Indian J. Plant Physiol., Vol. 11, No. 3, (N.S.) pp. 253-260 (Jul.-Sept., 2006)

PHYSIOLOGICAL ANALYSIS OF GROWTH AND YIELD OF INDIAN MUSTARD AS AFFECTED BY IRRIGATION AND SULPHUR

ISSA PIRI AND S.N. SHARMA*

Division of Agronomy, Indian Agricultural Research Institute, New Delhi-110 012

Received on 31 Jan., 2006, Revised on 19 June, 2006

SUMMARY

The present study was carried out during rabi seasons of 2003-04 and 2004-05 to find out the effect of irrigation and sulphur on growth and yield characters of Indian mustard. The results revealed that application of two irrigations at 45 DAS and 90 DAS significantly increased plant height, dry matter accumulation, relative growth rate and secondary branches/plant over one irrigation. However, effects of one irrigation and two irrigations were at par on leaf area index, net assimilation rate and primary branches/plant but recorded significantly higher values of above physiological parameters over no irrigation in both the years. Seed yield of mustard increased significantly with increasing levels of irrigation. Application of sulphur also significantly increased the plant height, dry matter accumulation, LAI, RGR, NAR, primary and secondary branches per plant and seed yield of Indian mustard. The significant response was observed up to 45 kg S/ha.

Key words: **Indian mustard, irrigation, physiological characters, sulphur.**

INTRODUCTION

Oilseeds play a vital role in Indian economy, accounting for 5 per cent of the gross national product and 10 per cent of the value of agricultural product (FAO 2001). Rapeseeds and mustard account for 21 per cent of the total oilseeds area and 23 per cent of the total oilseed production of the country (GOI 2005). However, the productivity of oilseeds including mustard is low as compared to other countries. Of the several reasons for low productivity of mustard as compared to world average, unavailability of adequate irrigation is the most important one. Crop receiving two irrigations at pre-flowering and pod filling stages produced about 33 per cent more seed yield than unirrigated one (Gangasaran and Giri 1986).

Sulphur is an important element for protein and oil synthesis in *Brassica* species. It is a component of amino acids like cystein, cystine, methionine and required for chlorophyll and protein synthesis. Sulphur is also involved in the synthesis of oil in oilseeds. Glucosinolates and thioglucosides are very much affected by the deficiency of sulphur in plants. Sawarkar et al. (1987) reported that S-deficiency can reduce the crop yield to the extent of 10-34 per cent. The response of Indian mustard to sulphur ranged from 20 to 100 kg S/ha (Mahapatra and Chatterjee 1992, Mohan and Sharma 1992, Khanpara *et al*. 1993). The present study was therefore conducted to study the effect of irrigation and sulphur on growth and yield characters of Indian mustard.

MATERIALS AND METHODS

The field experiment was conducted on Indian mustard during *rabi* seasons of 2003-04 and 2004-05 at the research farm of the Division of Agronomy, IARI, New Delhi. The experiment was laid out in split plot

* Corresponding author

design with three irrigation levels (no irrigation, one irrigations of 7 cm at 45 days after sowing and two irrigations at 7 cm each at 45 and 90 days after sowing) in main plots and four levels of sulphur (0, 15, 30 and 45 kg S/ha) and two sources (cosavet and gypsum) of sulphur in sub-plots with three replications. Indian mustard cv. Pusa Jagganath was sown in rows spaced at 45 x 15 cm on 18th October in 2003 and 20th October in 2004. The soil of the experimental site was sandy loam having 195.0 kg ha^{-1} available N, 11.0 kg ha^{-1} available P, 165.0 kg ha^{-1} available K and 14 ppm available S. In addition to irrigations applied as per treatments crop received 31.1 mm rainfall during 2003-2004 and 60.7 mm during 2004-2005. The consumptive use of water ranged from 166 to 177 mm with no irrigation, 204 to 217 mm with one irrigation and 240 to 245 mm with two irrigations. Plant height and dry matter accumulation were measured at 45 and 90 DAS and at harvest. Net assimilation rate (NAR) and relative growth rate (RGR) were determined between 45 and 90 DAS and between 90 DAS and harvest. Leaf area index was measured at 45 and 90 DAS. The observations on primary and secondary branches/plant and seed yield were taken at maturity stage.

RESULTS AND DISCUSSION

Plant height: Plant height at 45 DAS was not influenced due to different irrigation levels, whereas at 90 DAS, one and two irrigations being at par, increased plant height significantly over no irrigation (Table 1). Difference in one and two irrigations was not observed because second irrigation was applied at 90 DAS. However, at harvest stage application of two irrigations significantly enhanced plant height over one irrigation in both the years of investigation. The more moisture availability with two irrigations might enabled plants to grow taller than other irrigation regimes at the time of harvest. Singh and Srivastava (1986), Jadhav (1988) and Malviya *et al*. (1988) also reported that application of two irrigations to mustard crop significantly produced taller plants compared to no irrigation and one irrigation.

In both the years at 45 DAS, plant height increased with increasing level of sulphur, however, the difference between 15 and 30 kg S/ha was not significant in 2004-2005 (Table 1). At 90 DAS plant height increased when rate of S application was increased from 0 to 45 kg S/ ha in both the years. At harvest, plant height increased when rate of S application was increased from 0 to 15 kg S/ha in 2003-2004 and from 0 to 45 kg S/ha in 2004-2005. The increase in plant height with the application of sulphur is attributed to increased metabolic processes in plants with sulphur application which seems to have promoted meristematic activities resulting in higher apical growth and expansion of photosynthetic surface. Increase in plant height of Indian mustard with an increase in rate of sulphur application has also been reported by a number of workers (Khanpara *et al*. 1993, Singh and Gangasaran 1993, Tomar *et al*. 1997 and Rana *et al*. 2001). Sources of sulphur (gypsium and cosavet) did not affect the plant height significantly in both the years of experimentation.

Dry matter accumulation: As first irrigation was applied at 45 DAS, irrigation effect was not expected to influence the dry matter accumulation at 45 DAS (Table 2). At 90 DAS, one and two irrigations, being at par, significantly increased dry matter per plant in both the years of study. At harvest, two irrigations resulted in significantly higher dry matter accumulation than one irrigation, which in turn, was significantly superior over no irrigation. This may be because of increased plant height, branch number per plant and leaf area development with higher moisture conditions as compared with less moisture availability to plants. Jadhav (1988) and Sharma and Kumar (1988) also reported an increase in dry matter due to increase in level of irrigations.

Increasing levels of sulphur up to 45 kg/ha progressively and significantly increased dry matter accumulation at 45 and 90 DAS as well as at harvest in both the years (Table 2). The chloroplast protein synthesis is stimulated by availability of sulphur to plant and this might resulted in greater photosynthetic efficiency and ultimately increased dry matter production per plant. Khanpara *et al*. (1993), Tomar *et al*. (1997) and Patel and Shelke (1998) also reported an increase in dry matter accumulation in mustard due to sulphur fertilization. Application of cosavet significantly increased dry matter accumulation over gypsum in both the years at all the stages of crop growth.

Table 1. Plant height (cm) as affected by irrigation and levels of sulphur in Indian mustard cv. Pusa Jagganath

Treatment	2003-04			2004-05		
	45 DAS	90 DAS	Harvest	45 DAS	90 DAS	Harvest
Irrigation						
No irrigation	47.3	142.1	147.6	52.3	147.6	151.7
One irrigation	47.4	155.9	168.1	52.5	160.5	172.2
Two irrigations	47.6	155.1	184.3	52.9	163.3	188.1
S.Em±	0.9	2.8	2.3	1.05	2.2	2.6
CD (P=0.05)	NS	10.9	9.2	NS	8.6	10.1
Sulphur (kg S/ha)						
0	39.3	145.0	150.0	43.3	149.2	162.0
15	45.8	149.2	164.8	50.8	154.3	168.9
30	48.8	150.8	167.5	53.9	157.3	171.4
45	51.8	156.8	172.0	57.9	163.8	176.0
S.Ed. (0 vs. 15/30/45)	1.6	5.4	5.1	1.9	4.6	5.5
CD (P=0.05)	3.2	10.6	10.0	3.8	9.0	10.9
S.Em ±	0.9	3.1	2.9	1.1	2.6	3.2
CD (P=0.05)	2.7	8.9	8.5	3.2	7.6	9.2
Sources of sulphur						
Gypsum	48.1	151.4	166.7	53.5	157.0	170.7
Cosavet	49.5	153.1	169.6	54.9	159.9	173.5
S.Em ±	0.8	2.5	2.4	0.9	2.2	2.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Leaf area index (LAI): As in case of dry matter accumulation, the irrigation effects were not expected to influence LAI at 45 DAS as the first irrigation was applied at this stage (Table 3). At 90 DAS two irrigations, being at par with one irrigation, markedly enhanced LAI over no irrigation in both the years. Adequate and timely supply of water is well known to increase the turgidity and cell division resulting in higher meristematic activity leading to greater leaf area. The increase in LAI of mustard with an increase in the level of irrigation has also been reported by Singh and Gangasaran (1993) and Bharati *et al*. (2003).

Each successive increase in the level of sulphur markedly increased LAI in both the years (Table 3). It is known that sulphur resembles nitrogen in its capacity to enhance cell division and expansion. It is also reported to have favourable effect on chlorophyll synthesis resulting in more number of leaves and leaf area and higher chlorophyll content. The significant increase in leaf area index in mustard were also reported by Singh and Gangasaran (1993) and Patel and Shelke (1998). Both the sources were found at par in respect of LAI of mustard.

Table 2. Dry matter accumulation (g/plant) as affected by irrigation and levels and sources of sulphur in Indian mustard cv. Pusa Jagganath

Treatment	2003-04			2004-05		
	45 DAS	90 DAS	Harvest	45 DAS	90 DAS	Harvest
Irrigation						
No irrigation	6.9	49.7	60.3	7.6	55.4	66.5
One irrigation	7.0	57.1	65.7	7.8	63.6	73.1
Two irrigations	6.9	57.6	74.2	7.6	66.0	82.8
S.Em ±	0.1	1.1	1.3	0.2	1.2	1.4
CD (P=0.05)	NS	4.2	5.1	NS	4.7	5.3
Sulphur (kg S/ha)						
0	4.8	37.3	51.2	5.3	41.5	56.8
15	5.7	49.1	59.5	6.3	55.6	66.0
30	7.2	58.6	70.3	8.0	66.0	77.5
45	8.9	65.6	78.2	10.0	73.4	87.6
S.Ed. (0 vs. 15/30/45)	0.2	1.7	2.3	0.2	1.9	2.4
CD (P=0.05)	0.4	3.3	4.5	0.5	3.8	4.8
S.Em ±	0.1	1.0	1.3	0.1	1.1	1.4
CD (P=0.05)	0.4	2.9	3.8	0.4	3.2	4.0
Sources of sulphur						
Gypsum	6.6	54.9	66.5	7.3	61.4	74.0
Cosavet	8.0	60.5	72.1	8.9	68.7	80.1
S.Em ±	0.1	0.8	1.1	0.1	0.9	1.1
CD (P=0.05)	0.4	3.2	4.2	0.5	3.6	4.5

Relative growth rate (RGR): Application of two irrigations, being at par with one irrigation, significantly increased RGR over no irrigation between 45-90 DAS in both the years of investigation, whereas between 90 DAS and harvest, application of two irrigations also significantly increased RGR over one irrigation (Table 4). Similar finding was reported in Indian mustard by Prasad and Ehsanullah (1988).

Application of 30 kg S/ha, being at par with 15 kg S/ha, significantly enhanced RGR of mustard over no sulphur between 45-90 DAS in both the years (Table 4). Application of highest dose of sulphur (45 kg S/ha) significantly enhanced RGR over other levels of sulphur between 90 DAS-harvest stage in both the years of study. The increase in RGR in mustard due to application of sulphur has also been reported by Saha and Mandal (2000). Application of cosavet markedly enhanced RGR between 45-90 DAS over gypsum in both the years. However, between 90 DAS-harvest stage application of cosavet gave significantly enhanced RGR over gypsum only during 2004-2005.

Table 3. Leaf area index as affected by irrigation and levels and sources of sulphur in Indian mustard cv. Pusa Jagganath

Treatment	2003-04		2004-05	
	45 DAS	90 DAS	45 DAS	90 DAS
Irrigation				
No irrigation	0.82	2.30	0.84	2.40
One irrigation	0.87	2.70	0.88	2.90
Two irrigations	0.88	2.80	0.87	2.90
S.Em ±	0.01	0.04	0.02	0.04
CD (P=0.05)	NS	0.14	NS	0.15
Sulphur (kg S/ha)				
0	0.62	1.70	0.65	1.90
15	0.77	2.10	0.79	2.30
30	0.85	2.60	0.87	2.80
45	1.04	3.40	1.10	3.50
S.Ed. (0 vs. 15/30/45)	0.03	0.06	0.03	0.06
CD (P=0.05)	0.05	0.12	0.07	0.12
S.Em ±	0.01	0.04	0.02	0.04
CD (P=0.05)	0.04	0.01	0.06	0.11
Sources of sulphur				
Gypsum	0.81	2.40	0.84	2.61
Cosavet	0.83	2.50	0.86	2.63
S.Em ±	0.01	0.03	0.02	0.03
CD (P=0.05)	NS	NS	NS	NS

Net assimilation rate (NAR): One and two irrigations, being at par, significantly increased NAR over no irrigation between 45-90 DAS in both the years of study. Between 90 DAS and at harvest two irrigations also increased NAR significantly over one irrigation, which in turn, increased NAR over no irrigation (Table 4).

Application of 45 kg S/ha, being at par with 30 kg S/ha, significantly enhanced NAR over no sulphur and 15 kg S/ha between 45-90 DAS, whereas between 90 DAS and harvest NAR was increased significantly with increasing level of sulphur up to highest dose i.e. 45 kgs/ha during both the years of study (Table 4). As mentioned earlier the increasing level of sulphur increased the number of leaves and LAI per plant, which might have resulted in increased photosynthesis and assimilation rates. These, in turn, increased the growth characters and NAR. Similar results in mustard were also reported by Saha and Mandal (2000). Cosavet markedly enhanced NAR in both the years over gypsum except between 45-90 DAS during 2004-05 where both the sources of sulphur were at par.

Table 4. Relative growth rate (RGR) and net assimilation rate (NAR) as affected by irrigation and sulphur in Indian mustard cv. Pusa Jagganath

Treatment	RGR (mg g^{-1} day^{-1})				NAR (mg m^{-2} day^{-1})			
	2003-04		2004-05		2003-04		2004-05	
	45-90 DAS	90-harvest	45-90 DAS	90-harvest	45-90 DAS	90-harvest	45-90 DAS	90-harvest
Irrigation								
No irrigation	34.57	4.84	31.00	4.37	3.21	0.22	2.87	0.20
One irrigation	59.57	13.14	53.71	11.98	3.75	0.40	3.36	0.35
Two irrigations	60.00	14.26	54.00	12.86	3.74	0.80	3.37	0.73
CD (P=0.05)	2.80	0.71	2.53	0.66	0.24	0.037	0.183	0.035
Sulphur (kg S/ha)								
0	47.00	8.70	42.00	7.93	1.09	0.31	0.96	0.27
15	50.16	9.50	45.17	8.60	3.65	0.41	3.28	0.36
30	51.83	10.87	46.67	9.88	3.93	0.49	3.52	0.44
45	54.33	12.88	49.00	11.63	4.37	0.59	3.92	0.55
CD (P=0.05)	2.21	0.54	2.18	0.52	0.17	0.028	0.152	0.024
Sources of sulphur								
Gypsum	49.78	10.65	44.67	9.77	3.87	0.44	3.48	0.39
Cosavet	54.44	11.52	49.22	10.31	4.10	0.56	3.67	0.51
CD (P=0.05)	2.46	0.60	2.42	NS	0.19	0.031	0.170	0.027

Number of primary branches/plant: One and two irrigations significantly increased number of primary branches/plant over no irrigation but remained at par with each other in both the years of study (Table 5). Similar type of results have also been reported by Jadhav (1988).

Application of 45 kg S/ha markedly produced more number of primary branches than control during both the years of study. The different levels of sulphur remained at par with each other (Table 5). Similar results were also reported by Rana *et al*. (2001). Application of cosavet increased number of primary branches/plant significantly over gypsum during 2003-04 but in 2004-05 both the sources of sulphur remained at par.

Number of secondary branches/plant: Two irrigations recorded significantly more number of secondary branches per plant than one irrigation during both the years (Table 5). Likewise, one irrigation increased number of secondary branches/plant significantly over no irrigation. These results were in conformity with those of Prasad and Ehsanullah (1988).

Number of secondary branches/plant increased significantly with increasing level of sulphur up to 30 kg S/ha in both the years of study (Table 5). Sulphur has its vital role in the primary and secondary metabolism as a constituent of various organic compounds. These results were in conformity with those of Kachroo and Kumar (1988).

Seed yield: Application of two irrigations recorded significantly higher seed yield than one irrigation, which in turn, gave significantly higher seed yield than no irrigation in both the years (Table 5). The significant

Table 5. Number of primary and secondary branches/plant and seed yield as affected by irrigation and sulphur in Indian mustard cv. Pusa Jagganath

Treatment	Primary branches/plant (Nos.)		Secondary branches/plant (Nos.)		Seed yield (q/ha)	
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
Irrigation						
No irrigation	5.9	5.9	14.5	16.2	12.8	14.2
One irrigation	6.8	6.8	18.3	20.3	18.8	20.8
Two irrigations	7.1	7.2	20.3	22.6	20.6	22.9
CD (P=0.05)	0.4	0.5	1.1	1.3	1.4	1.3
Sulphur (kg S/ha)						
0	6.2	6.2	14.5	16.3	15.3	17.0
15	6.5	6.4	17.3	19.2	16.6	18.5
30	6.5	6.8	18.4	20.5	17.7	19.7
45	7.0	7.1	19.0	21.2	18.8	20.9
CD (P=0.05)	0.3	0.4	0.9	1.1	1.0	1.1
Sources of sulphur						
Gypsum	6.5	6.6	17.8	19.8	17.3	19.2
Cosavet	6.9	6.9	18.6	20.7	18.0	20.1
CD (P=0.05)	0.04	NS	NS	NS	NS	NS

improvement in the mustard seed yield might be due to the cumulative effect of significant improvement in the growth parameters and yield attributes.

The seed yield also increased significantly with the successive increase in the level of applied sulphur in both the years (Table 5). Increase in physiological parameters particularly LAI, CGR, RGR, NAR and number of primary and secondary branches/plant played important role in increasing the size of source, which in turn, played crucial role in increasing size of sink i.e. grain yield through increased synthesis of photosynthates and their proper translocation and mobilization from source to sink. Similar observastions were made by Bharati et al. (2003).

The results of present study, thus, indicate that irrigation at 45 and 90 days after sowing and application of 45 kg S/ha are optimum for increasing productivity of Indian mustard.

ACKNOWLEDGEMENTS

The first author is grateful to Dean, P.G. School and Head, Division of Agronomy, IARI for providing necessary facilities for doing research. The author is also thankful to Iran Ministry of Science, Research and Technology for providing necessary study leave and financial support for Ph.D. programme at IARI, New Delhi.

REFERENCES

Bharati, V., Prasad, U.K. and Singh, J.P. (2003). Effect of irrigation and sulphur on yield and nutrient uptake of Indian mustard. *J. Farming Sys. Res. Dev*. **8:** 97-98.

FAO (2001). Year Book. Food and Agriculture Organization, Rome.

Gangasaran and Giri, G. (1986). Growth and yield of mustard as influenced by irrigation and plant population. *Ann. Agric. Res.* **7:** 68-74.

GOI (2005). Agriculture at Glance. Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India, New Delhi.

Jadhav, S.N. (1988). Water use and productivity of mustard as influenced by sowing dates, insect pest control measures and irrigation. Ph.D. Thesis, Division of Agronomy, Indian Agricultural Research Institute, New Delhi.

Kachroo, D. and Kumar, A. (1988). Nitrogen and sulphur fertilization in relation to yield attributes and yield of Indian mustard (*Brassica juncea*). *Indian J. Agron*. **37:** 549-555.

Khanpara, V.D., Porwal, B.L., Sahu, M.P. and Patel, J.C. (1993). Effect of nitrogen and sulphur on growth and yield of mustard (*Brassica juncea*). *Indian J. Agron*. **38:** 266-269.

Mahapatra, A.K. and Chandrajee, R. (1992). Effect of sulphur application on yield, quality and nutrient uptake of unirrigated Indian rape (*Brassica napus*). *Indian J. Agron*. **37:** 201-204.

Malviya, D.D., Patel, J.C. and Vyas, M.M. (1988). Studies on irrigation, nitrogen and phosphorus levels on growth and yield of mustard. *Indian J. Agron.* **33:** 245-248.

Mohan, K. and Sharma, H.C. (1992). Effect of nitrogen and sulphur on growth, yield attributes, seed and oil yield of Indian mustard. *Indian J. Agron*. **37:** 748-754.

Patel, J.R. and Shelke, V.B. (1998). Effect of farmyard manure, phosphorus and sulphur on growth, yield and quality of Indian mustard (*B. juncea*). *Indian J. Agron*. **43:** 713-717.

Prasad, U.K. and Eshannullah, M. (1988). Effects of irrigation and nitrogen on yield and yield attributes of mustard. *Indian J. Agron.* **33:** 47-51.

Rana, K.S., Rana, D.S. and Kumar, P. (2001). Growth and yield of taramiric (*Eruca sativa*) as affected by nitrogen and sulphur under dryland conditions. *Indian J. Agron.* **46:** 168-170.

Saha, A. and Mandal, B.K. (2000). Growth and yield of yellow sarson and mustard in relation to sulphur nutrition in lowland entisol under rainfed condition. *J. Oilseeds Res.* **17:** 307-314.

Sawarkar, N.J., Shukla, S.S. and Tomar, P.S. (1987). Effect of sulphur fertilization on yield and quality of mustard. *J. Oilseeds Res.* **4:** 227-229.

Sharma, O.K. and Kumar, A. (1997). Effect of irrigation scheduling and nitrogen on yield and nitrogen uptake of mustard. *Indian J. Agron*. **33:** 436-444.

Singh, B.N. and Srivastava, S.P. (1986). Effect of irrigation and nitrogen fertilization on growth and yield of mustard in mid hills of Meghalaya. *Indian J. Agron.* **31:** 135-138.

Singh, S. and Gangasaran. (1993). Effect of irrigation, nitrogen and sulphur on growth, yield attributes, yield and quality of water use of toria. *Indian J. Agron.* **38:** 417-421.

Tomar, T.S., Singh, S., Kumar, S. and Tomar, S. (1997). Response of Indian mustard to nitrogen, phosphorus and sulphur fertilization. *Indian J. Agron*. **42:** 148-151.