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Full Length Research Paper

Effect of irrigation frequency and application levels of sulphur fertilizer on water use efficiency and yield of Indian mustard (*Brassica juncea*)

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A field experiment was conducted at Indian Agricultural Research Institute, New Delhi during the crop season of 2007 to 2008 and 2008 to 2009 to study the effect of irrigation and sulphur on yield and water use efficiency of Indian mustard *(Brassica juncea* var. PusaJagannath). The experiment was carried out in split plot design with three replications. The treatments consisted of three levels of irrigation in the main plots [no irrigation, one irrigation at 45 days after sowing (DAS), and two irrigations at 45 DAS and 90 DAS] and four levels of sulphur in sub-plots (0, 15, 30, and 45 kg S/ha). The results showed that in both years of experimentation, application of two irrigations significantly increased the India mustard yield as indicated by dry matter accumulation, seed production, biological/biomass yield, and harvest index, in comparison to no irrigation. Also, the application of two irrigations, been on par with one irrigation, significantly enhanced seed and biological yield to 20.6 and 78.0 q/ha respectively in the first year, and 22.9 and 86.7 q/ha respectively in the second year, and the highest harvest index was obtained from the application of two irrigations in both years of the study. Water use efficiency as indicated by seasonal consumptive water use increased progressively with the increasing number of irrigations. Also, the amount of soil moisture extraction by the crop from upper layers increased and those from lower depth decreased with increase in the level of irrigation (from no irrigation to two irrigations) in both years of the study. Application of two irrigations to mustard gave higher net (yield) return and benefit-cost (B: C ratio) over one irrigation, which in turn, gave higher net benefit-cost return and B: C ratio than no irrigation. The increasing levels of sulphur application increased Indian mustard dry matter accumulation, seed and biological yield and harvest index. Seasonal consumptive water use by the crop and water use efficiency increased progressively with the increase level of sulphur application up to 45 kg S/ha . Quantity of soil moisture extraction from deeper layer increased with increase in the levels of sulphur application.

Key words: Indian mustard, Irrigation, Sulphur, Water use efficiency, Economic evaluation.

INTRODUCTION

India mustard is a member of the Brassicaceae family and has become one of the most important sources of oil production in the world. Mustard is generally grown on marginal lands with poor fertility under rainfed conditions.

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Irrigation and fertilizer management are important agronomic practices for higher yield. Irrigation influences favor the growth and yield attributes of mustard by supplementing the water need of the crop. It also enhances availability of different nutrients to crop plants. In a field investigation carried out by Chauhan et al. (2001) with Indian mustard, they reported that irrigation applied at branching, flowering and grain filling stages significantly increased seed yield of Indian mustard over that of pre-flowering, pod formation and grain filling stages. Bharati and Prasad (2002) found that seed yield of mustard increased significantly up to an IW: CPE ratio of 0.8 with two irrigations, ach of 5 cm depth. Irrigation, thus, plays a vital role in increasing the growth and yield of mustard. So in researches, water use efficiency measurement is very important. Tomar et al. (1992) showed that consumptive use of water was increased significantly up to 2 irrigations applied at pre-flowering and fruiting stages, but water use efficiency was increased only up to one irrigation applied at pre flowering in mustard. Yadav et al. (1999) reported that consumptive use of water increased by increasing irrigation levels, whereas water use efficiency decreased with irrigation.

Sulphur is an important constituent of mustard oil and its deficiency caused a significant reduction in yield and oil content of mustard. Jat et al. (2003) concluded that application of 90 kg S. ha^{-1} resulted in significantly higher seed and stalk yield. Singh et al. (2000) reported that application of sulphur up to 45 kg. ha^{-1} significantly increased the seed yield.

General goals of this study included water use efficiency, yield of Indian mustard and economical assessment of this crop in New Delhi city in 2007 to 2008 years, under the condition of irrigation intervals and sulphur fertilizer.

MATERIALS AND METHODS

The experiment of irrigation intervals and sulphur fertilizer on quality and quantity characteristics of Indian mustard (*Brassica juncea*) was conducted during *rabi* seasons of 2007 to 2008 and 2008 to 2009 at the Agronomy farm of the Indian Agricultural Research Institute, New Delhi. The site lies at longitude 28°38′ N, and latitude 77º11′ 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 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 the main plots and four levels (0, 15, 30 and 45 kg S/ha) of sulphur in the sub-plots. In this experiment, there was 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 as 100 cm. Sub plots were established with 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_20_5 ha as DAP and 40 kg K_20 ha^{-1} as muriate of potash was applied to each plot. Half dose of nitrogen and full dose of P_20_5 and K_20 were applied as basal application. The sulphur was applied as per treatment through two sources of Cosavet arid Gypsum. The desired quantity of fertilizer was drilled 5 cm below the seedling depth crop rows before sowing of the 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 years were sown after a pre-sowing irrigation. The seeds of Indian mustard strain VSL-5 (PusaJgannath) were hand drilled at about 3 to 4 cm depth in the third week of October during both 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 three times 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 drying, the weight of the biological yield (seed+ stalk) from the net plot was recorded. Threshing was done using Pullman's thresher. The seeds were collected, cleaned and the seed yield was recorded. In this experiment, other factors that were measured included:

Dry matter accumulation

Dry matter of five plant at 45, 90 DAS and at harvest was recorded and average was taken.

Harvest index (HI)

Harvest index was calculated by dividing the economic (seed) yield from the net plot by the total biological yield (seed+ stalk) from the same area and multiplying by 100.

$$HI = \frac{\text{Seed yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

Seasonal consumptive water use

Plot- wise soil samples were drawn at depth intervals of 0 to 30 cm, 30 to 60 cm, 60 to 90 cm and 90 to 120 cm before and after each irrigation and at harvest using a tube auger. Soil moisture percentage (w/w) was determined after oven drying the samples at 105°C for 24 h (until a constant weight was obtained). Consumptive use of water, consumptive water use efficiency and soil moisture extraction pattern were worked out from the soil moisture data.

Consumptive use of water

The consumptive use of water was computed using the following equation as stated by Dastane (1972):

$$CU = \sum_{K=1}^{N} (Ep \times 0.6) + \sum_{i=8}^{n} \frac{(M_1 i - M_2 i)}{100} \times dbi \times Di + ER$$

Cu = Consumptive use of water (mm); Ep = Pan evaporation values (mm) from the USWB Class 'A' pan for the interval from the date of irrigation to the date of sampling after irrigation. 0.6 = A constant factor used to get Et value by multiplying Ep value for a given

Table 1. Physico-chemical properties of soil.

Mechanical composition of soil	Year	
	2007-2008	**2008-2009**
Soil separates (%)		
Sand	61.5	61.7
Silt	16.5	16.4
Clay	22.0	21.9
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
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
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
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

period; M_1i = moisture percentage of i^{th} layer on the date of sampling after irrigation; M_2i = moisture percentage of i^{th} layer on the date of sampling before irrigation; dbi = bulk density of the i^{th} layer (gc/m); Di = depth of the i^{th} layer of the soil (mm); ER = effective rainfall (mm), if any during the period under consideration; n = number of soil layers; n = number of days from irrigation to sampling after irrigation.

Soil moisture extraction pattern

Soil moisture extraction was worked out from different layers, namely, 0 to 30, 30 to 60, 60 to 90 and 90 to 120 cm separately and summed up treatments-wise over entire crop season. Layerwise soil moisture extraction was expressed as percentage of total quantity of moisture extracted from root zone under a given treatment.

Crop water use efficiency (WUE)

The water use efficiency in kg seed/ha-mm for a given treatment was calculated by dividing the seed yield with the respective total consumptive water use for the crop period.

$$\text{Water use efficiency} = \frac{\text{Seed yield (kg/ha)}}{\text{Consumptive use of water (mm)}}$$

Table 2. Effect of irrigation and sulphur fertilizer on dry matter accumulation (g/plant).

Treatment	2007-2008			2008-2009		
	45 DAS	90 DAS	Harvest	45 DAS	90 DAS	Harvest
Irrigation						
No irrigation	6.9[a]	49.7[b]	60.3[c]	7.6[a]	55.4[c]	66.5[c]
One irrigation	7.0[a]	57.1[a]	65.7[b]	7.8[a]	63.6[b]	73.1[b]
Two irrigation	6.9[a]	57.6[a]	74.2[a]	7.6[a]	66.0[a]	82.8[a]
Levels of sulphur (kg S/ha)						
0	4.8[d]	37.3[d]	51.2[d]	5.3[d]	41.5[d]	56.8[d]
15	5.7[c]	49.1[c]	59.5[c]	6.3[c]	55.6[c]	66.0[c]
30	7.2[b]	58.6[b]	70.3[b]	8.0[b]	66.0[b]	77.5[b]
45	8.9[a]	65.6[a]	78.2[a]	10.0[a]	73.4[a]	87.6[a]

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

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

RESULTS AND DISCUSSION

Dry matter accumulation

The effect of irrigation and sulphur level treatments on dry matter accumulation was significant (P<5%). In both years, dry matter accumulation at 45 DAS was not significantly affected due to different irrigation regimes whereas at 90 DAS, one and two irrigations, been at par, significantly increased dry matter per plant over no irrigation in both years of the study (Table 2). At harvest, two irrigations resulted in significantly higher dry matter accumulation 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) reported an increase in dry matter due to increased level of irrigations.

Data presented in Table 2 revealed that increasing levels of sulphur up to 45 kg/ha significantly increased dry matter accumulation at 45 and 90 DAS at harvest over the 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. Khanpara et al. (1993), Tomar et al. (1997) and Palet and Shelke (1998) also reported an increase in dry matter accumulation in mustard due to sulphur fertilization.

Seed yield

The effect of irrigation and sulphur level treatments on seed yield was significant (P<5%). Application of two irrigation recorded significantly higher yield than one irrigation, which in turn, gave significantly higher seed yield than no irrigation in both years (Table 3). The percent increase in seed yield due to two irrigations was 10.7 and 10.1 over one irrigation and 60.9 and 61.3 over no irrigation in 2007 to 2008 and 2008 to 2009, respectively.

Similarly, one irrigation increased seed yield over no irrigation by 45.3 and 46.5% in 2003 to 2004 and 2004 to 2005, respectively (Table 3). The significant improvement in the mustard seed yield might be the cumulative effect of significant improvement in the value of yield attributes like number of siliquae per plant, number of seeds/siliqua and test weight. Gangasaran and Giri (1985), Singh and Srivastava (1986), Reddy and Sinha (1987), Jadhav (1988), Prassad and Ehsanullah (1988), Katole and Sharma (1991), Ehsanullah et al. (1991) and Bharati and Prasad (2002) reported an increase in seed yield of mustard due to irrigation.

The seed yield of mustard increased significantly with the successive increase in the level of applied sulphur in both years. Application of 15, 30 and 45 kg S/ha increased seed yield of mustard over the control by 9, 16 and 23%, respectively (Table 3). These values indicate that the response of mustard to sulphur was positive in both years. However, the sulphur use efficiency decreased with increasing rate of sulphur application (Table 3). The higher yield with sulphur application may be attributed to higher yield components like siliquae/plant, and test weight that improved with the application of sulphur in this crop. Increase in seed yield with an increase in the rate of sulphur application has also been reported by Sawarkar et al. (1987), Das and Das (1994), Tripathi and Sharma (1993), Chauhan et al. (1996) and Bhagat and Soni (2000).

The interaction between irrigation and levels of sulphur indicated that without irrigation, there was no significant

Table 3. Effect of irrigation and sulphur levels on seed yield (q/ha).

Treatment	2007-2008	2008-2009
Irrigation		
No irrigation	12.8^{c}	14.2^{b}
One irrigation	18.8^{b}	20.8^{a}
Two irrigation	20.6^{a}	22.9^{a}
Levels of sulphur (kg S/ha)		
0	15.3^{d}	17.0^{d}
15	16.6^{c}	18.5^{c}
30	17.7^{b}	19.7^{b}
45	18.8^{a}	20.9^{a}

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

Table 4. Interaction effect of irrigation and sulphur levels on seed yield (q/ha).

Levels of sulphur (kg/ha)	2007-2008			2008-2009		
	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation
0	11.0^{b}	16.4^{d}	18.4^{d}	12.2^{b}	18.2^{c}	20.5^{d}
15	12.8^{a}	17.7^{c}	19.8^{c}	14.6^{a}	19.9^{b}	22.0^{c}
30	13.3^{a}	18.9^{b}	20.8^{b}	14.7^{a}	21.3^{ab}	23.1^{b}
45	13.8^{a}	20.3^{a}	22.3^{a}	15.3^{a}	22.5^{a}	24.9^{a}

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

difference between 15 and 45 kg S/ha, whereas with one or two irrigations, 45 kg S/ha gave significantly higher yield than 15 kg S/ha (Table 4).

Total biomass

The effect of irrigation and sulphur level treatments on total biomass was significant (P<5%). Application of two irrigations significantly enhanced total biomass production over no irrigation in both years of the study (Table 5). It is clear that the seed and straw yield increased with increasing levels of irrigation. Sharma (1994) and Prassad (1995) also reported an increase in total biomass of mustard with increasing irrigation frequency.

Application of 45 kg S/ha significantly enhanced total biomass of mustard than 0, 30 and 15 kg S/ha application in both years (Table 5). Enhancement in seed yield due to application of sulphur was attributed to the increase in total biomass of the crop with increasing level of sulphur. Similar results were also reported by Jat et al. (2003).

Harvest index

The effect of irrigation and sulphur level treatments on harvest index was significant (P<5%). The data revealed that application of two irrigation, been on par with one irrigation, significantly increased harvest index over the control in both years of the study (Table 6). Availability of more moisture to plants might have resulted in the production of more photosynthates which might have helped in the translocation of more photosynthates to seeds and increased harvest index. These results were in conformity with those of Jadhav (1988). Application of 30 kg S/ha been on par with 15 kg S/ha significantly enhanced harvest index of mustard. Application of 15 kg S/ha also remained on par with no sulphur in both years of the experimentation (Table 6). The higher harvest index with sulpur application may be due to higher increase in seed yield. These results were in conformity with those of Ali et al. (1996).

Seasonal consumptive water use

Seasonal consumptive use of water by the crop increased progressively and appreciably with increase in number of irrigations (Table 7). This was expected because irrigation increased the available water in the soil profile and this facilitated more loss of water through evapotranspiration as compared to no irrigation. The crop

Table 5. Effect of irrigation and sulphur levels on total biomass (q/ha).

Treatment	2007-2008	2008-2009
Irrigation		
No irrigation	54.6[c]	60.5[c]
One irrigation	70.8[b]	78.5[b]
Two irrigation	78.0[a]	86.7[a]
Levels of sulphur (kg S/ha)		
0	62.9[d]	69.7[d]
15	65.8[c]	72.9[c]
30	68.0[b]	75.6[b]
45	72.0[a]	79.9[a]

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

Table 6. Effect of irrigation and sulphur levels on harvest index (%).

Treatment	2007-2008	2008-2009
Irrigation		
No irrigation	23.4[b]	23.5[b]
One irrigation	26.3[a]	26.4[a]
Two irrigation	26.4[a]	26.5[a]
Levels of sulphur (kg s/ha)		
0	24.3[b]	24.3[b]
15	25.2[ab]	25.4[ab]
30	26.0[a]	26.1[a]
45	26.1[a]	26.1[a]

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

Table 7. Effect of irrigation and sulphur levels on moisture use.

Treatment	Seasonal consumptive water use (mm)			Water use efficiency (kg seed/mm ha)		
	2007-2008	2008-2009	Mean	2007-2008	2008-2009	Mean
Irrigation						
No irrigation	166.7[c]	177.2[c]	171.8[c]	7.7[b]	8.0[b]	7.9[b]
One irrigation	204.4[b]	216.7[b]	210.5[b]	9.1[a]	9.6[a]	9.4[a]
Two irrigation	239.9[a]	245.3[a]	242.3[a]	8.8[a]	9.3[a]	9.0[a]
Levels of sulphur (kg S/ha)						
0	193.2[d]	204.2[d]	198.7[d]	7.9[b]	8.3[b]	8.1[b]
15	202.5[c]	211.3[c]	206.9[c]	8.2[b]	8.8[b]	8.5[b]
30	206.2[b]	216.7[b]	211.5[b]	8.6[ab]	9.1[ab]	8.9[ab]
45	212.1[a]	220.2[a]	216.2[a]	9.0[a]	9.5[a]	9.4[a]

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

consumptively used slightly more amount of water in 2007 to 2008 compared to 2008 to 2009 season probably due to higher rainfall in the second season as compared to the first season. These results are similar to those obtained earlier by Tomar et al. (1992), Yadav et al. (1999), Mehrotra et al. (1978) and Raut et al. (2000).

Table 8. Soil moisture extraction pattern (%) between 45 and 90 DAS as affected by irrigation and sulphur levels.

Treatment	2007-2008				2008-2009			
	Soil layer (cm)				Soil layer (cm)			
	0-30	30-60	60-90	90-120	0-30	30-60	60-90	90-120
Irrigation								
No irrigation	40.4[b]	30.5[a]	21.6[a]	7.5[a]	41.3[b]	31.6[a]	21.9[a]	5.2[a]
One irrigation	42.6[ab]	31.4[a]	19.8[ab]	6.2[b]	42.9[ab]	31.9[a]	20.3[ab]	4.9[a]
Two irrigation	44.1[a]	32.5[a]	18.4[b]	6.0[b]	44.5[a]	32.2[a]	18.8[b]	4.5[a]
Levels of sulphur (kg S/ha)								
0	42.8[a]	30.8[a]	19.8[a]	6.6[a]	43.5[a]	31.2[a]	19.8[a]	5.5[a]
15	42.6[a]	30.9[a]	19.9[a]	6.6[a]	43.1[a]	31.5[a]	20.0[a]	5.4[a]
30	42.2[a]	31.4[a]	20.0[a]	6.4[a]	42.6[a]	32.1[a]	20.4[a]	4.9[a]
45	42.0[a]	31.6[a]	20.0[a]	6.4[a]	42.4[a]	32.2[a]	20.5[a]	4.9[a]

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

Seasonal consumptive use of water by the crop increased progressively with the increasing level of sulphur application up to 45 kg/ha (Table 7). One of the reasons for higher consumptive use values with sulphur application might be due to greater extraction of soil moisture by the plant as a result of better growth and development. Similar results were also reported by Raut et al. (2000).

Water use efficiency

Water use efficiency of the crop increased with the application of one irrigation over no irrigation and two irrigations in both years (Table 7). This might be because of more rational use of moisture by crops grown with this treatment. Similar results were found by Tomar et al. (1992), Yadava et al. (1999) and Mehrotra et al. (1978).

There was increase in water use efficiency with increasing sulphur level up to 45 kg S/ha in both years (Table 7). The higher water use efficiency obtained with sulphur application was due to higher seed yield obtained. Similar results were found by Raut et al. (2000).

Soil moisture extraction pattern

Data on soil moisture extraction pattern by mustard from different layers of soil on various treatments at different stages (45, 90 DAS and at harvest) are presented in Tables 8, 9, and 10.

In general, data of both years indicated that the extraction of soil moisture from the top layer of the soil (0 to 30 cm) was the highest which was followed by 30 to 60 cm layer; it declined in lower layers (60 to 120 cm) indicating thereby active root zone of the crop as 0 to 60 cm from the soil moisture extraction point of view.

Prassad (1995) data clearly shows that application of one irrigation enhanced more moisture extraction from 0 to 30 cm and 0 to 60 cm layer compared to the control and the highest application of two irrigations also resulted in the highest percentage of moisture extraction from these two layers as compared to one irrigation during all the phases of crop growth. The trend is almost similar in both years. The results are in agreement with those obtained previously by Khan and Agarwal (1985).

Although application of sulphur had little effect on moisture extraction pattern but in general application of sulphur helped in more moisture extraction from deeper layer compared to no sulphur application during all the growth stages. The trend was almost similar in both years. Similar results were obtained by Reddy et al. (1987) and Parihar and Tripathi (1989).

Economics

Data on economic evaluation of irrigation and levels and sources of sulphur are presented in Table 11.

A perusal of the data presented in Table 10 revealed that application of two irrigation to mustard fetched higher net return (Rs 25362) and B: C ratio (2.06) over one irrigation (net return of Rs 22084 and B: C ratio of 1.83), which in turn, gave higher net return and B: C ratio than no irrigation (net return of Rs 11681 and B: C ratio of 099). Similar results were obtained by Chauhan et al. (2002) and Sharma (1994).

Mustard that received 45 kg S/ha fetched the highest net return (Rs 21321) and B:C ratio (1.72) followed by 30 kg S/ha (net return of Rs 19718 and B:C ratio of 1.63)

Table 9. Soil moisture extraction pattern (%) between 45 and 90 DAS as affected by irrigation and sulphur levels.

Treatment	2007-2008				2008-2009			
	Soil layer (cm)				Soil layer (cm)			
	0-30	30-60	60-90	90-120	0-30	30-60	60-90	90-120
Irrigation								
No irrigation	38.9[a]	32.5[a]	23.5[a]	5.1[a]	39.1[a]	32.8[a]	23.7[a]	4.4[a]
One irrigation	39.4[a]	32.7[a]	23.8[a]	4.1[ab]	39.6[a]	33.0[a]	24.0[a]	3.4[ab]
Two irrigation	39.8[a]	33.0[a]	23.9[a]	3.3[b]	40.0[a]	33.4[a]	24.3[a]	2.3[b]
Levels of sulphur (kg S/ha)								
0	39.6[a]	32.7[a]	23.6[a]	4.1[a]	39.6[a]	32.9[a]	23.9[a]	3.6[ab]
15	39.6[a]	32.9[a]	23.7[a]	3.8[a]	39.8[a]	33.2[a]	24.0[a]	3.0[ab]
30	39.5[a]	33.2[a]	23.7[a]	3.6[a]	40.0[a]	33.5[a]	24.1[a]	2.4[b]
45	38.9[a]	33.2[a]	23.8[a]	4.1[a]	38.9[a]	32.8[a]	24.2[a]	4.1[a]

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

Table 10. Soil moisture extraction pattern (%) between 45 and 90 DAS as affected by irrigation and sulphur levels.

Treatment	2007-2008				2008-2009			
	Soil layer (cm)				Soil layer (cm)			
	0-30	30-60	60-90	90-120	0-30	30-60	60-90	90-120
Irrigation								
No irrigation	36.3[a]	33.2[a]	25.1[a]	5.4[a]	37.0[a]	33.5[a]	25.6[a]	3.9[a]
One irrigation	37.0[a]	33.5[a]	25.3[a]	4.2[ab]	37.4[a]	33.9[a]	25.7[a]	3.0[ab]
Two irrigation	37.3[a]	33.6[a]	25.4[a]	3.7[b]	37.9[a]	33.9[a]	25.7[a]	2.5[b]
Levels of sulphur (kg S/ha)								
0	36.8[a]	33.3[a]	25.2[a]	4.7[a]	37.0[a]	33.4[a]	25.6[a]	4.0[a]
15	36.9[a]	33.4[a]	25.2[a]	4.5[a]	37.4[a]	33.7[a]	25.9[a]	3.0[ab]
30	36.9[a]	33.5[a]	25.3[a]	4.3[a]	37.5[a]	33.9[a]	25.4[a]	3.2[ab]
45	37.0[a]	33.4[a]	25.5[a]	4.1[a]	37.5[a]	34.0[a]	25.6[a]	2.9[b]

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

Table 11. Effect of irrigation levels, sulphur levels on gross and net return and benefit-cost ratio of mustard (mean of two years).

Treatment	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio (Rs/Re invested)
Irrigation			
No irrigation	21726	11681	0.99
One irrigation	34127	22084	1.83
Two irrigation	37655	25362	2.06
Levels of sulphur (kg S/ha)			
0	27398	16003	1.36
15	29806	18087	1.54
30	31986	19718	1.63
45	32688	21321	1.72

and 15 kg S/ha (Net return of Rs 18087 and B:C ratio of 1.54). The control gave least (Net return of Rs 16003 and B:C ratio of 1.36). Similar results were obtained by Singh at al. (1999), Chauhan et al. (2002) and Sharma (1994).

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