Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2017 14(1): 84-94. **OPEN ACCESS**

Management of sulphur and its application stages on canola phenology, maturity and biomass yield under Maize-Canola cropping system

Asim Muhammad[*1], Muhammad Younis[1] Asad Ali Khan[1] and Imran Ahmad[2]

[1]Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture Peshawar, 25130, **Pakistan**

[2]Department of Horticulture, Faculty of Crop Production Sciences, The University of Agriculture Peshawar, 25130, **Pakistan**

***Correspondence:** asimmuh@aup.edu.pk **Received:** 19 Feb. 2017 **Accepted:** 13 Mar. 2017 **Published online:** 23 March. 2017

Research was conducted at Agronomy Research Farm of The University of Agriculture Peshawar, during winter season 2013-14, to study the "Management of sulphur and its application stages on canola phenology, maturity and biomass yield under maize-canola cropping system". Five sulphur (S) levels (15, 30, 45, 60, 75 kg ha^{-1}) and its application stages (AT) i.e. at seedling, bolting and flowering stages along with a control treatment, using Abasin-95 canola variety. Experiment was laid out in randomized complete block (RCB) design having four replications. Plot size was 5m x 3.2m. Sulphur applied plots showed early flowering (110 d), early maturity (173 d), taller plants (172.4 cm), higher siliques plant^{-1} (255), more seeds silique^{-1} (22), biomass yield (10574 kg ha^{-1}), heavier thousand seeds weight (4.9 g) as compared to control plots. Sulphur applied at the rate of 60 kg ha^{-1} increased plant height (176 cm), siliques plant^{-1} (270), seeds silique^{-1} (24), thousand seeds weight (5.2 g), biomass yield (11461 kg ha^{-1}) and harvest index (21.5 %). Sulphur applied at bolting stage increased plant height (174.1 cm), siliques plant^{-1} (274) and thousand seeds weight (5.2 g). The interaction of sulphur levels and application stages significantly affected plant height and siliques plant^{-1}. It is concluded that 60 kg ha^{-1} sulphur application at bolting stage enhance early flowering, maturity, produced comparatively higher plant heights, siliques plant^{-1}, seeds silique^{-1} and biomass yield.

Keywords: Canola, sulphur, application stages, phenology, maturity, biomass.

INTRODUCTION

Introduction of canola (*Brassica napus*) in many places of Pakistan has been successful. Pakistan's traditional rapeseed and mustard oil seed crops are grown in both irrigated and rainfed conditions in large areas in four provinces of the country (Khan et al*.* 2004). The average yield of Pakistan is very low which 922 kg ha $^{-1}$ as compared to other developed countries of agriculture world (MNFSR, 2013). Khyber Pakhtunkhwa (KP) average yield is 452 kg ha^{-1}. The total area (238900 ha) of rapeseed and mustard is under cultivation, in which Khyber Pakhtunkhwa contributed 18800 ha. Pakistan's total production of rapeseed and mustard is 220300 tones (MNFSR, 2013), in which KP are 8500 tones. Rapeseed was cultivated on an area of 586 thousand acres with seed production of 218 thousand tones and 68 thousand tones oil yield (GOP, 2014). While canola was grown on an area of 38 thousand acres with total seed production of 16 thousand tonnes and 6 thousand tonnes oil yield (GOP, 2014). Pakistan due to the recent introduction of production technology, production of many aspects of the productive package needs to be unveiled. The average level of production in Canada is 3200 kg ha^{-1}, EU is 3500 kg ha^{-1} and Australia production is 2000 kg ha^{-1} (Reddy, 2004). Higher per unit area yield developed with better management of nutrients can be achieved through modern agriculture cultural practices adaptation. On the basis of sustainable management of soil nutrients, fertilizer types, quantities and time of application is a key concept for the bumper crop which is included in the application procedure.

Fertilizers always played an important role in increasing crop yields. Rapeseed and mustard NPK (Kumar, 2001), Farmyard's (Bhatia & Shukla, 1982) and zinc, boron, sulphur application reported to increase seed production. In addition to the positive responses of NPK with FYM (Patel & Shelk, 1998) to both yield and oil contents (Ghosh et al*.* 1995), sulphur (S) application is prime important. Sulphur is cystine, cysteine and methionine, vitamin-like component is necessary for amino acids synthesis and enzyme systems in plants trigger (Havlin et al*.* 2004). Sulphur under deficient conditions, the level of crop production may not be sustainable and seriously affected by applied NPK fertilizer efficiency (Ahmed et al*.* 1994). Plant uptakes S from the soil through continuous removal of S massive budget cuts and the affected soil S all over the world (Aulakh, 2003). Sulphur for agricultural production in many European countries is one of the limiting nutrients (Zhao et al*.* 2002). Rahmatullah et al*.* 1999; Ahmed et al*.* 1994; Subhani et al*.* 2003 reported that application of different S fertilizer (10-50 kg S ha^{-1}) enhance significantly ranging from (5.2-76.7 %) rapeseed and mustard seed crop production.

Sulphur fertilization practice in Pakistan as a plant nutrient is not considered and little known about the status of the sulphur in this country. Sulphur is a fourth key nutrient in crop production. Most crops require sulphur as phosphorus (Hassan et al. 2007). Pakistan land area (70-80 %) were deficient (S <10 µ g g^{-1}) in S (Ahmed et al*.* 1994). Demands for crop S increased, inherent supply of S deficiencies or less available of S within the rooting zone of plant can maintain that is likely to occur on Earth, having a coarse texture of low organic matter and S in the subsoil or physically unavailable sources. Many of Pothwar earth soil can fit into this category (Nizami et al*.* 2004). Sulphur fertilizer can be applied in a number of ways including before and after seeding (or) limited amount during seeding etc. The different application stages of S have profound effect on canola quality, growth and productivity. The application of 20 kg ha^{-1} S at sowing time improves oil, glucosinolate and protein content (Ahmad et al. 2007). Similarly, Jan et al*.* (2008) obtained higher oil content only with application of sulphur at sowing time. Application of sulphur at sowing enhanced maturity in canola, whereas no difference for plant height was observed when sulphur was applied at sowing or rosette stage (Ahmad et al*.* 2006). Application of S after 42 days of sowing had decreased the seed yield on one site, but had higher seed yield and also resulted in improving the uptake of S both in seed and biomass when applied earlier (Nuttall & Ukrainetz, 1991). Keeping in view, the importance of Sulphur both for improving the production and quality of canola, the present research was hypothesized to quantify the effects of sulphur rates and its application time on the growth and production of canola in agro-climatic condition of Peshawar.

MATERIALS AND METHODS

Experimental details and treatments:

Research was conducted on "Management of sulphur and its application stages on canola phenology, maturity and biomass yield**"** was carried out at Agronomy Research Farm of The University of Agriculture Peshawar, during Rabi 2013-14. The experiment was consisting of four sulphur levels (15, 30, 45, 60, 75) and three application stages (Seedling, bolting, flowering) with control plots. The experiment was carried out in randomized complete block design having four replications. Ammonium sulphate was used as source of sulphur. Previous crop was Maize, before canola "Abasin-95" was sown. Seed was sown at the rate of 10 kg ha^{-1} in 24th October 2013, while harvesting was done in the last week of April 2014. The size of the plot was 5m ×3.2m, having 8 rows, 40cm apart and 5m long. The surface soil samples (0-15 cm) collected from the experimental site were analyzed for physico-chemical characteristics as suggested by Jackson (1973) and results are summarized in Table 1. Phosphorous was applied at sowing time @ 50 kg ha^{-1} from Single Super Phosphate source. Nitrogen was applied @ 75 kg ha^{-1} from urea

$$\text{Biomass yield (kg ha}^{-1}) = \frac{\text{Biomass yield of the harvested rows}}{\text{Row - row distance} \times \text{Row length} \times \text{No. of rows}} x10000$$

source (half at sowing time + half at flowering) after subtracting the amount of N been supplied through ammonium sulphate. Thinning was carried out to maintain normal plant population. All other cultural practices including irrigation, weeding and hoeing etc were carried out uniformly in all plots. Weather data for the growing period of canola is presented in Figure 1.

Table 1. Pre-sowing Physical and chemical analysis of soil properties at 0-15 cm depth of soil.

S.No	Soil properties	Values/rating
1	Soil texture	Sandy loam
2	Soil pH (1:2)	7.7
3	Soil EC	0.32 (ds m^{-1})
4	Available nitrogen	238.33 (kg ha^{-1})
5	Available Phosphorous	21.07 (kg ha^{-1})
6.	Available sulphur	6.24 (ppm ha^{-1})

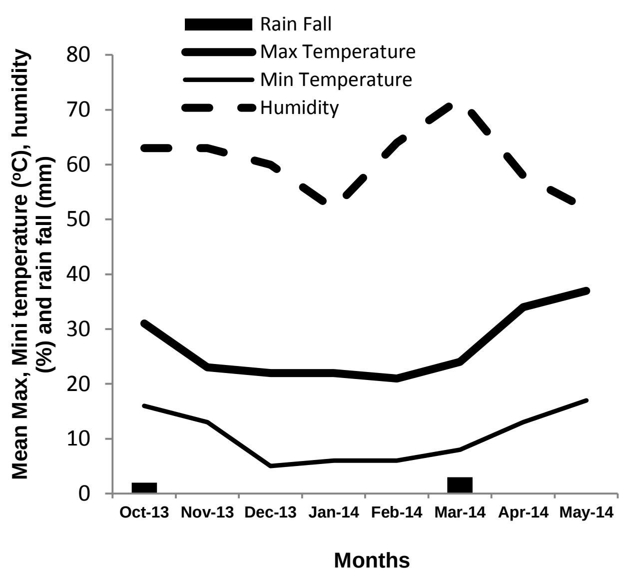

Figure 1: Mean maximum, minimum temperature (^{o}C), humidity (%) and rainfall (mm) for the growing period of canola (2013-14).

RESEARCH PARAMETERS:

The following parameters were studied during the experiments.

Days to flower initiation:

Days to flower initiation were taken from the date of sowing, when 50% plants in each plot got 1st flower initiation stage.

Days to physiological maturity:

Days to physiological maturity was taken from the date of sowing, when 50% siliques turned from green to yellow in each plot.

Plant height:

Plant height of ten randomly selected plants in every plot were recorded at physiological maturity stage and then averaged.

Siliques plant^{-1}:

Siliques plant^{-1} was recorded on ten randomly selected plants when the siliques was counted in each plot and then averaged accordingly.

Seeds silique^{-1}:

Seeds silique^{-1} was determined by selecting ten siliques randomly from the two central rows in each plot. These were threshed manually; seeds were counted and then averaged.

1000 seeds weight (g):

Thousand seeds weight data was recorded in each plot, after threshing; thousand seeds were counted and weighed.

Biomass yield (Kg ha^{-1}):

Biomass yield was calculated after harvesting four central rows in each plot at harvest maturity stage, dried, weighed, and converted to kg ha^{-1} using above equation.

Statistical analysis:

The data was analyzed using Planned Randomized complete block design. Analysis was done by using MS Excel sheet. Upon significant differences, the main effects of both Sulphur levels and application stages were separated using least significant differences (LSD) test (Jan et al. 2009).

RESULTS AND DISCUSSION

Days to flowering initiation:

Canola (*Brassica napus* L.) has a higher sulphur requirement than most cereals and to meet that demand, additional sulphur may be needed in a balanced fertilizer program (Khan et al. 2011). Sulphur is important plant nutrient for mustards and beneficial for increasing yield in canola and 40 kg ha^{-1} is optimum to grow canola in soils low in sulphur (Haneklaus et al. 1999; Ghosh et al. 2000). Therefore sulphur nutrition must be seriously considered in a canola fertility program (Sharifi, 2012). Sulphur is the key component of balanced nutrient application for higher yields and superior quality produce (Begum, et al. 2012). Statistical investigation of the data showed that days taken to flowering initiation were positively influenced by sulfur levels and application timing in canola is given in Table. 2. Sulfur levels had significantly ($P \leq 0.05$) affected days to flowering initiation of canola. Flowering initiation were delayed (113 d) in control plots, while earlier flowering initiation (110 d) was recorded with sulfur applied plots. While Ur et al. (2013) repoted that soil applied sulphur and foliar thiourea (1,000 mg L^{-1}) delayed the flowering and maturity. More days to flowering initiation (111 d) were taken by the canola grown at 15 kg S ha^{-1} applied plots, while less days (110) were recorded for gradually increasing sulfur levels from (30 to 75 kg ha^{-1}). The non-significant interaction was found in sulfur and their application timings for days to flowering initiation.

Days to physiological maturity:

Statistical analysis of the data showed that days to physiological maturity were not significantly affected by sulfur levels and time of application (Table. 2). The Interaction of S x AT was found non-significant for days to physiological maturity. Similar results were also coated by Ahmad et al. (2006) who investigated that days to physiological maturity was not significantly affected by sulphur application. Maturity is a genetic phenomenon of the plant and it's depend upon on environmental condition. However, sulfur fertilized plots was observed early maturity (173 d) as compared to control plots (176 d).

Plant height (cm):

Sulfur levels significantly affected plant height of canola (Table. 3). Plant height increased from (167.4 cm) to (176.4 cm) when increasing sulfur dose from 15 to 75 kg S ha^{-1}. Sulfur application timings significantly affected plant height. Sulfur application at bolting stage significantly increased plant height (174.1 cm) as compared to application timing at seedling (171.8 cm) and flowering stage (171.2 cm). Interaction of S x AT significantly affected plant height. The data showed that sulfur application increased plant height at 60 kg S ha^{-1} (179.6 cm) followed by 75 kg S ha^{-1} (179 cm) at bolting stage. The data showed that plant height was gradually increased with increasing sulphur application (15-60 kg S ha^{-1}) at three application stages. While after further increasing sulphur level (75 kg S ha^{-1}) their plant height decreased (Fig. 2). Ahmad et al. (2006) reported that sulphur application highly affected plant height of canola. These results are in conformity with Tomer et al. (1997) who investigated that when increasing sulphur levels, plant height was significantly increased. These consequences also verify the conclusions of Subhani et al. (2003) who observed that the 50 kg ha^{-1} S application produced higher plant height of canola. The lower or no S application to canola crop inversely affected the growth of canola investigated by Holmes, (1980). Fismes et al. (2000) who found that vegetative growth of crop is improved by N while nitrogen use efficiency increase by sulphur and the present increase in plant height could be the consequence of improved N use efficiency. These outcomes are in conformity with those reported by Sharifi, (2012) that yield, plant height and yield components of canola were significantly affected by suphur. Plant height was not significantly affected by N and S application stages in canola. Similar results are also reported by Afridi et al. (2002) who reported that the sole application was considered better than split application. Among sulphur application stages taller plant heights was observed by bolting stage, while lower plant height was recorded by seedling and flowering stage. The plant height was increased from 0 to 250 kg S ha^{-1}, but this increase was not significant (Soleymani, 2010).

Siliques plant^{-1}:

Sulfur levels significantly affected siliques plant^{-1} of canola (Table. 3). Siliques plant^{-1} increased from 240 to 270 when increasing sulfur dose from 15 to 60 kg S ha^{-1}. Sulfur application timing significantly affected siliques plant^{-1}. Sulfur application at bolting stage significantly increased siliques plant^{-1} 274 as compared to application timings at seedling 233 and flowering stage 258. Interaction of S x AT significantly affected siliques plant^{-1}. The data showed that higher siliques plant^{-1} 281 and 306 was obtained at 45 and 60 kg ha^{-1} sulfur applied plots at bolting stage respectively. Siliques plant^{-1} increased gradually when increasing dose of sulfur from 15 to 60 kg S ha^{-1} at bolting as compared to flowering and seedling stages. Further increasing doses, decreased siliques plant^{-1}(Fig. 3).

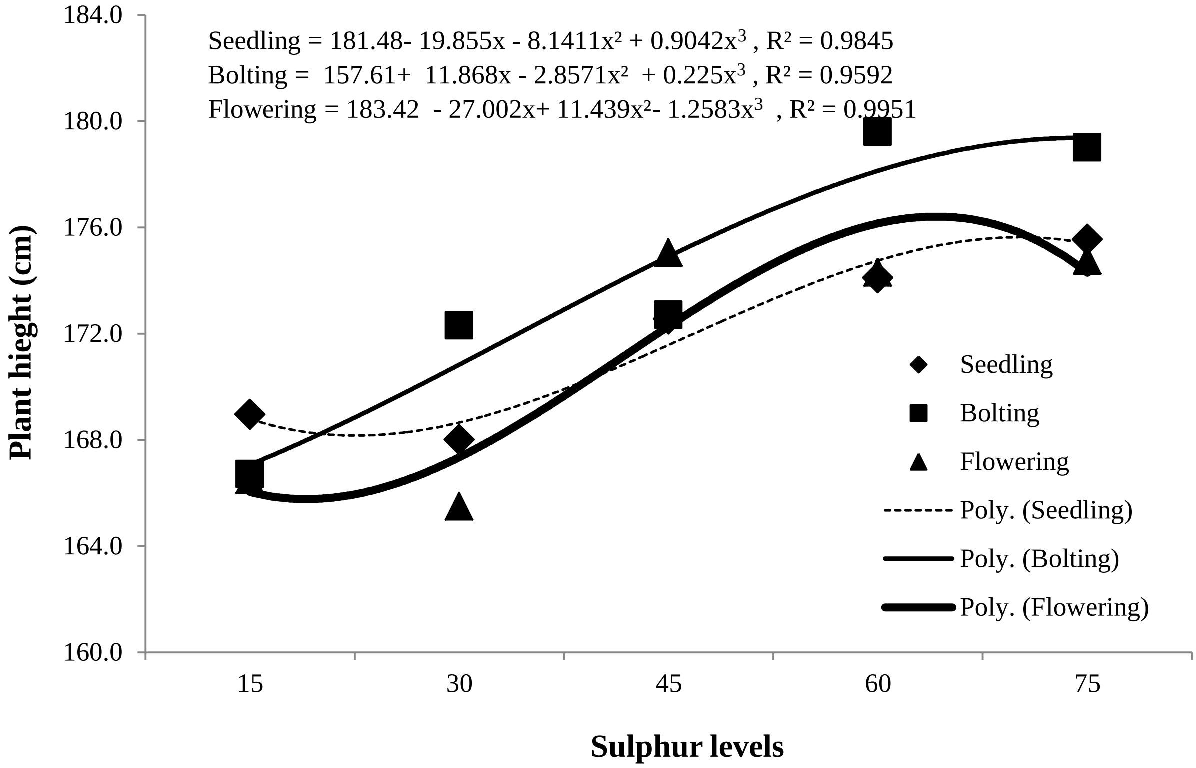

Figure 2: Plant height of canola as affected by sulphur levels and application stages.

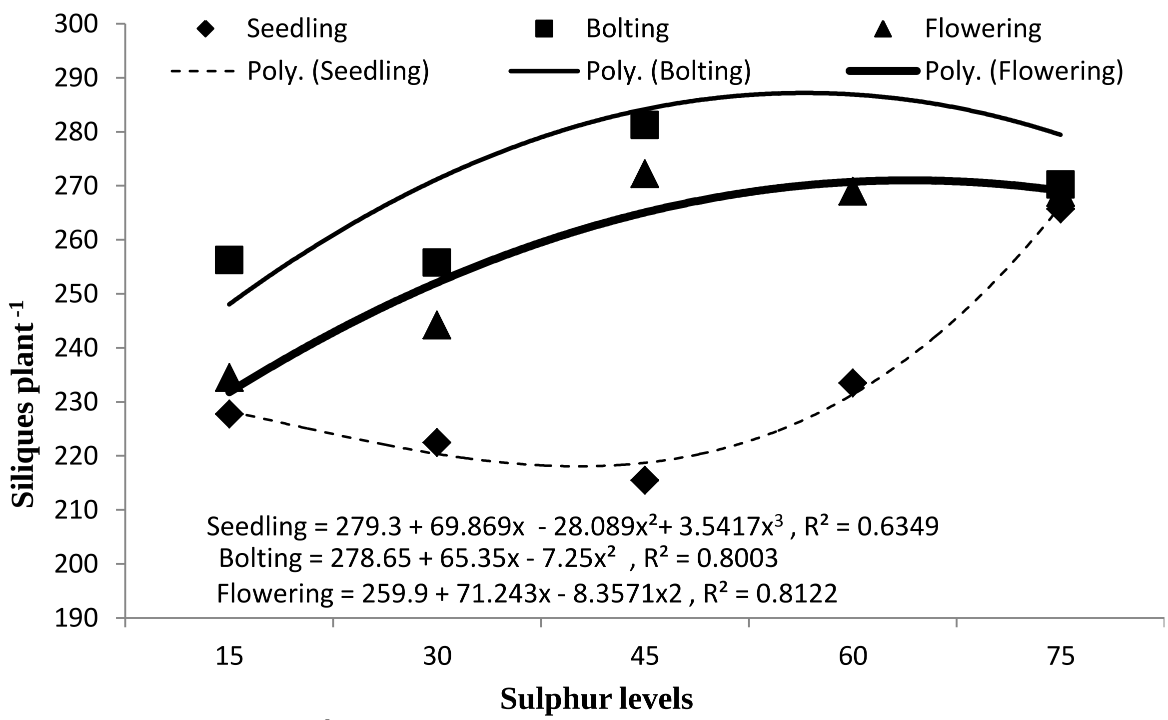

Figure 3: Siliques plant^{-1} of canola as affected by sulphur levels and application stages.

Table. 2. Days to flowering initiation and physiological maturity of canola as affected by sulphur levels and application stages.

Application time(AT)	Days to flowering initiation: S (kg ha^{-1}) 15	30	45	60	75	Mean	Days to physiological maturity: S (kg ha^{-1}) 15	30	45	60	75	Mean
Seedling	111	110	110	110	110	110	172	174	174	175	173	173
Bolting	112	110	110	110	110	110	173	174	174	173	175	174
Flowering	111	110	110	111	112	111	173	174	174	174	174	173
Mean	111 a	110 b	110 b	110 b	110 b		173	174	174	174	174	
Control	113	LSD		S	AT	SxAT	Control	176	LSD	S	AT	SxAT
Rest	110		P≤ 0.05	0.72			Rest	173	P≤ 0.05	Ns	Ns	
					Ns	Ns						Ns

Table. 3. Plant height (cm) and siliques plant^{-1} of canola as affected by sulphur levels and application stages.

Application time(AT)	Plant height: S (kg ha^{-1}) 15	30	45	60	75	Mean	Siliques plant^{-1}: S (kg ha^{-1}) 15	30	45	60	75	Mean
Seedling	169.0	168.0	172.6	174.1	175.6	171.8 b	228	223	216	234	266	233 c
Bolting	166.7	172.3	172.7	179.6	179.0	174.1 a	256	256	281	306	270	274 a
Flowering	166.5	165.5	175.1	174.3	174.8	171.2 b	235	244	272	269	269	258 b
Mean	167.4 c	168.6 c	173.4 b	176.0 a	176.4 a		240 c	241 c	256 b	270 a	268 ab	
Control	130.9	LSD	S	AT	SxAT	Control		192	LSD	S	AT	SxAT
Rest	172.4	P≤ 0.05	2.26	1.75	3.91	Rest		255	P≤ 0.05	13.64	10.56	11.81

Means of same category followed by different alphabets reveal significant differences among mean values (P≤0.05) using LSD test.

Table. 4. Number of seeds silique^{-1} and thousand seeds weight (g) of canola as affected by sulphur levels and application stages.

	Seeds Silique^{-1}						Thousand seeds weight (g)					
Application time(AT)	S (kg ha^{-1}) 15	30	45	60	75	Mean	S (kg ha^{-1}) 15	30	45	60	75	Mean
Seedling	18	20	22	24	24	22	4.4	4.3	4.7	5.3	4.8	4.7 b
Bolting	21	21	23	25	22	23	5.4	5.2	5.1	5.2	5.2	5.2 a
Flowering	18	21	21	24	24	22	4.4	5.0	4.9	5.2	4.6	4.8 b
Mean	19 c	21 b	22 b	24 a	23 b		4.7 b	4.8 b	4.9 ab	5.2 a	4.9 ab	
Control	15		LSD	S	AT	SxAT	Control	3.2	LSD	S	AT	SxAT
Rest	22		P≤ 0.05	1.59	Ns	Ns	Rest	4.9	P≤ 0.05	0.34	0.26	Ns

Table. 5. Biomass yield (kg ha^{-1}) and harvest index (%) of canola as affected by sulphur levels and application stages.

	Biomass yield (kg ha^{-1})						Harvest index (%)					
Application time(AT)	S (kg ha^{-1}) 15	30	45	60	75	Mean	S (kg ha^{-1}) 15	30	45	60	75	Mean
Seedling	9363	9121	10600	11548	10788	10284	14.2	17.0	18.9	21.2	21.5	18.6
Bolting	10198	10863	10025	11513	11850	10890	14.5	15.6	20.3	22.0	20.0	18.5
Flowering	9796	10125	10713	11325	10788	10549	13.7	16.1	18.7	21.4	21.6	18.3
Mean	9785b	10036b	10446 ab	11462 a	11142 a		14.1 d	16.2 c	19.3 b	21.5 a	21.0 ab	
Control	8469		LSD	S	AT	SxAT	Control	13.4	LSD	S	AT	SxAT
Rest	10574		P≤ 0.05	1033	Ns	Ns	Rest	18.4	P≤ 0.05	1.92	Ns	Ns

Means of same category followed by different alphabets reveal significant differences among mean values (P≤0.05) using LSD test

Table. 6. Analysis of variance of days to flowering initiation, physiologlogical maturity, plant height, siliques plant^{-1}, seeds silique^{-1}, 1000-seeds wt (g), biomass yield (kg ha^{-1}), and harvest index (%)of canola as affected by sulphur levels (S) and application stages (AT).

Source of variance	D.F.	Flower initiation	Physiological maturity	Plant height	Siliques plant^{-1}	Seeds silique^{-1}	1000-Seeds wt (g)	Biomass yield (kg ha^{-1})	H.I (%)
Rep	3	1.18	0.10	2.40	285.68	2.86	0.07	1745287.04	5.01
Treatments (T)	15	3.69**	3.37**	501.60**	3318.44**	30.11**	1.23**	3518813.50*	40.06**
Control Vs Rest	(1)	30.46**	23.75**	6441.33**	14954.71**	199.66**	11.25**	16611081.67**	94.14**
S Levels (S)	(4)	3.64**	3.14	209.69**	2492.72**	51.99**	0.45*	6112988.54**	122.01**
Application stages (AT)	(2)	1.40ns	0.72ns	44.70**	8506.35**	6.50**	1.31**	1843977.92ns	0.36ns
S x AT	(8)	0.94ns	1.59ns	19.30*	979.79**	3.88**	0.34ns	1003901.35ns	2.25ns
Error	45	0.77	1.29	7.57	275.14	3.76	0.17	1578991.76	5.45
Total	63								

* = Significant at 5% level of probability, ** = Significant at 1% level of probability, ns = Non-significant.

Table. 7. Co-efficient of variance (C.V) for days to flowering initiation, physiological maturity, plant height, siliques plant^{-1}, seeds silique^{-1}, 1000-seeds wt (g), biomass yield (kg ha^{-1}), and harvest index (%) of canola as affected by sulphur levels (S) and application stages (AT).

Parameters	Flower initiation	Physiological maturity	Plant height	Siliques plant^{-1}	Seeds silique^{-1}	1000-Seeds wt (g)	Biomass yield (kg ha^{-1})	H.I (%)
C.V (%)	0.79	0.65	1.62	6.60	9.00	8.63	12.03	12.87

Seeds silique^{-1}:

The results of analysis of variance revealed that sulfur had significant effect on seeds silique^{-1} (Table. 4). Sulfur applied plots produced significantly higher seeds silique^{-1} 22 as compared to control plots 15. Higher seeds silique^{-1} 24 was recorded up to 60 kg ha^{-1} S application plots, while 15 kg S ha^{-1} received plots were counted lower seeds silique^{-1} 19. Application timing and interaction of S x AT was found non-significant.

Thousand seeds weight (g):

Mean values of data on thousand seeds weight revealed that sulfur and their time of application had significantly affected thousand seeds weight (Table. 4). Lower thousand seeds weight of 3.2g was recorded in control plots as compared to sulfur fertilized plots 4.9g. Mean values for sulfur levels showed significant increase in thousand seeds weight with increasing the levels of sulfur. Heavier seeds weight 5.2g were recorded in the 60 kg S ha^{-1} received plots, while lighter seeds weight 4.7g were noted 15 kg S ha^{-1} applied plots. The time of sulfur application had significantly affected thousand seeds weight and higher seeds weight was observed at bolting stage while lighter seeds weight was observed when sulfur were applied in seedling and flowering stage. The interaction of S x AT had no significant influence on thousand seeds weight.

Biomass yield (Kg ha^{-1}):

Biomass yield is the ultimate product of all photosynthetic activities which is highly affected by nutrients and its application stages. The yield potential was improved by both crop growth rate and duration of the growth period (Diepenbrock, 2000). Analysis of variance revealed that sulfur levels have significant result on the biomass yield of canola (Table. 5). The increasing S rates up to 60 kg ha^{-1} significantly increased the biomass yield. Maximum biomass yield (11461 kg ha^{-1}) produced at the rate of 60 kg S ha^{-1} followed by 75 kg S ha^{-1} applied plots. Similar results were recorded by Sattar et al*.* (2011) who found that N and S combine application enhance plant growth and yield component of canola and also resulted higher seed yield and biomass yield of canola. Collectively highest biomass yield (10574 kg ha^{-1}) was recorded in sulfur treated plots as compared to (8469 kg ha^{-1}) control plots. These results are closely connected and comparable with Khandkar et al*.* (1991) who found that biomass yield enhanced significantly with sulphur levels. Our outcomes are in conformity with Malik et al*.* (2004) who investigated that biomass yield was significantly affected by S levels. This was may be due to stimulatory effects of sulphur on cell division which helped in leaf expansion and increased light interception improved the vegetative growth (Garg et al. 2006).The positive correlation was occurring between the sulphur application and biomass yield production of canola. These results are in line with those of Sharma & Gupta (1991) who reported that sulphur application was increased; also increase occur in biomass yield of canola may be due to the fact that sulphur enhances vegetative growth, grain formation and starch. The application timings and interaction of S x AT had no significant effect on biomass yield.

Harvest index (%):

Sulfur levels had significantly influenced harvest index of canola (Table. 5). Higher harvest index (18.4 %) was noted in plots that received sulfur as compared to control plots (13.4 %). Harvest index increased from 14.1 to 21.5 % when sulfur rate was increased from 15 to 60 kg ha^{-1} followed by 75 kg S ha^{-1}. The Comparison between different S levels, it was noted that the lower harvest index was obtained in control plots, while harvest index were increased when S applied up to 60 kg ha^{-1}. Application timings and interaction of S x AT were found non-significant for harvest index. Canola (*Brassica napus* L.) has a higher sulphur requirement than most cereals and to meet that demand, additional sulphur may be needed in a balanced fertilizer program (Khan et al. 2011). Sulphur is important plant nutrient for mustards and beneficial for increasing yield in canola and 40 kg ha^{-1} is optimum to grow canola in soils low in sulphur (Haneklaus et al. 1999; Ghosh et al.2000). Therefore sulphur nutrition must be seriously considered in a canola fertility program (Sharifi, 2012).

CONCLUSION

Application of sulphur at the rate of 60 kg ha^{-1} produced tallest plants (172.4 cm), more siliques plant^{-1} (270), seeds silique^{-1} (24), thousand seeds weight (5.2 g), biomass yield (11461 kg ha^{-1}) and harvest index (21.5 %). Sulphur applied at bolting stage increased plant height (174.1 cm), siliques plant^{-1} (274), thousand seeds weight (5.2 g) and seed yield (1998 kg ha^{-1}). It is recommended that the application of sulphur (60 kg ha^{-1}) at bolting stage is recommended for better growth, early maturity and maximum biomass yield in Peshawar valley.

ACKNOWLEGEMENT

The authors acknowledged the Directorate of New Developmental Farm, The University of Agriculture Peshawar for providing seeds and fertilizers for completion of this research work.

REFERENCES

Afridi, M. Z., M. T. Jan, I. Ahmad & M. A. Khan 2002. Yield components of canola in response to NPK nutrition. Pak. J. Agron, 1(4): 133-135.

Ahmad, G., Jan, A., Inamullah & Arif, M. 2006. Phenology and physiology of canola as affected by nitrogen and sulphur fertilization. J. of Agron, 5(4): 555-562.

Ahmad, G., Jan, A., Arif, M., Jan, M. T. & Khattak, R. A. 2007. Influence of nitrogen and sulphur fertilization on quality of canola (*Brassica napus* L.) under rainfed conditions. J. Zhejiang Univ. Sci. B, 8(10):731-737.

Aulakh, M. S. 2003. Crop response to sulphur nutrition. In: Y. P. Abrol and A. Ahmad (eds.) Sulphur in Plants. Kluwer Academic Publ. Dordrecht. pp. 341–354.

Begum F., Muhammad, F. H. & R. I. Mondal. 2012. Influence of sulphur on morpho-physiological and yield parameters of rapeseed (*Brassica campestris* L.). Bangladesh J. Agril. Res, 37(4): 645-652.

Bhatia, K.S. & Shukla, K.K. 1982. Effect of continuous application of fertilizers and manure on some physical properties of eroded alluvial soil. J. Indian Soc. Soil Sci, 30:33-36.

Diepenbrock, W. 2000. Yield analysis of winter oilseed rape (*Brassica napus* L.). Field Crops Res, 67(1): 35-49.

Fismes, J., Vong, P. C. Guckert, A. & Frossard, E. 2000. Influence of sulphur on apparent N-use efficiency, yield and quality of oilseed rape (*Brassica napus* L.) grown on a calcareous soil. Eur. J. Agron, 12(2): 127-141.

Ghosh, D.C., Panda, P.K. & Sahoo, P.M. 1995. Response of rainfall rapeseed (*Brassica compestris*) to NPK. Indian J. Agric, *Res.* 29: 5–9.

Ghosh, P.K., K.M. Hati, K.G. Mandal, A.K. Misra, R.S. Chaudhary, and K.K. Bandyopadhyay. 2000. Sulphur nutrition in oilseeds and oilseeds-based cropping systems. Fert. Newsl, 8(45): 51-52.

GOP. 2014. Economic Survey Report 2013-14. Govt. of Pak. Finance Division, Islamabad.

Hassan, F., Munaf, A., Qadir, G. & Basra, S. M. A. 2007. Effects of sulphur on seed yield, oil, protein and glucosinolates of canola cultivars. Int. J. Agri. Biol, 9 (3): 504-508.

Haneklaus, S., Paulsen, H.M., Gupta, A.K., Bloem, E., Schnug, E., 1999. Influence of Sulphur Fertilization on Yield and Quality of Oilseed Rape and Mustard. *In*: New Horizons for an Old Crop. Proc. 10th Int. Rapeseed Congr. Canberra, Australian Capital Territory (ACT), Australia.

Havlin, J. L., Beaton, J. D., Tisdale, S. L. & Nelson, W. L. 2004. Soil fertility and fertilizers. An introduction to nutrient management. 7th ed. Pearson Education, Singapore. p. 221.

Holmes, M. R. J. 1980. Nitrogen; In Nutrition of the oilseed rape crop. Applied Sci. Pub. Barking Essex, England. P.21-67.

Jackson, M.L. 1973. Soil chemical analysis, Prentice Hall of India Pvt. Ltd., New Delhi.

Jan, A., Ahmad, G., Jan, M. T., Jamal, M. & Subhan, F. 2008. Oil yields of canola as affected by N and S levels and methods of application under rainfed conditions. Sarhad J. Agric, 24 (1): 1-10.

Jan, M. T., Shah, P., Hoolinton, P. A., Khan, M. J. & Sohail, Q. 2009. Agriculture research: Design and Analysis: Deptt. of Agronomy, NWFP Agric. Uni. Peshawar, Pakistan.

Khandkar, U.R., Malviya, P.K. & Nigam, K.B. 1991. Influence of N and S applications on mustard (*Brassica juncea* L.) in vertisol. Res. and Development Reporter, 8: 189.

Khan, T. A., Norton, R., Edis, R., Walker, C. & Chen, D. 2011. Comparing N and S sources to improve yield and nutrient efficiency in canola cropping systems in South-Eastern Australia. 7th Australian Research Assembly on Brassicas (ARAB). Wagga Wagga August 2011.

Kumar, P.R. 2001. Rapeseed-mustard. In: Breeding field crops, Chopra V.L. (ed.). Oxford-IBH publication. 394-432 pp.

Malik, M. A., Khan, H. Z. & Wahid, M. A. 2004. Growth, seed yield and oil content response of canola (*Brassica napus* L.) to varying levels of sulphur. Agriculture & Biology, 6 (6) :1153-1155.

MNFSR. 2013. Ministry of National Food Security and Research, Agric. Statistics of Pakistan. Govt. of Pak, Economic Wing, Islamabad.

Nizami, M. I., Shafiq, M., Rashid, A. & Aslam, A. 2004. The soils and their Agricultural development potential in Pothwar. WRRI & NARC, Islamabad, Pakistan. pp. 5-7.

Nuttall, W. F. & Ukrainetz, H. 1991. The effect of time of S application on yield and sulphur uptake of canola. Comm. in Soil Sci. Plant Analy, 22 (3-4): 269-281.

Patel, J.R. & Shelke, V.B. 1998. Effect of farm yard manure, phosphorus and sulphur of Indian Mustard *(Brassica campestris)*. Indian J. Agron, 43(4): 713–17.

Rahmatullah, Nabi, G., Salim, M. & Zia, M. S. 1999. Relationship between seed sulphur and phosphorus and seed yield of *Brassica napus* on two Alfisols fertilized with different sulphur sources. Pak. J. Biol. Sci, 2: 462-465.

Reddy, S. R. 2004. Rapeseed & Mustard. In Agronomy of field crops. p. 423-437. Kalyani publishers. India.

Sattar, A., Mumtaz, A., Cheema, M. A., Wahid, M. F., Saleem & Hassan, M. 2011. Interactive effect of sulphur and nitrogen on growth, yield and quality of canola. Crop & Environment, 2(1): 32-37.

Sharifi, R. S. 2012. Sulphur fertilizer effects on grain yield & the sum of physiological indices of canola (*Brassica napus* L.). Annals of Biol. Res, 3 (11): 5034-5041.

Sharma, R. A. & Gupta, R. K. 1991. Response of rainfed soybean sunflower sequence to N and S fertilization in black clay soils. J. Ind. Soc. Soil Sci, 39: 197-200.

Soleymani, A, Shahri, M. M., Shahrajabian, M. H. & Naranjani, L. 2010. Responses of cultivars of canola to sulphur fertilizer and plant densities under climatic condition of Gorgan region, Iran. Journal of Food, Agriculture & Environment, 8 (3&4) : 2 9 8 - 3 0 4 .

Subhani, A., Shabbir, G., Fazil, M., Mahmood, A., Khalid, R. & Cheema, N. M. 2003. Role of sulphur in enhancing the oil contents and yield of rapeseed under medium rainfed conditions. Pak. J. Soil Sci, 22(4): 50-53.

Tomer, T.S., S. Singh, S. Kumar & S. Tomer, 1997. Response of Indian mustard (*Brassica juncea* L.) to nitrogen, phosphorus and sulphur fertilization. Indian J. Agron, 42: 148–51.

Ur Rehman, H., Iqbal, Q., Farooq, M., Wahid, A., Afzal, I. & Basra, S. M. A. 2013. Sulphur application improves the growth, seed yield and oil quality of canola. Acta Physiol Plant, 35 (10): 2999–3006.

Zhao, F. J., McGrath, S. P., Blake, M. M. A., Link, A. & Tucker, M. 2002. Crop responses to sulphur fertilization in Europe. Proceedings of International Fertilizer Society. Cambridge, UK. No. 504: 27.