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Full Length Research Paper

Effect of irrigation intervals and sulphur fertilizer on growth analyses and yield of *Brassica juncea*

Issa Piri[1], Mohsen Moussavi Nik[2], AbolfazlTavassoli[3]* and Fatemeh Rastegaripour[3]

[1]Agriculture Department, Payame Noor University, PO Box 19395-4697, Tehran, I. R. of Iran.
[2]Department of Agriculture, Zabol University, Zabol, Iran.
[3]Department of Agriculture, Shirvan Branch, Islamic Azad University, Shirvan, Iran.

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In order to study of Effect of irrigation intervals and sulphur fertilizer on growth analyses and yield of Indian mustard (*B. juncea* var. Pusa Jagannath), a field experiment was conducted at Indian Agricultural Research Institute, New Delhi during crop season of 2007-2008 and 2008-2009. The experiment was carried out in split plot designed with three replications. The treatments consisted of three levels (no irrigation, one irrigation at 45 days after sowing (DAS) and two irrigations at 45 DAS and 90 DAS) of irrigation in main plots and four levels (0, 15, 30 and 45 kg S/ha) of sulphur in sub-plots. The results showed that in both years of experimentation application of two irrigations significantly increased plant height and number of primary branches per plant over one irrigation, which resulted in significantly higher straw yield. Also application of two irrigations, being on par with one irrigation, significantly increased RGR and NAR over no irrigation at all the stages of plant growth in both the years of investigation. The increasing level of sulphur increased plant height, number of primary branches, yield straw and leaf area index, relative growth rate and net assimilation rate at all the stages of crop growth.

Key words: Indian mustard, irrigation, sulphur, growth indicators.

INTRODUCTION

Indian mustard (*Brassica juncea*) is one of the oilseed crops and has been cultivated in India since ancient times. India is the third largest rapeseed/mustard seed producer in the word (Chauhan et al., 2002). The crop accounts for nearly one-third of the oil produced in India (Chauhan et al., 2002). Irrigation and fertilizer management are important agronomic practices for higher yield. Prasad (1995) observed significant increase in plant height, siliquae per plant, grain yield and straw yield with four irrigations. Mahapatraet et al. (1992) observed significant increase in grain yield when crop was irrigated at 3 critical growth stages than 1 or 2 stages. Sulphur plays a vital role in the yield of mustard. Sulphur is the fourth major nutrient in crop production (Singh et al., 2000). Sulphur increased dry matter in plant and thus it is effective on growth analyses. Growth analysis is the procedure of analyzing plant growth rate by expressing it as the algebraic product of a series of factors. Plant growth analysis is generally expressed in the indices of growth, such as crop growth rate, relative growth rate, net assimilation rate, leaf area index, and leaf area ratio. Mandal and Sinha (2004) reported that dry matter production and CGR significantly increased with increasing level of sulphur up to 20 kg S. ha^{-1} and LAI up to 40 kg S. ha^{-1}.

The aim of this study was to investigate the effect of irrigation intervals and sulphur fertilizer on the following: (i) straw yield of Indian mustard; and (ii) measurement of growth analyses.

MATERIALS AND METHODS

Experiment of irrigation intervals and sulphur fertilizer on quality and quantity characteristics of Indian mustard (*Brassica juncea*) was conducted during seasons of 2007-2008 and 2008-2009 at the Agronomy farm of the Indian Agricultural Research Institute, New Delhi. The site lies at longitude 28°38´ N, and latitude 77°11´ E and the altitude of the area is 228.6 m above sea level.

The climate of this area is semi-arid and subtropical with dry and hot summer and cold winter (Jadhav, 1988). June is the hottest

*Corresponding author. E-mail: Tavassoli_abolfazl@yahoo.com

Table 1. Physico-chemical properties of soil.

A. Mechanical composition of soil	**Years**	
Soil separates (%)	**2007-2008**	**2008-2009**
Sand	61.5	61.7
Silt	16.5	16.4
Clay	22.0	21.9
B. Physical properties of soil		
Depth of soil		
1. Field capacity		
0-30 cm depth	17.2	17.3
30-60 cm depth	17.6	17.7
60-90 cm depth	17.8	17.7
90-120 cm depth	18.0	18.1
2. Permanent wilting point (%)		
0-30 cm depth	6.7	6.6
30-60 cm depth	6.7	6.2
60-90 cm depth	6.8	6.8
90-120 cm depth	6.8	6.8
3. Bulk density (g cc^{-1})		
0-30 cm depth	1.5	1.5
30-60 cm depth	1.5	1.5
60-90 cm depth	1.4	1.5
90-120 cm depth	1.4	1.4
C. Chemical composition of soil		
1. Organic carbon (%)	0.38	0.36
2. Total nitrogen (kg/ha)	365.0	359.0
3. Total S (ppm)	178.0	173.0
4. Total P (%)	0.031	0.030
5. Available N (kg/ha)	197.0	193.0
6. Available P (kg/ha)	11.6	10.4
7. Exchangeable K (kg/ha)	167.0	163.0
8. Available S (ppm)	14.0	15.0
9. pH	7.6	7.5
10. EC	0.31	0.30

month with mean monthly temperatures ranging from 41°C to 46°C, while January is the coldest month with monthly minimum temperatures ranging from 5 to 7°C. There is occasional frost during December and January. The mean annual rainfall is about 650 mm of which about 80% is received during a short span of three months from July to September. The annual pan evaporation is about 850 mm. The soil characteristic of Indian Agricultural Research Institute is sandy loam in texture (Table 1). The experimental design was split plot, using randomized complete block design with three replications. The treatments consisted of three levels (no irrigation, one irrigation at 45 days after sowing (DAS) and two irrigations at 45 DAS and 90 DAS) of irrigation in main plots and four levels (0, 15, 30 and 45 kg S/ha) of sulphur in sub-plots. In this experiment there is about 10 cm distance between every plant. Distances of main plots from each other was 200 cm and the distances of sub plots from each other was 100 cm. Sub plots are established of 8 rows in the long term of 6 m and with distances of 45 cm.

A uniform dose of 80 kg N ha^{-1} as urea, 60 kg P_2O_5 ha as DAP and 40 kg K_2O ha^{-1} as muriate of potash was applied to each plot. Half dose of nitrogen and full dose of P_2O_5 and K_2O were applied as basal application. The sulphur was applied as per treatments through two sources of Cosavet arid Gypsum. The desired quantity of fertilizer was drilled 5 cm below the seedling depth in crop rows before sowing of seed. Rest of the dose of nitrogen was applied at flowering stage. Thinning was done to maintain a uniform plant population in each plot at three weeks after sowing. Crop in both the years were sown after a pre-sowing irrigation. The seeds of Indian mustard strain VSL-5 (PusaJgannath) were hand drilled at about 3-4 cm depth in third week of October during both the years. Rows were spaced 45 cm apart and 5.0 kg seed per ha was used for sowing in both the experiments. The Irrigation as per treatment was given at 45 and 90 days after sowing. Metasystox at 0.2% was sprayed thrice at 10 days interval during pod development stage to protect the crop from aphids. The crop from the net plot area was harvested by cutting the ground level and allowed for sun

Table 2. Effect of irrigation and sulphur fertilizer on plant height (cm).

Treatment	2007-2008			2008-2009		
	45 DAS	90 DAS	Harvest	45 DAS	90 DAS	Harvest
Irrigation						
No irrigation	47.3[a]	142.1[b]	147.6[c]	52.3[a]	147.6[b]	151.7[c]
One irrigation	47.4[a]	155.9[a]	168.1[b]	52.5[a]	160.5[a]	172.2[b]
Two irrigation	47.6[a]	155.1[a]	184.3[a]	52.9[a]	163.3[a]	188.1[a]
Levels of Sulphur (kg S/ha)						
0	39.3[d]	145.0[c]	150.0[c]	43.3[c]	149.2[c]	162.0[c]
15	45.8[c]	149.2[b]	164.8[b]	50.8[b]	154.3[b]	168.9[b]
30	48.8[b]	150.8[b]	167.5[b]	53.9[ab]	157.3[b]	171.4[b]
45	51.8[a]	156.8[a]	172.0[a]	57.9[a]	163.8[a]	176.0[a]

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

drying in doughing seed. After sun dry, the weight of the stalk yield from the net plot was recorded. In this experiment, others factors that were measured included: Plant height, number of primary branches/plant and growth indicators such as:

Leaf area index (LAI)

The functional leaves of the five plants, which were selected at random, were used for leaf area estimation. The leaf area was recorded with an Automatic Leaf Area Meter (LI3100 LICOR Ltd., Lincoln, Nebraska, USA). The leaf area index was worked out using the formula:

$$LAI = \frac{\text{Leaf area } (cm^2)}{\text{Land area } (cm^2)}$$

Relative growth rate (RGR) at 45 and 90 DAS

The increase in dry weight in unit time over unit original weight of the plant is called RGR and is calculated by using the following formula given by Blackman (1919).

$$RGR\ (g/g/day) = \frac{LnW_2 - LnW_1}{t_2 - t_1}$$

Where; W_1= Dry weight of the plant at tome t_1, W_2=Dry weight of the plant at time t_2 and Ln =Natural logarithm.

Net assimilation rate (NAR)

NAR was computed at different periodical intervals (45,90DAS and at harvest) by using the following formula given by Evans (1982).

$$NAR\ (gm^{-2}day^{-1}) = \frac{(W_2-W_1)\ (\log_e L_2 - \log_e L_1)}{(t_2-t_1)\ (L_2-L_1)}$$

W_1 and W_2 are total dry weight of plants at time t_1 and t_2, respectively and L_1 and L_2, are total leaf area of plants at time t_1 and t_2, respectively.

The data were analyzed using SAS statistical packages; mean comparison was done using Duncan at 5% probability level.

RESULTS AND DISCUSSION

Plant height

The effect of irrigation and sulphur levels treatments was significant on plant height (P<5%). Plant height at 45 DAS was not influenced significantly due to different irrigation levels, whereas at 90 DAS one and two irrigations being at par, increased plant height significantly over no irrigation. Difference in one and two irrigation was not observed (Table 2). Because second irrigation was applied at 90 DAS and not expected to be superior to one irrigation in respect of plant height. 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 enabled plants to grow taller than other irrigation regimes at the time of harvest. Singh and Srivastava (1986), Jadhav (1988) and Malavia et al. (1988) also reported that application of two irrigations to mustard crop significantly produced taller plants compared to no irrigation and one irrigation.

Plant height increased with increasing level of sulphur at all growth stages in both the years. however, the difference between 0 and 15 kg S/ha at 90 DAS in both the years and at harvest in second year, 15 and 30 kg S/ha at 90 DAS and at harvest in first year and at 45 DAS in second year and between 30 and 45 kg S/ha at 45 DAS in second year and between 15 and 30kg S/ha at 90 DAS in first year and at harvest in both the years were not significant (Table 2). The increase in plant height with the application of sulphur is attributed to increased metabolic processes in plants with sulphur application

Table 3. Effect of irrigation and sulphur fertilizer on Number of branches.

Treatment	Number of primary branches/plant	
	2007-2008	2008-2009
Irrigation		
No irrigation	5.9[b]	5.9[c]
One irrigation	6.8[a]	6.8[b]
Two irrigation	7.1[a]	7.2[a]
Levels of Sulphur (kg S/ha)		
0	6.2[b]	6.2[c]
15	6.5[b]	6.4[c]
30	6.5[b]	6.8[b]
45	7.0[a]	7.1[a]

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

Table 4. Effect of irrigation and sulphur fertilizer on straw yield (q/ha).

Treatment	2007-2008	2008-2009
Irrigation		
No irrigation	41.7[c]	46.3[c]
One irrigation	52.1[b]	57.9[b]
Two irrigation	57.6[a]	63.8[a]
Levels of Sulphur (kg S/ha)		
0	47.5[c]	52.8[c]
15	49.1[b]	54.1[bc]
30	50.5[b]	56.0[b]
45	53.2[a]	59.1[a]

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

which seems to have promoted meristematic activities resulting in higher apical growth and expansion of photosynthetic surface. Increase in plant height with an increase in rate of sulphur application has also been reported by a number of workers (Khanpara et al., 1993; Tomar et al., 1997; Rana et al., 2001).

Number of primary branches/plant

The effect of irrigation and sulphur levels treatments was significant on Number of primary branches/plant (P<5%).One and two irrigations significantly increased number of primary branches/ plant over no irrigation but remained on par with each other in both the years of study (Table 3). This may be due to more uptakes of nutrients and photosynthates due to more availability of moisture with application of irrigation. Similar type of results has also been reported by Yusuf (1973), Singh and Srivastava (1986) and 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 on par with each other (Table 3). The increase in number of primary branches of plant due to 45 kg S/ha may be due to enhanced photosynthesis, as sulphur is moved in the formation of chlorophyll and activation of enzymes. Similar results were also reported by Rana et al. (2001), Khanpara et al. (1993), Sharma (1994) and Chauhan et al. (1996).

Straw yield

The effect of irrigation and sulphur levels treatments was significant straw yield (P<5%). application of two irrigations recorded significantly higher straw yield than one irrigation which in turn gave significantly higher straw yield than no irrigation in both the years of study (Table 4). The increase in straw yield also may be attributed to higher plant height than more number of total branches. Similar result was also reported by Sharma (1994), Prasad (1995) and Malavia et al. (1988).

Application of 45 kg S/ha recorded significantly higher

Table 5. Effect of irrigation and sulphur fertilizer on LAI and RGR.

Treatment	LAI				RGR (Mg.g^{-1}.day^{-1})			
	2007-2008		2008-2009		2007-2008		2008-2009	
	45 DAS	90 DAS	45 DAS	90 DAS	45-90	90-Harvest	45-90	90-Harvest
Irrigation								
No irrigation	0.82^{b}	2.30^{b}	0.84^{c}	2.40^{b}	34.57^{b}	4.84^{c}	31.00^{b}	4.37^{b}
One irrigation	0.87^{a}	2.70^{a}	0.88^{b}	2.90^{a}	59.57^{a}	13.14^{b}	53.71^{a}	11.98^{b}
Two irrigation	0.88^{a}	2.80^{a}	0.87^{a}	2.90^{a}	60.00^{a}	14.26^{a}	54.00^{a}	12.86^{a}
Levels of Sulphur (kg S/ha)								
0	0.62^{d}	1.70^{d}	0.65^{d}	1.90^{d}	47.00^{c}	8.70^{c}	42.00^{d}	7.93^{d}
15	0.77^{c}	2.10^{c}	0.79^{c}	2.30^{c}	50.16^{b}	9.50^{b}	45.17^{c}	8.60^{c}
30	0.85^{b}	2.60^{b}	0.87^{b}	2.80^{b}	51.38^{b}	10.87^{b}	46.67^{b}	9.88^{b}
45	1.04^{a}	3.40^{a}	1.10^{a}	3.50^{a}	54.33^{a}	12.88^{a}	49.00^{a}	11.63^{a}

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

straw yield than 30 kg S/ha in both the years of experimentation. Further, application of 30 kg S/ha being on par with 15 kg S/ha recorded significantly higher straw yield over no sulphur in both the years of study (Table 4). This may be due to the effect of sulphur in increasing growth attributes and production of more dry matter with sulphur application. Sharma (1994) and Jat et al. (2003) also reported an increase in straw yield of mustard with increasing sulphur levels.

Leaf area index (LAI)

The effect of irrigation and sulphur levels treatments was significant LAI (P<5%). Irrigation had no significant effect on LAI of mustard 45 DAS in both the years of investigation, whereas at 90 DAS two irrigations, being on par with one irrigation, markedly enhanced LAI over no irrigation in both years (Table 5). 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 with an increase in the level of irrigation application has also been reported by Bharati et al. (2003).

Each successive increase in the level of sulphur markedly increased LAI at 45 and 90 DAS in both the years (Table 5). Resembles that nitrogen increase in LAI can be explained in view of the fact that sulphur resembles that nitrogen in its capacity to enhance cell division and call elongation or expansion. It is reported to have favorable effect on chlorophyll synthesis resulting in more number of leaves with bigger size and higher chlorophyll content .the significant increases in leaf area index in mustard were also recorded by Patel and Shelke (1998).

Relative growth rate (RGR)

The effect of irrigation and sulphur levels treatments was significant RGR (P<5%). Application of tow irrigations, being on 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 5). An optimum moisture regime is very important for the balanced metabolic activities of the plants, which in turn might have result in increased growth of the plants similar finding was reported by Prasad and Ehsanullah (1988).

Application of 30 kg S/ha being on par with 45 kg S/ha and 15 kg S/ha significantly enhanced RGR of mustard over no sulphur in both the years of study at 45-90 DAS. Application of highest dose of sulphur (45 kg S/ha) significantly enhanced RGR over all the preceded levels of sulphur at 90 DAS – harvest stage in both the years of study (Table 5). This may be due to the fact that sulphur helps to increase the availability of many other nutrients which are important for plant growth and

Table 6. Effect of irrigation and sulphur fertilizer on NAR ($mg.m^{-2}.day^{-1}$).

Treatment	2007-2008		2008-2009	
	45-90	90-Harvest	45-90	90-Harvest
Irrigation				
No irrigation	3.21[b]	0.22[c]	2.87[b]	0.20[c]
One irrigation	3.75[a]	0.40[b]	3.36[a]	0.35[b]
Two irrigation	3.74[a]	0.80[a]	3.37[a]	0.73[a]
Levels of Sulphur (kg S/ha)				
0	1.09[c]	0.31	0.96[d]	0.27[d]
15	3.65[b]	0.41[c]	3.28[c]	0.36[c]
30	3.93[ab]	0.49[b]	3.52[b]	0.44[b]
45	4.37[a]	0.59[a]	3.92[a]	0.55[a]

Mean followed by similar letters in each column, are not significantly different at the 5% level of probability.

development. The in cease in RGR in mustard due to application of sulphur has also been reported by Yadav (1999), Kachroo and Kumar (1997), Saha and Mandal (2000).

Net assimilation rate (NAR)

The effect of irrigation and sulphur levels treatments was significant NAR (P<5%). One and two irrigation being at par, significantly increased NAR over no irrigation between 45-90 DAS in both the years of study. Between 90 DAS and harvest two irrigations also increased NAR significantly over one irrigation which, in turn, increased NAR over no irrigation (Table 6). It may be due to the fact that irrigation facilitates higher uptake of nutrients by plants and resulted in building up new tissues and there-by enhancing the vegetative growth and photosynthetic activities of plants.

Application of 45 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 increased significantly with increasing level of sulphur up to highest dose i.e. 45 kg / ha during both the years of study (Table 6). The increasing level of sulphur might have increased the number of leaves and leaf area index per plant, which resulted in increased photosynthesis and assimilation rates, cell devotion and cell elongation or expansion. These, in turn, increased the growth characters and NAR. Similar results in mustard were also reported by Yadav (1999) and Saha and Mandal (2000).

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