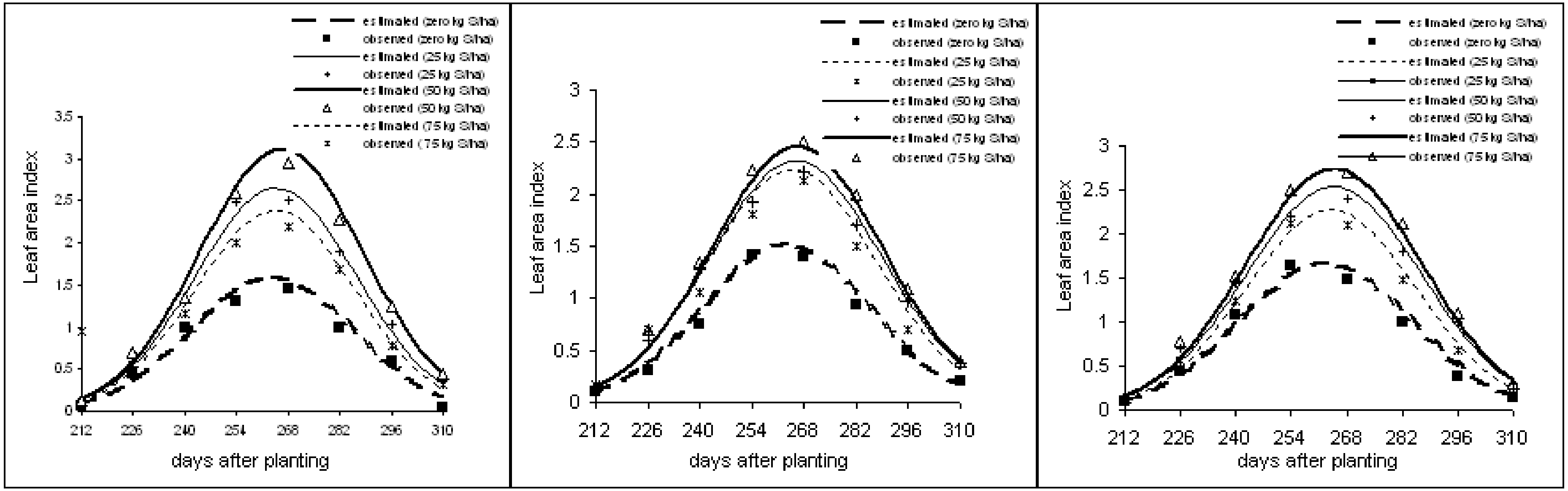

Fig 5- variances of leaf area index Opera (left), Fornax (center) and Slmo (right) cultivars in various levels of sulfur fertilizer

Table 3- Mean comparisons of treatment compound of various levels of sulphur fertilizer on yield and yield components of canola cultivars

Grain yield (ton/ ha)			1000 grain weight (gr)			Number of pods per plant			The number of grains per pod			Characteristic	
Opera	Slmo	Fornax	Opera	Slmo	Fornax	Opera	Slmo	Fornax	Opera	Slmo	Fornax	Canola cultivars	
.92 f	.75 i	.81h	2.7 de	2.4 g	2.3 g	87.4 de	81.5 i	77.4 h	17.55 f	8.87 h	16.47 g	zero	levels of sulphur fertilizer (kg/ha)
1.109 b	.86 g	.92 f	3.9 a	2.7 de	2.6 ef	94.3 b	89.4 j	83.4 f	20.017 d	18.74 e	18.74 e	25	
1.154 a	.92 f	.97 e	3.7 a	3.5 a	3.3c	91.8 b	92.3 f	86.4 d	23.86 a	22.68 b	21.69 c	50	
1.165 a	1.069 c	1.014 d	3.8a	3.7 a	3.28c	97.4 a	84.4 c	85.4 e	23.57 a	21.2 dc	21.69c	75	

Means with similar letters in each column are not significantly different

CONCLUSION

1- Sulphur fertilizer must be seriously considered in a canola fertility program.
2- sulphur fertilizer showed significant effects on yield, yield components and physiological indices of canola such as total dry matter, crop growth rate, relative growth rate and leaf area index.

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