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Effect of different sulphur levels and irrigation scheduling on growth, yield attributes, yield and water productivity of Indian Mustard [(*Brassica juncea* (L.)]

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Abstract

A field experiment was conducted during rabi *2021-22 at Research Farm, Department of Soil Science, CCS Haryana Agricultural University, Hisar, Haryana. The experiment was laid out in split plot design with three replications comprising of three levels of irrigation in main plots viz. Control (I_1), one irrigation (I_2) and two irrigation (I_3) with five sulphur dose in sub plots viz. Control (S_1) 20 kg S ha^{-1} (S_2), 30 kg S ha^{-1} (S_3), 40 kg S ha^{-1} (S_4) and 50 kg S ha^{-1} (S_5). Results revealed that among the different irrigation levels, application of two irrigation (one at flowering and second irrigation at pod formation) recorded significantly higher plant height (210.60 cm), number of primary branches plant^{-1} (6.53), number of secondary branches plant^{-1} (15.08) and yield attributes like number of siliqua plant^{-1} (694.76), pod length (5.67 cm), number of seed siliqua^{-1} (13.71) and grain yield (25.87 kg ha^{-1}) of mustard. In case of Sulphur levels, the application of 40 kg S ha^{-1} was found to have significantly superior plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1} and yield attributes like number of siliqua plant^{-1}, pod length, number of seed siliqua^{-1} and grain yield of mustard which was observed to be statistically at par with 50 kg S ha^{-1}. Moreover, highest irrigation water productivity (4.08 kg m$^{3)}$ as well as total water productivity (1.12 kg m$^{3)}$ of mustard crop was recorded with the application of single irrigation applied at flowering stage followed by two irrigations* i.e. *one at flowering and other at pod formation stage. Whereas, with the increase in the level of applied sulphur, irrigation water productivity and total water productivity of mustard crop was observed to be increased at each level. Highest irrigation water productivity of 4.24 kg m^{-3} and total water productivity with a value of 1.15 kg m^{-3} of mustard was obtained with the application of 50 kg S ha^{-1}.*

Keywords: Irrigation level, sulphur dose, water productivity and mustard yield.

Introduction

Indian mustard (*Brassica juncea* L.) is one of the most important oilseed crop of *rabi* season contributing approximately 16.65% of the annual edible oil (Anonymous, 2022). By 2050, to fulfill the nutritional requirement of the projected 1685 million population of India we need to produce 17.84 million tonnes of edible oil. It seems difficult to reach the estimated target with present status of resource and technology management in Indian agriculture (Hedge, 2012). In India, the area coverage of rapeseed and mustard is 6.70 million hectares after soybean and it holds second position in production

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with 10.21 million tonne after soybean (Anonymous, 2022). In Haryana, mustard covers an acreage of 0.65 million hectares with 1.31 million tone of production and productivity of 2028 kg ha^{-1} (Anonymous, 2022). Per hectare productivity of the rapeseed-mustard is quite low in the country *i.e.* up to 1524 kg ha^{-1} (Anonymous, 2022). Low productivity of mustard may be due to its cultivation in inherently low fertile soil, with very less or no use of additional inputs likes irrigation, applied nutrients etc. (Ray *et al.*, 2015). Irrigation is one of the important component in crop production which improves the crop growth and productivity of rapeseed and mustard. Proper nutrient management along with application of irrigation is considered to be the most important factor to increase mustard yield. Application of sulphur along with NPK is very imperative for improving quality and yield of Indian mustard as sulphur is a constituent of amino acids, vitamins and sulpho-lipids (Morris, 2007; Singh & Pal, 2011). Due to its suitability and versatility to exploit residual soil moisture it has been proved as a potential winter crop. Proper irrigation scheduling coupled with best nutrient management practice will not only decrease the gap between requirement and production of mustard in Haryana and India but also improves quality of the crop. Indian mustard is more responsive towards sulphur as compared to other oilseed crops. Keeping the above facts in view, the present investigation was undertaken to study the effect of irrigation levels and sulphur dose on growth, yield attributes, yield and water productivity of Indian mustard [(*Brassica juncea* (L.)] under irrigated conditions during *rabi* 2021-22.

Materials and Methods

The field experiment was conducted at Research Farm, Department of Soil Science, CCS Haryana Agricultural University, Hisar, Haryana (29°10' N, 75°46' E) during *rabi* 2021-22.Hisar is situated in the western part of Haryana at a MSL of 215 m and close to the border of Rajasthan having semi-arid climate. The soil texture of the experimental field was sandy loam to loam in lower depths in the profile, alkaline in reaction (pH 7.86), low organic carbon content (0.44) and available N (135), medium available P (13.18) and high in available K (312.3).The average rainfall in the area fluctuates between 350 to 450 mm with considerable variation in total rainfall and its distribution. Approximately 80-90 per cent of the total rainfall is received from July to September from the southwest monsoon and the rest is received in the form of cyclonic showers during the winter and spring seasons. Mean relative humidity remains nearly constant at about 80-90 per cent from July to end of March and starts decreasing to about 40 to 50 per cent by the end of April and rises again to approximately 80 per cent from May to July.

During crop season of 2021-22, the rainfall received was 1.2, 64, 5.8 and 0.0 mm in the month of December, January, February and March, respectively. The average weekly maximum and minimum temperatures, morning and evening relative humidity, wind speed, sun shine hours, PAN evaporation and rainfall recorded at the Meteorological laboratory, situated at the Research Farm for *rabi* 2021-22 are depicted in Fig. 1.

The mean weekly maximum and minimum temperature ranges were 34.9–14.2°C and 16.4–4.4°C, respectively recorded during the crop season. Mean morning relative humidity was between 99.0 and 86.5 per cent, while evening relative humidity was between 81.1 and 29.1 per cent. During the crop season weekly mean wind velocity range was 1.0- 6.1 km hr-1, with the range nearly rising in magnitude as the crop season progressed. The brightest week during the crop season was the 12th standard week, with 7.6 sunshine hours per day, and the least bright week was the 3rd week, with 0.8 hours per day. The highest evaporative demand was 3.7 mm per day during the 12th standard week, while the lowest open pan evaporation was recorded during the 3rdstandard week with 0.7 mm per day. Total rainfall of 9.8 mm was recorded during crop season. Weekly meteorological data from the Department of Agricultural Meteorology at CCS Haryana Agricultural University in Hisar throughout the experimental crop season (*Rabi* 2021-22) is provided in Table 1 and Figure 1. The experiment was laid out in split plot design replicated three times consisting three treatments of irrigation in main plot viz. Control (I_1), one irrigation (I_2) and two irrigation

(I_3) and five sulphur levels in sub plot viz. Control (S_1) 20 kg S kg ha^{-1} (S_2), 30 kg S kg ha^{-1} (S_3), 40 kg Skg ha^{-1} (S_4) and 50 kg S kg ha^{-1} (S_5). Indian mustard variety RH 725 was sown @ 4 kg seed ha^{-1} on 20th October, 2021 with plant geometry of 30×15 cm apart. Optimum plant population maintained by thinning operation and planting gaps were filled by re-sowing of seeds. Two weeding and hoeing operation was done in the crop to remove the weeds as well as to provide aeration in the plant rhizosphere for proper root development. The observations were recorded on the different growth parameters viz. plant height (cm), number of primary and secondary branches plant-1 at maturity, yield attributes, and seed yield. The experimental crop was harvested in the month of March 16th. The produce from net plots were harvested in one lot and tied in bundles and allowed to complete sun drying. After that the complete dried material was passes through threshing operation. After threshing and winnowing the clean seeds from each plot were weighed and the weight was recorded as seed yield in kg plot^{-1} and then converted in kg ha^{-1}.

To determine the soil profile's moisture content, we employed the gravimetric method. Soil samples were collected on a plot-by-plot basis at specific depth intervals: 0 to 15 cm, 15-30 cm, 30-45 cm, 45-60 cm, and 60-90 cm soil layers. These samples were taken at various stages, including at sowing, before and after each irrigation and at the time of harvest. A screw auger was used to extract these soil samples, and their fresh weight (W_1) was recorded. Subsequently, the soil samples were subjected to oven drying at 105°C for a duration of 24 hours, resulting in the determination of their dry

Table 1: Weekly meteorological data during the crop season (November, 2021 to May, 2022)

Week No.	Temperature (°C) Max.	Min.	Relative Humidity M	E	Av. Wind Speed (Km/h)	Bright Sun Shine Hours	PAN Evaporation (mm)	Rainfall (mm)
45	28.8	11.3	91.8	35.4	1	4	1.6	0
46	26.9	8.2	90.8	32	1.1	5.8	1.9	0
47	26.9	8.2	90.1	29.7	2	7	1.6	0
48	23.3	9.2	96.4	54.1	1.7	4	1.4	0
49	24.2	7.9	97.7	47.8	2.1	6.3	1.4	0
50	20.2	5	95.7	47.1	2	4.9	1.2	0
51	20.5	4.4	91.8	42.8	2.6	6.3	1.2	0.0
52	19.6	5.5	94.6	56.1	2.3	4.1	1.3	0.2
1	18.7	10.2	99.3	67.6	4.8	3.1	1.0	5.7
2	15.2	6.8	95.4	77.4	3.2	1.5	1.1	0.0
3	14.2	7.1	95.9	81.1	3.5	0.8	0.7	0.4
4	16.0	5.9	99.2	61.5	3.7	3.7	1.9	3.1
5	20.2	6.6	97.4	64.9	4.5	5.2	1.1	0.0
6	21.7	7.8	95.1	45.6	3.3	7.3	1.5	0.8
7	25.2	6.9	97.6	48.3	2.2	8.4	2.2	0.0
8	25.0	10.2	87.1	48.1	6.1	7.6	2.7	0.0
9	24.3	8.7	94.3	46.7	4.5	8.2	2.5	0.0
10	27.8	10.8	92.5	42.0	2.9	7.4	3.4	0.0
11	33.5	16.3	88.7	40.3	3.6	7.9	3.1	0.0
12	34.9	16.2	86.5	29.1	3.7	7.6	3.7	0.0
13	37.9	15.6	72.3	16.8	3.4	8.4	5.6	0.0
14	40.0	15.5	75.1	29.3	3.0	8.7	5.8	0.0
15	40.8	20.3	67.7	42.6	4.7	7.9	7.0	0.0
16	39.9	20.9	70.7	40.3	5.4	8.2	7.8	0.2
17	40.9	20.7	60.3	25.9	4.3	9.1	7.1	0.0
18	40.9	24.2	59.7	25.3	6.6	7.8	7.5	0.0

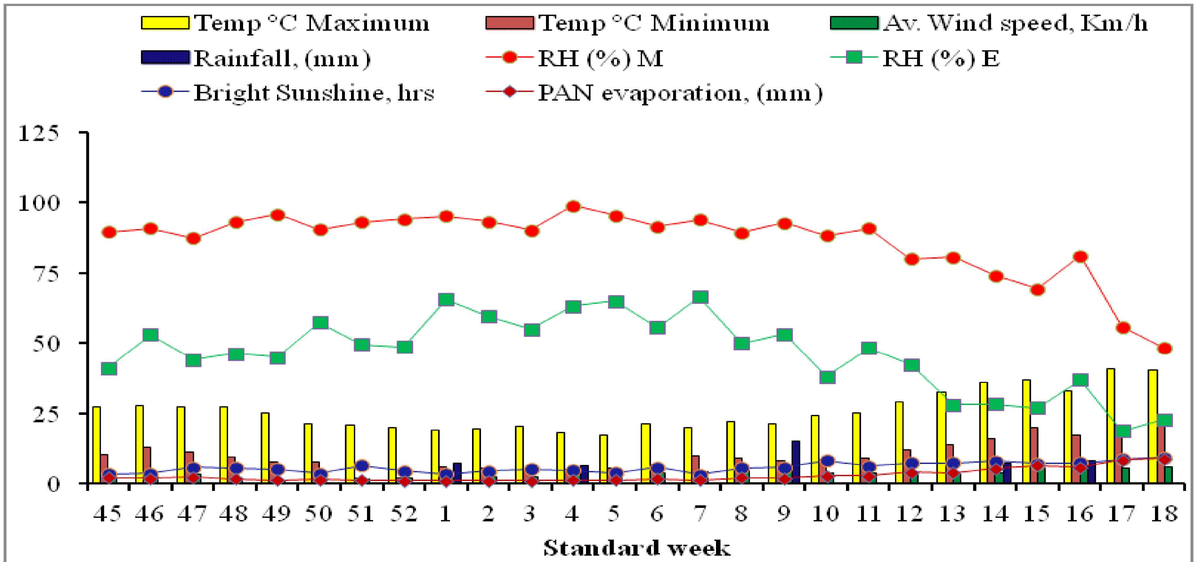

Fig. 1: Weekly weather data during *Rabi* 2021-22

weight (W_2). The moisture content of these soil samples was then calculated using the following formula:

Soil moisture content (%) = ((W1-W2) / W1) ×100

Where,

W1= Fresh Weight of Soil (g)

W2= Dry weight of Soil (g)

Water use efficiency (kg ha^{-1} mm): To calculate the water use efficiency (expressed as kg ha^{-1} mm) for a specific treatment, we divided the seed yield (kg ha^{-1}) by the total consumptive water use (mm) during the crop period corresponding to that treatment. This calculation of water use efficiency was performed using the following formula:

WUE = Seed yield (kg ha^{-1}) / Consumptive water use (mm)

Results and Discussion

Growth parameters:

Application irrigation had significant effect on plant height, primary branches per plant, number of secondary branches per plant, number of siliqua per plant, pod length (cm) and number of seed per pod of brassica (Table 2). Application of two irrigation I_3 (Flowering and pod formation) recorded significantly higher plant height, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, pod length (cm) and number of seed per podover I_1 and I_2,treatments (Table 2). This might be due to the fact that sufficient soil moisture was maintain by providing irrigation, had significant effect on the grain tissue area and higher photosynthetic assimilation, thus as a result plant growth improved with a higher accumulation of dry matter (Lal et al. 2013).

Plant height, number of primary branches, number of secondary branches per plant,number of siliqua per plant, pod length (cm) and number of seed per pod of mustard crop was increased with the increased level of sulphur. Application of sulphur at 50 kg S ha^{-1} significantly higher plant height, number of primary branches, number of secondary branches per plant number of siliqua per plant, pod length (cm) and number of seed per pod and remained statically attar with the application ion 50 kg S ha^{-1} (Table 2).

Yield and yield attributes:

Application of different irrigation levels had a significant effect on number of siliqua per plant, pod length (cm), number of seed per pod and seed yield of brassica (Table 2). Application of two irrigation I_3 (Flowering and pod formation) recorded significantly higher number of siliqua per plant, pod length (cm), number of seed per pod and seed yield of brassica over I_1 and I_2, treatments (Table 2). This might be due to the fact that sufficient soil moisture was maintained by providing irrigation, had significant effect on the grain tissue area and higher photosynthetic assimilation rate resulting in better plant growth with a higher accumulation of dry matter (Lal et al. 2013). Supply of water at flowering might have resulted in lengthening of the flowering period, which increased the number of siliqua (Clark and Simpson, 1978) and consequently the seed yield. Dastane et al. (1971) also reported that higher yield and yield attributes might be due to higher photosynthesis and translocation of assimilates toward reproductive structure owing to sufficient soil moisture. During liner phase of development at time of sufficient soil moisture availability, enough assimilate might have been produced and utilized by the plant during the growth and development stage and thus excess diverted toward storage compound. But at later phase for greater assimilate demand of plant sink *i.e.* reproductive structure, more remobilisation of storage compounds to active sites as a result of increased moisture in soil might have increased the yield significantly. The highly significant positive correlation existing between seed yield and yield attributes confirmed the above findings. These findings are in agreement with the results of Panda et al. (2004).

Number of siliqua per plant, pod length (cm), number of seed per pod and seed yield of mustard crop was increased with the increase in the level of sulphur. Application of sulphur at 50 kg S ha^{-1} produced significantly higher number of siliqua per plant, pod length (cm), number of seed per pod and seed yield (Table 2) which was statistically at par with 40 kg S ha^{-1}. However, the magnitude of increase at 50 kg S ha^{-1} compared with 30 and 40 kg S ha^{-1}, respectively, was 3.60 and 1.75% in case of seed yield. The presence of adequate sulphur availability may contribute to enhanced cell division, elongation, tissue development, multiplication and synthesis of essential amino acids (cysteine, cystine, methionine). In addition, an adequate supply of sulphur may facilitate the availability of sulfolipids, Fe-S clusters, co-enzyme A, and amino acids, which collectively contribute to the development of chlorophyll. Similar results have also been reported by Kapur et al. (2010), Kumar et al. (2011) and Parmar and Parmar (2012). The increase in yield owing to S application is imminent, as the crop has higher S requirement (Aulakh et al., 1985) and the soil was deficient in available S.

Table 2: Effect of irrigation schedules and sulphur levels on growth, yield attributes and yield of mustard

Treatments	Plant height (cm) at harvest	No. of primary branches/plant	No. of secondary branches/plant	No. of siliqua/plant	Pod length (cm)	No. of seed/pod	Yield (q/ha)
Irrigation Scheduling (I)							
Control (No post-sowing irrigation)	199.01	4.86	12.25	665.84	4.81	11.41	23.47
One irrigation at flowering	203.33	5.88	13.99	687.93	5.29	12.66	24.91
Two irrigation first at flowering and second at pod formation	210.60	6.53	15.08	694.76	5.67	13.71	25.87
S.Em+	0.65	0.10	0.20	3.88	0.07	0.06	0.10
C.D. (P=0.05)	2.61	0.39	0.81	11.31	0.27	0.25	0.42
Sulphur levels (S)							
Control	188.97	4.90	12.17	563.96	4.58	11.32	23.36
NPK+20 kg S ha^{-1}	195.60	5.34	12.99	609.14	4.93	11.97	24.07
NPK+30 kg S ha^{-1}	205.11	5.82	13.91	727.71	5.27	12.77	24.99
NPK+40 kg S ha^{-1}	215.17	6.26	14.78	752.80	5.67	13.41	25.44
NPK+50 kg S ha^{-1}	216.73	6.46	15.02	760.61	5.84	13.50	25.89
S.Em+	2.30	0.12	0.27	5.01	0.09	0.22	0.19
C.D. (P=0.05)	6.75	0.35	0.79	14.60	0.27	0.64	0.57

Table 3: Effect of irrigation schedules on consumptive use of water, and water productivity of mustard

Treatments	Soil moisture depletion(cm)	Effective rainfall (cm)	Irrigation water(cm)	Total water(cm)	Grain yield (q/ ha)	Water productivity (kg m^3) Irrigation water	Totalwater
Irrigation scheduling							
Control (No post-sowing irrigation	9.90	7.04	0	16.94	23.46	0	1.38
One irrigation at flowering	9.05	7.04	6.1	22.19	24.91	4.08	1.12
Two irrigation first at flowering and second at pod formation	8.56	7.04	12.2	27.80	25.86	2.12	0.93
Sulphur levels (S)							
Control	9.20	7.04	6.1	22.34	23.35	3.82	1.05
NPK +20 kg S ha^{-1}	9.19	7.04	6.1	22.33	24.06	3.94	1.07
NPK+30 kg S ha^{-1}	9.17	7.04	6.1	22.31	24.98	4.09	1.12
NPK+ 40 kg S ha^{-1}	9.16	7.04	6.1	22.30	25.44	4.17	1.14
NPK+ 50 kg S ha^{-1}	9.15	7.04	6.1	22.29	25.88	4.24	1.15

Water productivity (WP):

The irrigation water productivity and total water productivity of mustard crop was observed to be higher with the application of one irrigation applied at flowering stage (4.08 kg m^3) as compared to two irrigations applied at flowering and pod formation (Table 3). With increase in sulphur levels, increase in irrigation water productivity and total water productivity was observed. The higher total water productivity obtained when sulphur was applied @ 50 kg S ha^{-1} in comparison to other levels of sulphur due to higher seed yield. The increase in evapo-transpiration and infiltration losses due to more water application might be owing to increasing number of irrigation resulted into higher consumptive use probably the increase in seed yield was more as compared to amount of water used for total biomass production which might have increased irrigation water productivity and total water productivity under no irrigation a as compared one or two irrigation.

Conclusion

In the present study, both irrigation and sulphur levels had an prominent effect on growth, yield attributes and yield of mustard. Among the different irrigation levels, application of two irrigations (one at flowering and second irrigation at pod formation) exhibited a significant enhancement in yield and yield attributes of mustard. In addition, application of sulphur at 50 kg S ha^{-1} produced growth, yield attributes and yield of mustard, however, significant improvement in these parameters were observed to be statistically at par with 40 kg S ha^{-1} indicating optimum level of sulphur application in promoting yield attributes and yield of mutard.

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Competing interests

Authors have declared that no competing interests exist.

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