African Journal of Agricultural Research Vol. 7(6), pp. 958-963, 12 February, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR12.125
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Effect of sulphur fertilizer on sulphur uptake and forage yield of *Brassica juncea* in condition of different regimes of irrigation

Issa Piri[1], Ali Rahimi[2], Abolfazl Tavassoli[3]*, Fatemeh Rastegaripour[3] and Mahdi Babaeian[3]

[1]Agriculture Department, Payame Noor University, P. O. Box 19395-4697, Tehran, I. R. of Iran.
[2]Department of Agriculture, Yasuj Branch, Islamic Azad University, Yasuj, Iran.
[3]Department of Agriculture, Zahedan Branch, Islamic Azad University, Zahedan, Iran.

Accepted 4 January, 2012

To study the effect of irrigation and sulphur on Indian mustard, 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 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. The results showed that in both the years of experimentation, application of two irrigations significantly increased plant height and number of primary and secondary branches per plant over one irrigation, which resulted in significantly higher dry matter accumulation and forage yield with two irrigations as compared to one irrigation. Also, application of two irrigations being on par with one irrigation, significantly increased sulphur content in forage over no irrigation, which resulted in increased sulphur uptake by crop in both the years of study. The increasing level of sulphur increased plant height, dry matter accumulation. Application of 45 kg S/ha produced more number of primary branches than control during both the years of study and other levels of sulphur remained on par with each other, whereas number of secondary branches/plant increased significantly with increasing level of sulphur up to 30 kg/ha in both the years of study. Forage yield of mustard increased significantly with the successive increase in the level of applied sulphur in both the years. Sulphur content in forage and sulphur uptake increased significantly with increasing level of sulphur.

Key words: Indian mustard, irrigation, fertilizer, forage yield, sulphur uptake.

INTRODUCTION

Indian mustard an annual plant (*Brassica juncea*) in the mustard family, having yellow flowers, petiolate leaves and oil-rich seeds. It was used as a traditional health food in many countries. In addition to oil production, the leaves and stems of Brassica family provide high quality forage matter because of their low fiber and high protein content and can be milled into animal feeds. *B. juncea* is cultivated in low hills both as a pure crop and in mixture with cereal especially wheat. The crop can be raised well both under rainfed and irrigated conditions. Being more responsive to fertilizers, it gives better returns under irrigated conditions. The mustard crop is usually grown under arid and semi-arid conditions.

About one third of the world lands are classified as arid and semi-arid region and aridity is the most common environmental stress and approximately includes 25% of the world land. Thus, irrigation plays a vital role in growth and yield of this crop in these regions. Most of the investigations conducted to determine the irrigation requirement of mustard crop. Mailwat et al. (1998) reported that seed yield was 0.68 t/ha without irrigation and 0.94 t/ha with two irrigations. Narayan and Bhushun (1998) observed that percent increase in yield over no irrigation was highest with 3 irrigations applied at branching, flowering and pod filling stages as compared to branching or branching and

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

Table 1. Physico-chemical properties of soil.

Mechanical composition of soil	Years	
	2007-08	2008-09
Soil separates (%)		
Sand	61.5	61.7
Silt	16.5	16.4
Clay	22.0	21.9
Chemical composition of soil		
Organic carbon (%)	0.38	0.36
Total nitrogen (kg/ha)	365.0	359.0
Total S (ppm)	178.0	173.0
Total P (%)	0.031	0.030
Available N (kg/ha)	197.0	193.0
Available P (kg/ha)	11.6	10.4
Exchangeable K (kg/ha)	167.0	163.0
Available S (ppm)	14.0	15.0
pH	7.6	7.5
EC	0.31	0.30

flowering stages. Raut et al. (2000) reported that three irrigations were applied at pre-flowering, 50% flowering and seed filling stages recorded significantly higher seed yield of mustard. Sultana et al. (2009) reported that application of three irrigations recorded significant increase in yield of rapeseed. Prassad (1995) reported that application of four irrigations recorded significant increase in nitrogen, phosphorus and sulphur content in mustard tissue. Bharati and Rathore (1982) observed that total nitrogen uptake by mustard grown on a clay loam soil with one irrigation at flowering stage was significantly higher than the control. Piri et al. (2011) observed that mustard yield would increase with three irrigations during the growth season. Sharma and Kumar (1992) reported that irrigation not only increased the growth but also enhanced the efficiency of applied nutrients.

Sulphur plays an important role in the chemical composition of mustard tissue. Sulphur is the fourth major nutrient in crop production. The nitrogen and sulphur requirements of crops are closely related because both nutrients are required for protein synthesis. Sulphur is a component of the amino acid, cysteine, and methionine needed for protein synthesis. Sulphur is involved in the synthesis of chlorophyll. Sulfur is one of the 16 elements essential to crop production. This situation is true especially for the Brassica family, which has a higher requirement for S than other annual crops such as wheat (Hall, 1999). It is typically considered a secondary macronutrient (along with calcium and magnesium), but is essential for maximum crop yield and quality. Sulfur is often ranked immediately behind nitrogen, phosphorus, and potassium in terms of importance to crop productivity. Sulfur is a component of the amino acids cysteine and methionine, making it essential for protein synthesis in plants. Plants contain a large variety of other organic sulfur compounds, such as glutathione, sulfolipids and secondary sulfur compounds which play an important role in physiology and protection against environmental stress and pests.

Sulphur is required in the development of fertile canola flowers and other plants of Brassica family (Hall, 1999). Much research has done for studying effect of sulphur fertilizers on mustard and other crops. Rana et al. (2001) found that application of 40 kg S. ha^{-1} significantly increased the plant height and number of primary branches in taramira. Chauhan et al. (2002) reported that increase in the S levels significantly improved growth and yield attributes of Indian mustard. Singh et al. (1998) observed significant effect of sulphur levels on growth attributes of mustard up to 90 kg S. ha^{-1}. Patel and Shelke (1998) conducted a two years experiment and revealed that sulphur fertilization at 60 kg S. ha significantly increased the plant height, total dry matter accumulation in Indian mustard. Piri et al. (2011) on Indian mustard, and Khalid et al. (2009) on canola reported that consumption of sulphur fertilizer lead to increase of yield of these crops. The aim of this research is studying the effect of sulphur fertilizer on sulphur uptake and forage yield of *B. juncea* in the condition of different regimes of irrigation at New Delhi, Indian.

MATERIALS AND METHODS

Experiment of irrigation intervals and sulphur fertilizer on quality and quantity characteristics of Indian mustard (*B. juncea*). This research was conducted during seasons of 2007-2008 and 2008-09 at the Indian Agricultural Research Institute, New Delhi. The site lies at longitude 28°38' N, and latitude 77°11' E and the height 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 winters. June is the hottest month with mean monthly temperatures ranging from 41 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 characteristics of Indian Agricultural Research Institute are indicated in 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 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 selected 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 source of Cosavet. The desired quantity of fertilizer was drilled 5 cm below the seedling depth in crop rows before sowing of seed. The rest of the dose of nitrogen was applied at the 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

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

Treatment	Year 2007-2008			Year 2008-2009		
	60 DAS	120 DAS	Harvest	60 DAS	120 DAS	Harvest
Irrigation						
No irrigation	54.2	146.4	147.6	59.4	149.8	151.7
One irrigation	54.2	161.5	168.1	60.1	166.3	172.2
Two irrigation	54.4	162.3	184.3	60.4	167.8	188.1
Levels of sulphur (kg S/ha)						
0	45.1	147.3	150.0	48.4	153.8	162.0
15	53.7	157.2	164.8	52.6	159.9	168.9
30	54.1	160.0	167.5	59.4	161.5	171.4
45	56.9	166.2	172.0	61.7	164.9	176.0

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 drying *in situ*. After sun dry, the weight of the dry matter accumulation, biological yield and forage yield from the net plot was recorded.

In this experiment, other factors that were measured included, plant height, number of primary branches/plant, number of secondary branches/plant, sulphur content in forage. The sulphur content in forage was determined with di-acid digestion by turbidty method on a spectrophotometer using 420 nm wave lengths. Sulphur uptake by crop: Percent sulphur content in seeds and stalk was multiplied with their yields for each treatment plot-wise and sulphur uptake by seeds and stalk was reported in kg/ha. 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 60 DAS was not influenced significantly due to different irrigation levels, whereas at 120 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 the second irrigation was applied at 120 DAS and not expected to be superior to the first 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 120 DAS in both the years and at harvest in the second year, 15 and 30 kg S/ha at 120 DAS and at harvest in the first year and at 60 DAS in the second year and between 30 and 45 DAS in second year and between 30 and 45 kg S/ha at 120 DAS in the 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 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 uptake of nutrients and photosynthesis due to more availability of moisture with application of irrigation. A similar type of result 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

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

Treatment	Number of primary branches/plant		Number of secondary branches/plant	
	Year		Year	
	2007-2008	2008-2009	2008-2009	2007-2008
Irrigation				
No irrigation	5.9	5.9	14.5	16.2
One irrigation	6.8	6.8	18.3	20.3
Two irrigation	7.1	7.2	20.3	22.6
Levels of sulphur (kg S/ha)				
0	6.2	6.2	14.5	16.3
15	6.5	6.4	17.3	19.2
30	6.5	6.8	18.4	20.5
45	7.0	7.1	19.0	21.2

activation of enzymes. Similar results were also reported by Rana et al. (2001), Khanpara et al. (1993), Sharma (1994) and Chauhan et al. (1996).

Number of secondary branches/plant

The effect of irrigation and sulphur levels treatments was significant on number of secondary branches/plant (P<5%). In both the years of experimentation, two irrigations recorded significantly more number of secondary branches per plant than one irrigation. Likewise, one irrigation increased number of secondary branches/plant significantly over no irrigation in both the years (Table 3). Irrigation application might have increased the availability of nitrogen to the plant at early growth stages and nitrogen being an essential constituent of nucleic acid, protoplasm and protein, play a fundamental role in metabolism, growth, development, reproduction and transmission of heritable characters, so the number of secondary branches also increased by this condition under irrigation regime. These results were in conformity with those of Malavia et al. (1988), Prasad and Ehsanullah (1988) and Yusuf (1973).

Number of secondary branches/plant increased significantly with increasing level of sulphur up to 30 kg S/ha in both the years of study. Further increase in the rate of sulphur application had no significant effect on the number of secondary branches/plant in both the years of experimentation (Table 3). 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 Khanpara et al. (1993), Sharma (1994), Chauhan et al. (1996) and Kachroo and Kumar (1997).

Dry matter accumulation (biological yield)

The effect of irrigation and sulphur levels treatments was significant on dry matter accumulation (P<5%). In both the years, dry matter accumulation biological yield at 60 DAS was not significantly affected due to different irrigation regimes. Whereas at 120 DAS one and two irrigations, being at per significantly increased dry matter per plant over no irrigation in both the years of study (Table 4). At harvest, two irrigations resulted in significantly higher dry matter accumulation biological yield than one irrigation, which was significantly higher than no irrigation. This may be because of increased plant height and branch number per plant with higher moisture conditions as compared with less moisture availability to plants. Jadhav (1988) and Sharma and Kumar (1980) also reported an increase in dry matter due to increase in the level of irrigations.

Data presented in Table 4 revealed that increasing levels of sulphur up to 45 kg/ha significantly increased dry matter accumulation (biological yield) at 60 and 120 DAS at harvest over control in both years. The chloroplast protein synthesis is stimulated by availability of sulphur to plant and higher synthesis of chloroplast results 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.

Forage yield

The effect of irrigation and sulphur levels treatments was significant in forage yield (P<5%). application of two irrigations recorded significantly higher forage yield than one irrigation, which in turn gave significantly higher forage yield than no irrigation in both the years of study (Table 5). The increase in straw yield also may be attributed to higher plant height than more number of total branches. A similar result was also reported by Sharma (1994), Prassad (1995), Malavia et al. (1988) and Sharma (1992).

Application of 45 kg S/ha recorded significantly higher forage yield than 30 kg S/ha in both the years of

Table 4. Effect of irrigation and sulphur fertilizer on dry matter accumulation biological yield (g/plant).

Treatment	Year 2007-2008			Year 2008-2009		
	60 DAS	120 DAS	Harvest	60 DAS	120 DAS	Harvest
Irrigation						
No irrigation	7.8	52.7	60.3	8.1	69.9	66.5
One irrigation	8.0	60.0	65.7	8.2	65.8	73.1
Two irrigation	8.1	60.1	74.2	8.2	67.6	82.8
Levels of sulphur (kg S/ha)						
0	5.4	41.7	51.2	5.9	46.8	56.8
15	6.2	53.6	59.5	7.1	60.7	66.0
30	7.8	61.2	70.3	8.8	72.4	77.5
45	10.2	66.9	78.2	10.8	80.0	87.6

Table 5. Effect of irrigation and sulphur fertilizer on straw forage yield (q/ha).

Treatment	Year 2007-2008	Year 2008-2009
Irrigation		
No irrigation	49.7	52.1
One irrigation	58.6	63.6
Two irrigation	69.4	72.7
Levels of sulphur (kg S/ha)		
0	54.6	57.0
15	57.8	59.8
30	61.5	67.2
45	68.4	73.4

experimentation. Further, application of 30 kg S/ha being on par with 15 kg S/ha recorded significantly higher forage yield over no sulphur in both the years of study (Table 5). This may be due to the effect of suphur 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 forage yield of mustard with increasing sulphur levels.

Sulphur content in forage

The effect of irrigation and sulphur levels treatments was significant in the sulphur content in forage (P<5%). Application of two irrigations being on par with one irrigation, significantly increased sulphur content in forage over no irrigation in both the seasons (Table 6). Availability of more moisture might have helped in better absorption and translocation of sulphur by forage of mustard. Similar results have been reported by Raut et al. (2000) and Singh (1993).

Sulphur content in mustard forage increased significantly with increasing level of Sulphur up to the highest level (45 kg S/ha) (Table 6). Application of sulphur increases the availability of sulphur for crop which results in higher sulphur content in seed and Straw of crop. Similar results have been reported by Singh (1993) and Raut et al. (2000).

Sulphur uptake by crop

The effect of irrigation and sulphur levels treatments was significant in sulphur uptake by crop (P<5%). Application of two irrigations significantly increased sulphur uptake by both seed and straw, which in turn, increased sulphur uptake over no irrigation in both the years of study. Total uptake of sulphur by crop was maximum with application of two irrigations to crop (Table 6). This may be attributed to the influence of more available soil moisture under higher irrigation and this might have enhanced their availability in soil and hence their uptakes.

Increasing level of sulphur application up to the highest level of 45 kg S/ha resulted in significantly higher sulphur uptake over the previous level of Sulphur application in both the years of study (Table 6). The increase in sulphur uptake with increasing level of

Table 6. Effect of irrigation and sulphur fertilizer on Sulphur content and uptake in mustard.

Treatment	Sulphur content in forage (%)		Sulphur uptake by crop (forage+seed) (%)	
	Year		Year	
	2007-2008	2008-2009	2008-2009	2007-2008
Irrigation				
No irrigation	0.18	0.20	15.2	18.3
One irrigation	0.22	0.23	23.8	27.9
Two irrigation	0.23	0.24	27.8	32.5
Levels of sulphur (kg S/ha)				
0	0.14	0.15	15.8	18.6
15	0.19	0.20	19.9	23.2
30	0.23	0.24	23.4	27.4
45	0.25	0.26	26.3	30.6

sulphur was due to increase in seed and straw yield and sulphur content with increasing level of irrigation. The significant increase in sulphur uptake by mustard was also recorded by Bharati et al. (2003), Raut et al. (2000) and Sharma et al. (1994).

REFERENCES

Bharati V, Prassad UK, Singh JP (2003). Irrigation and sulphur on yield and nutrient uptake of Indian mustard. J. Farming Syst. Res. Dev., 8(1):97-98.

Chauhan DR, Paroda S, Ram M (1996). Response of Indian mustard to bio fertilizers.Sulphur and nitrogen fertilization. Indian J. Agron., 41(4): 600-603.

Chauhan DR, Ram M, Singh I (2002). Response of Indian mustard. To irrigation and fertilization with varicose sources and levels of sulphur. Indian J. Agron., 47(3): 422-426.

Das KN, Das K (1995). Effect of sulphur and nitrogen fertilization on growth and yield of toria (*Brassica campestris* subsp. Oleifera var. toria). Indian J. Agron., 4(92): 329-331.

Hall MR (1999). "Effect of Sulphur Source and Placement on Canola Yield." North Peace Applied Research Association Annual Report, pp. 45-48.

Jadhav SN (1988). Water use and productivity of mustard as influenced by soing dates, insect pest control measures and irrigation. Ph.D. thesis, division of agronomy, Indian Agricultural research institute, New Delhi.

Jat BL, Jangir RP, Khangarot SS (2003). Responses of mustard varieties to different levels of sulphur in loamy sand soil. J. Farming Syst. Res. Dev., 8(1):108-109.

Kachroo D, kumar A (1997). Nitrogen and sulphur fertilization in relation to yield attributes and yield of Indian mustard (*Brassica juncea*). Indian J. Agron., 37(3): 549-551.

Khalid R, Khan KS, Yousaf M, Shabbir G, Subhani A (2009).Effect of sulfur fertilization on rapeseed and plant available sulfur in soils of Pothwar, Pakistan. Sarhad J. Agric., 25(1): 65-71.

Khanpara VD, Porwal BL, Sahu MP, Patel JC (1993). Effect of nitrogen and sulphur on growth and yield of mustard (*Brassica juncea*). Indian J. Agron., 38(2): 266-269.

Kumar P, Singh RP, Singh RC, Chander,S (1996). Influence of irrigation scheduling on growth, seed quality and yield of mustard. Ann. Agric. Res., 17:184-185.

Malviya DD, Petal JC, Vyas MM (1988). Studies on irrigation, nitrogen and phosphorus levels on growth and yield of mustard. Indian J. Agron., 33: 245-248.

Patel JR, Shelke VB (1998). Effect of farmyard manure, phosphorus and sulfur on growth. Yield and quality of Indian mustard (*B. juncea*). J. Agron., 43(4): 713-717.

Piri I, MoussaviNik M, Tavassoli A, Rastegaripour F, Babaeian M (2011). Effect of irrigation frequency and application levels of sulphur fertilizer on water use efficiency and yield of Indian mustard (Brassica juncea). Afr. J. Biotechnol., 10(55): 11459-11467.

Prassad J (1995). Studies on sulphur use efficiency of mustard (*B. juncea*) as influenced by rate of gypsum application and levels of irrigation. M.Sc. (Ag) Thesis, RAU, Bikaner(Raj.).

Prassad UK, Eshannullah M (1988). Effect of irrigation and nitrogen on yield and yield attributes of mustard. Indian J. Agron., 33(1): 47-51.

Rana KS, Rana DS, Kumar P (2001). Growth and yield of taramiric (*Ercca sativa*) as affected by nitrogen and sulphur under dryland condition. Indian J. Agron., 46(1): 168-170.

Raut R, Abdul HF, Hadole SS, Jeughale GS (2000). Effect of irrigation and sulphur on concentration, uptake and availability of sulphur, nitrogen and phosphorus in mustard (*B. juncea*). J. Soils Crops, 10(1): 145-148.

Raut RF, Abdul HF, Ganvir MM, Wanjari SS, Hadole SS (2000). Consumptive use, water use efficiency, seed yield and quality of mustard as influenced by irrigation and sulphur application. J. Soils Crops, 10(2): 252-255.

Sharma AK, Sharma AM, Sharma YM (1994). Effect of irrigation, nitrogen and sulphur application on seed yield, quality and sulphur uptake by Indian mustard. Agric. Sci. Digest, 14: 63-67.

Sharma G, Sutaliya R, Prassad S, Sharma ML (2003). Effect of irrigation and intercropping system on growth yield and quality of mustard and linseed. J. Crop Res., 25(3): 579-581.

Sharma JP (1994). Response of Indian mustard to different irrigation schedules and nitrogen and sulphur levels. Indian J. Agron., 39: 421-425.

Sharma OK, Kumar A (1992). Effect of nitrogen fertilizer under different irrigation scheduling on production potential and economics of mustard. Fertilizer News, 37: 37-41.

Singh B, Kumar,A, Yadav YP, Dhankhar RS (2000). Response of Brassica to sulphur application. Indian J. Agron., 45(4): 752-755.

Singh BN, Srivastava SP (1986). Effect of irrigation and nitrogen fertilization on growth and yield of mustard in mid hills of Meghalaya. Indian J. Agron., 31(2): 135-138.

Singh RK, Kumar S, Verma BL, Singh V (1993). Effect of irrigation schedules on yield and water use efficiency and oil content of toria. Indian J. Agron., 38: 42-44.

Sultana S, Rukul Amin AKM, Hasanuzzaman M (2009). Growth and yield of rapeseed (*Brassica campestris* L.) as affected by levels of irrigation.Am-Euras. J. Sci. Res., 4(1): 34-39.

Tomar TS, Singh S, Kumar S, Tomar S (1997). Response of Indian mustard to nitrogen, phosphorus and sulphur fertilization. Indian J. Agron., 42(1): 148-151.

Yusuf M (1973). Effect of frequencies and timings of irrigation on growth, yield and quality of safflower, mustard and linseed.Ph.D. thesis, Division of Agronomy, Indian Agricultural Research institute, New Delhi.