Journal of Oilseed Brassica, 11 (2) : 103-109, July 2020

Variation in dry matter accumulation and growth indices of different mustard (*Brassica juncea* L.) hybrids as influenced by irrigation scheduling and sulphur fertilization

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(Received: 23 August 2019; Revised: 27 March 2020; Accepted: 02 May 2020)

Abstract

A field experiment was carried out to assess the variation brought out by irrigation scheduling and sulphur fertilization on the dry matter accumulation and growth indices of mustard hybrids during 2015-16 and 2016-17. The experimentwas laid in split plot design withthree irrigation scheduling (0.4, 0.6 and 0.8 IW/CPE) and two hybrids ('NRCHB-506' and 'PAC 432') as main plot treatment and three levels of sulphur (0, 30 and 60 kg S ha^{-1}) as sub-plot treatment replicated thrice. Results showed that application of irrigation at 0.8 IW/CPE, sulphur fertilization and cultivation of mustard hybrid 'PAC 432' resulted in increment in dry matter accumulation at different growth stages as well as harvest. Further, these treatments were also adjudged superior in terms of growth indices viz., leaf area index (LAI), average growth rate (AGR), crop growth rate (CGR), leaf area duration (LAD) and biomass duration (BMD) in comparison to other treatments during the course of the trial. In relation to interactional effect of individual treatment variables, mustard hybrid 'PAC 432' irrigated at 0.8 IW/CPE and fertilized with 60 kg S ha^{-1} produced maximum dry matter biomass while 'NRCHB-506' irrigated at 0.4 IW/CPE and no sulphur application ensued least dry matter production.

Key words: *Hybrid, irrigation scheduling, growth indices, mustard, sulphur*

Introduction

Globally, India holds prominent position among the vegetable oil economies by contributing sizeable portion in oilseed output and vegetable oil production. Among the oilseeds, rapeseed-mustard is the third largest oilseed after groundnut and soybean wherein India occupies one-fifth of global area under mustard contributing over one-tenth of production (Jat *et al*., 2019). Indian mustard's area, production and productivity is 6.3 million hectares, 8.0 million tonnesand1324 kg ha^{-1} respectively, whereas in Uttar Pradesh, mustard gives production of 9.45 lakh tonnes out of cultivation on an area of about 6.79 lakh hectares (DOAC, 2017). Though India occupies premier place in terms of acreage as well as production but the difference between the average global yield (20.47 q ha^{-1}) and domestic productivity (13.24 q ha^{-1}) still remains wide which can be narrowed with adoption of improved varieties or hybrids having higher genetic potential (Rana *et al*., 2019). In addition, mustard is traditionally grown under rainfed condition on residual soil moisture remained after monsoon season. However, changing climate along with global warming is bringing unprecedented changes in rainfall amount, distribution and pattern increasing its uncertainty which further aggravates moisture deficit during crop growth period of both *kharif* and *rabi* season. This situation calls for more efficient water management in mustard through scientific irrigation scheduling based on IW/CPE ratio which can provide momentum to both production and productivity of mustard under changing climate scenario for meeting the increasing demand of vegetable oil and reducing the import bill of state exchequer.

Further, optimum fertilization especiallywith sulphur determines yield, quality and resistance of mustard due to multi-functional behaviour of sulphur in synthesis of chlorophyll, seed protein, enzymatic complexes and vitamin components which is sine qua non for superior nutritional and market quality oilseed production. A yield enhancement of about 50 per cent can be received due to sulphur application under irrigated condition (Aulakh, 2003). However, indiscriminate use of high analysis fertilizer with low or no sulphur has madedeficiency of sulphur more prominent in Indian soils. So, in order to maintain and enhance the current production levels and quality, application of additional sulphur become necessaryfor oilseed crops in general and mustard in particular. Though literature document the beneficial effect of different inputs on the productivityof crops, reports ontheir influence on theperformance of hybrid mustard is limited especially with respect to eastern Uttar Pradesh. This field experiment was therefore, undertaken to assess the responseof mustard to irrigation scheduling, varieties and sulphur fertilization in theeastern region of Uttar Pradesh of India.

Materials and Methods

A field trial was conducted at the Agricultural Research Farm (25^{0}202 N, 83^{0}032 E; 76.216 m) of Institute of Agricultural Sciences, Banaras Hindu University, Varanasiduring the *Rabi* season of 2015-16 and 2016-17. On an average, the experimental site has an annual rainfall of 1100 mm and potential evapo-transpiration (PET) of 1525 mm creating an annual moisture deficit of about 425 mm. The maximum and minimum temperature of the site ranged between 20-42 ^{0}C and 9-28 ^{0}C, respectively. The climate of the experimental site during the course of trial isrepresented in figure 1 and 2. The initial analysis of the experimental soil revealed about sandy clay loam texture with pH 7.80, 7.72, organic carbon 0.43%, 0.44%, available N 205.28, 209.15 kg ha^{-1}, available phosphorus 19.11, 21.42 kg ha^{-1}, available potassium 235.22, 237.59 kg ha^{-1} and available sulphur 18.87, 20.73 mg kg^{-1} soil during first and second year of trial, respectively. The experiment consisted of eighteen treatment combinations arranged in a split plot design with 3 replications. The main plots consisted of 6 treatment combinations of 3 irrigation scheduling based on IW/CPE ratio (Irrigation water/ cumulative pan evaporation) namely irrigation at 0.4 IW/ CPE (I_1), irrigation at 0.6 IW/CPE (I_2) and irrigation at 0.8 IW/CPE (I_3) and two hybrids namely 'NRCHB-506' (V_1) and 'PAC 432' (V_2). The sub plots consisted of 3 treatments namely no sulphur (S_1), application of sulphur @ 30 kg ha^{-1} (S_2) and sulphur @60 kg ha^{-1} (S_3).

Field was prepared after harvest of *kharif* crop and a pre-sowing irrigation was applied uniformly to the experimental field. Afterwards, furrows were opened at a spacing of 45 cm between rows and seeds of both the varieties were sown as per treatment on 17th October in both the year (2015 and 2016) with seed rate of 5 kg ha^{-1}. Out of the recommended dose of fertilizer (RDF) for mustard hybrid (N-P_2O_5-K_2O 120-60-40 kg ha^{-1}), half of the recommended dose of N (60 kg ha^{-1}) and full dose of P (60 kg ha^{-1}) and K (40 kg ha^{-1})were applied as basal with source as urea (46% N), diammonium phosphate (18% N and 46% P_2O_5) and murate of potash (60% K_2O), respectively. Application of sulphur was carried out as per treatment withgypsum (18.5 % S) as source. After 35-40 days of sowing, top-dressing of the remaining half dose of nitrogen was done. As a measure of weed control, pre-emergence application of Pendimethalin 30 EC @ 1litre ha^{-1} was given. A plant to plant spacing of 15cm was maintained by thinning done after 15-20 days. All the standard package of practices except irrigation scheduling were followed and kept uniform in the entire plots. Irrigation of 5 cm depth were provided as per the IW/CPE ratio which came out as one, two and three irrigation in 0.4, 0.6 and 0.8 IW/CPE, respectively.

Dry matter accumulation (g m^{-2}) and growth indices such as leaf area index (LAI), average growth rate (AGR), crop growth rate (CGR), leaf area duration (LAD) and biomass duration (BMD) were calculated and recorded as per standard procedure. Leaf area index (LAI) was measured at 30, 60 and 90 days after sowing (DAS) with the help of plant canopy/meter/analyzer model no. LP-80 Accu PAR. The total area of the leaf was measured first followed by recording land area. Leaves of five plants taken from each penultimate row as treatment wise for dry matter observation were removed for leaf area estimation which was recorded with a leaf area meter (Systronics, 211). The

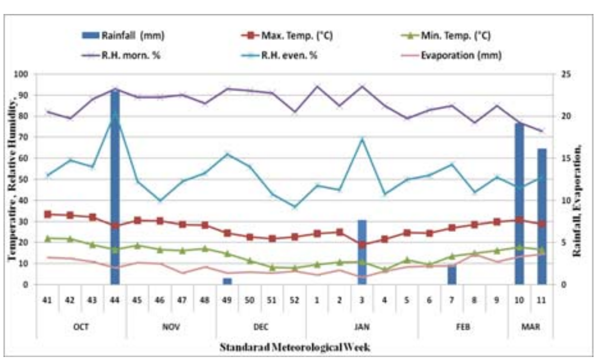

Figure 1: Standard week wise meteorological data recorded at meteorological observatory BHU., Varanasi during the period of experimentation for 2015-16

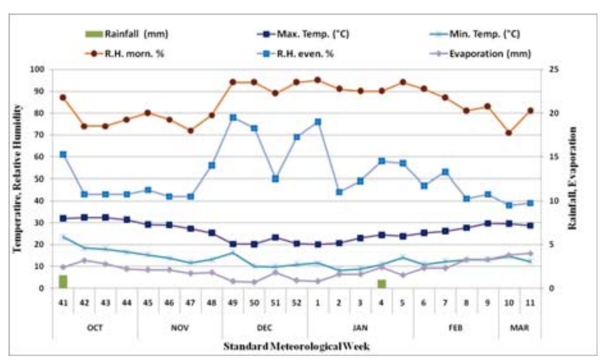

Figure 2: Standard week wise meteorological data recorded at meteorological observatory BHU, Varanasi during the period of experimentation for 2016-17

average of leaves area was multiplied with a total number of leaves. The LAI was worked out using the formula assuggested by Radford (1967).

LAI = Total leaf area plant^{-1} (cm^2)/ Land area plant^{-1} (cm^2)

Average Growth rate (AGR) measuring the rate of increase of dry matter is calculated using the formula:

AGR = $W_2 - W_1 / t_2 - t_1$ (g plant^{-1} day^{-1})

Where, W_1 and W_2 are the dry matter accumulation (g plant^{-1}) at first and second stage taken at time t_1 and t_2, respectively.

Crop Growth Rate (CGR) measuring the rate of increase of dry weight per unit land area per unit time is calculated using the formula proposed by Hunt (1978).

CGR= $Wm_2 - Wm_1 / t_2 - t_1$ (g m^{-2} day^{-1})

Where, Wm_1 and Wm_2 are the dry weights (g m^{-2}) at first and second stage taken at time t_1 and t_2, respectively.

Leaf Area Duration (LAD), an estimate of the ability of the plant to maintain the green leaves per unit area of the land over a period of time (Power *et al.*, 1967), is calculated from the formula:

LAD (days) = $\{(LAI_1 + LAI_2)/2\}*(t_2 - t_1)$

Where, LAI_1 and LAI_2 are the leaf area indices at first and second stage taken at time t_1 and t_2, respectively.

Biomass duration (BMD) measures persistence of biomass by multiplying biomass (g) and the time period (day) for which it is maintained.

BMD (g day) = $\{(W_1 + W_2)/2\}*(t_2 - t_1)$

Where, W_1 and W_2 are the dry weights (g) at first and second stage taken at time t_1 and t_2, respectively.

Recorded data was analyzed using appropriate method of 'Analysis of Variance (ANOVA)' given by Gomez and Gomez (1984).

Results and Discussion

Dry matter accumulation

The variation in dry matter accumulation (Table 1) of mustard crop as influenced by irrigation scheduling, varieties and levels of sulphur at different growth stages are reported significantly different during the course of trial. Among the irrigation scheduling treatments, highest dry matter accumulation was recorded with 0.8 IW/CPE (52.07 and 51.51 g m^{-2}at 30 DAS, 327.2 and 310.9 g m^{-2}at 60 DAS, 601.9 and 566 g m^{-2} at 90 DAS and 786.5 and 755.1 g m^{-2}at harvest) which was observed significantly superior to 0.4 IW/CPE at all stages except at 30 DAS during both the years.Further, the application of irrigation at 0.6 IW/ CPE produced significant variation in dry matter accumulation plant^{-1} in comparison to 0.4 IW/CPE at all growth stages except at 30 DAS but remained at par with 0.8 IW/CPE during both the years of trial. This result could be explained in the light of the fact that higher IW/ CPE ratio resulted in more frequent irrigation with reduced interval creating more congenial condition for plant growth in terms of optimum soil moisture, better nutrient and water uptake leading to improved cell growth, division as well as differentiation that ultimately culminates into higher dry matter production. The results are in parallel to the findings ofYadav*et al.* (2010) and Rathore *et al.* (2017).

Among the hybrids investigated, 'PAC 432' resulted in significantly better performance in comparison to

Table 1: Dry matter accumulation (g m^{-2}) of Indian mustard at different growth stages in relation to irrigation scheduling, varieties and levels of sulphur on Indian mustard

Treatment	30 DAS		60 DAS		90 DAS		Harvest	
	I	II	I	II	I	II	I	II
Irrigation Scheduling								
0.4 IW/CPE	46.74a	45.72a	271.9a	256.6a	462.9a	442.9a	578.91a	573.6a
0.6 IW/CPE	49.88a	47.85a	306.8b	287.7b	548.2b	525.1b	694.08b	685.0b
0.8 IW/CPE	52.07a	51.51a	327.2b	310.9b	601.9b	566.0b	786.5b	755.1b
Varieties								
NRCHB-506	47.37a	46.62a	278.9a	265.7a	512.3a	484.5a	625.8a	625.2a
PAC 432	51.76a	50.10a	325.1b	304.5b	563.0b	538.2b	747.1b	717.3b
Levels of sulphur (kg S ha^{-1})								
0	44.61a	44.08a	263.1a	253.3a	469.2a	443.4a	597.9a	583.6a
30	50.98b	49.39b	316.5b	293.8b	562.2b	537.0b	700.6b	685.9b
60	53.10b	51.62b	326.3b	308.2b	581.6b	553.5b	760.9b	744.3b

DAS = days after sowing; I= first year (2015-16); II= second year (2016-17).

Table 2: Growth indices (a) of Indian mustard at harvest in relation to irrigation scheduling, varieties and levels of sulphur on Indian mustard

Treatment	LAI						AGR			
	30 DAS		60 DAS		90 DAS		30-60		60-90	
	I	II	I	II	I	II	I	II	I	II
Irrigation Scheduling										
0.4 IW/CPE	0.84a	0.81a	3.41a	3.41a	2.40a	2.33a	0.52a	0.49a	0.44a	0.43a
0.6 IW/CPE	0.88a	0.83a	3.83b	3.72b	2.70b	2.58b	0.59b	0.55b	0.55b	0.55b
0.8 IW/CPE	0.93a	0.87a	4.04b	3.93b	2.88b	2.74b	0.63b	0.60b	0.63b	0.59b
Varieties										
NRCHB-506	0.83a	0.78a	3.61a	3.48a	2.56a	2.45a	0.53a	0.51a	0.54a	0.51a
PAC 432	0.94b	0.89b	3.91b	3.89b	2.77b	2.65b	0.62b	0.59b	0.55a	0.54a
Levels of sulphur (kg S ha^{-1})										
0	0.82a	0.78a	3.51a	3.38a	2.45a	2.41a	0.51a	0.49a	0.47a	0.44a
30	0.90b	0.85b	3.81b	3.75b	2.73b	2.59b	0.61b	0.57b	0.57b	0.56b
60	0.92b	0.87b	3.95b	3.92c	2.80b	2.65b	0.63b	0.59b	0.59b	0.57b

LAI= leaf area index; AGR= average growth rate (g $plant^{-1}$ day^{-1}); I= first year (2015-16); II= second year (2016-17).

'NRCHB-506' and recorded an increment of 9.26, 16.56, 9.89 and 19.38 per cent over 'NRCHB-506' at 30, 60, 90 DAS and at harvest, respectively during first year of experimentation. The corresponding figures for the second year of trial were observed as 7.46, 14.60, 11.08 and 14.73 per cent higher with 'PAC 432' over 'NRCHB-506' at 30, 60, 90 DAS and at harvest, respectively. The differential response exhibited by mustard hybrids can be attributed to genetic potential of the said varieties as also evident in the studies conducted by Archana and Singh (2011), Meena *et al.* (2013).

Dry matter accumulation at different growth stages as well as harvest of mustard showed successive increment with increase in level of sulphur in both the years of the study. Application of 60 kg S ha^{-1} recorded significantly higher dry matter accumulation over no sulphur but remained at par to sulphur applied at the rate of 30 kg ha^{-1}. Improved nutritional condition with sulphur fertilization could have attributed to this response as sulphur is a constituent of chlorophyll, proteins and many biologically active compounds which might have accelerated photosynthetic rate and growth. The results are also substantiated by the findings of Kumar *et al.* (2009), Singh *et al.* (2017) and Nath *et al.* (2018).

Growth indices

The effect of irrigation scheduling and sulphur application on growth indices (Table 2 and 3)of mustard hybrids was noted significant during the period of experimentation. Irrigation scheduling had significant effect on leaf area index of mustard crop at all stages except at 30 DAS in both the years of investigation. Crop irrigated at 0.8 and 0.6 IW/CPE were found significantly superior to that of 0.4 IW/CPE but were statistically at par to each other at all stages. The highest LAI were recorded with 0.8 IW/CPE while lowest values were observed with 0.4 IW/CPE. Similarly, growth indices namely, AGR, CGR, LAD and BMD were also observed significantly superior with 0.6 and 0.8 IW/CPE in comparison to 0.4 IW/CPE. Lower number of irrigation and wider interval between successive irrigations associated with 0.4 IW/CPE might have created soil moisture stress leading to reduced cell growth, stomatal conductance and decelerated photosynthetic activity and ultimately, lower crop growth and development. These findings are also supported by Rawal *et al.* (2017) who also reported similar findings with relation to AGR, CGR and BMD in maize.

While studying varietal response in terms of leaf area index, 'PAC 432' exhibited significantly higher LAI over 'NRCHB-506' to the extent of 13.25,8.31 and 8.20 per cent at 30, 60 and 90 DAS, respectively in the first year of field trial. While, increment in LAI of 'PAC 432' over 'NRCHB-506' in second year was recorded as 14.10, 11.78 and 8.16 per cent at 30, 60 and 90 DAS, respectively. Similarly, marked variation was noted among the hybrids in relation to AGR, CGR, LAD and BMD of mustard crop throughout the growth stages except for AGR and CGR during 60-90 DAS. Differential response of hybrids could be explained in the light of the genetic potential of cultivars as manifested in varied plant growth in terms of plant dry matter and photosynthetic surface leading to different growth indices. These results are also supported by the findings of Rashid *et al.* (2010), Datta *et al.* (2011) and Panda (2014).

Table 3: Growth indices (a) of Indian mustard at different growth stages in relation to irrigation scheduling, varieties and levels of sulphur on Indian mustard

Treatment	CGR (g m^{-2} day^{-1})				LAD (days)				BMD (g day)			
	30-60		60-90		30-60		60-90		30-60		60-90	
	I	II	I	II	I	II	I	II	I	II	I	II
Irrigation Scheduling												
0.4 IW/CPE	7.50a	7.03a	6.36a	6.20a	63.8a	63.2a	87.2a	86.1a	332.2a	316.3a	766.3a	732.5a
0.6 IW/CPE	8.56b	7.99b	8.04b	7.91b	70.6b	68.3b	98.0b	94.5b	371.8b	350.5b	890.6b	849.0b
0.8 IW/CPE	9.17b	8.64b	9.15b	8.50b	74.4b	71.9b	103.7b	100.0b	393.6b	377.8b	964.2c	914.6b
Varieties												
NRCHB-506	7.72a	7.30a	7.78a	7.29a	66.6a	63.9a	92.5a	88.9a	341.2a	326.6a	826.4a	785.2a
PAC 432	9.11b	8.48b	7.93a	7.78a	72.7b	71.7b	100.1b	98.1b	390.6b	369.8b	921.0b	878.8b
Levels of sulphur (kg S ha^{-1})												
0	7.28a	6.97a	6.86a	6.33a	65.1a	62.5a	89.5a	86.8a	321.7a	311.4a	764.5a	729.5a
30	8.85b	8.14b	8.19b	8.11b	70.6b	69.0b	98.2b	95.1b	382.3b	358.4b	913.9b	867.8b
60	9.11b	8.55b	8.51b	8.18b	73.2b	72.0b	101.4b	98.6b	393.6b	374.7b	942.7b	898.7c

CGR= crop growth rate; LAD= leaf area duration; BMD= biomass duration; I= first year (2015-16); II= second year (2016-17).

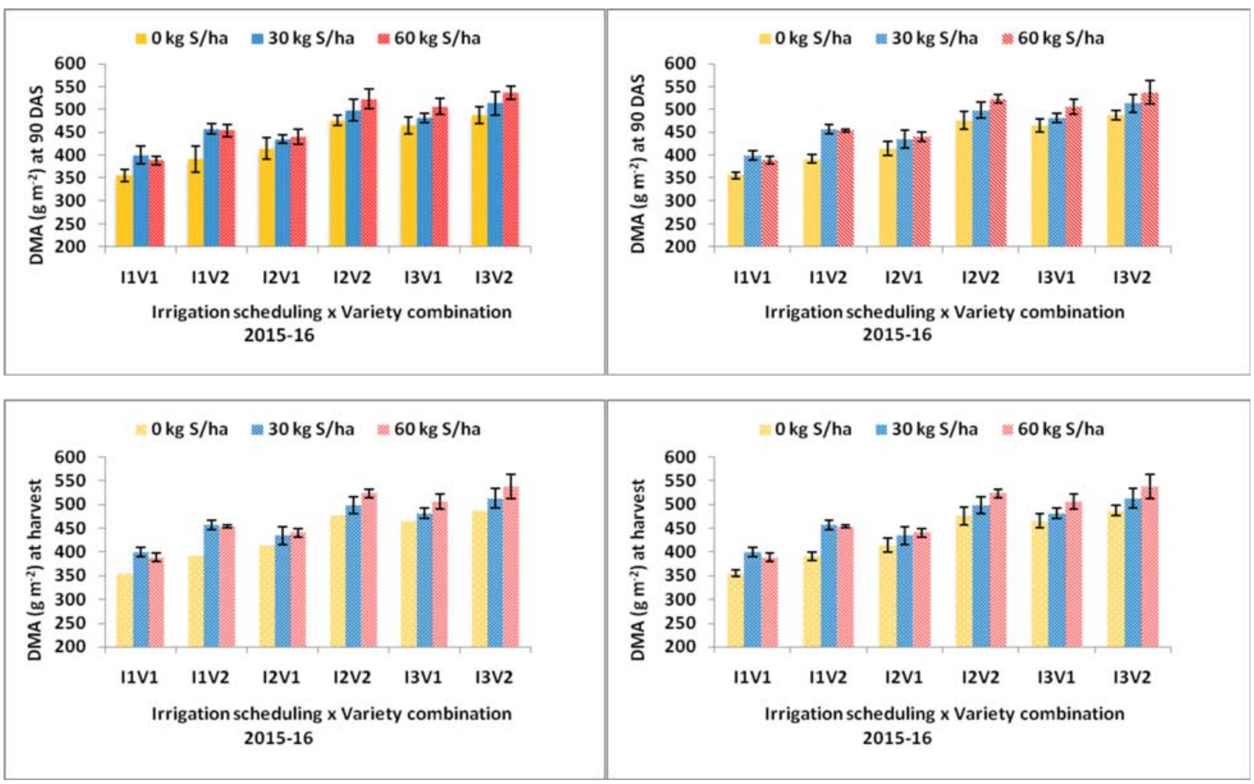

Figure 3: Interactional effect of irrigation scheduling, hybrids and sulphur levels on DMA (dry matter accumulation) at 90 DAS and harvest during period of experimentation (I1, I2 and I3 are irrigation at 0.4, 0.6 and 0.8 IW/CPE respectively; V1 and V2 are 'NRCHB-506' and 'PAC 432', respectively).

Significant effect of sulphur fertilization was noted in leaf area index of mustard crop and increase in levels of sulphur registered successive increase in LAI at all stages of crop growth in both the years. Among various sulphur levels, application of 60 kg S ha^{-1} recorded maximum LAI followed by LAI with 30 kg S ha^{-1}in both the years, respectively. However, increase in LAI with increase in sulphur levels was found significant only up to 30 kg S ha^{-1} at all stages during experimental period. Similar effect was also exhibited for AGR, CGR, LAD and BMD of mustard crop. Reduction in soil pH with sulphur application increases nutrient availability such as N, P, K, Zn, Fe and S which ultimately accelerates plant growth and development as also visible in form of higher dry matter accumulation, leaf area and improved growth indices. The findings are in parallel with the results reported by Ray *et al.* (2014), Negi *et al.* (2017) and Yadav *et al.* (2017).

Interactional effect

Interactional effect (Fig.3) of irrigation scheduling, varieties and levels of sulphur on dry matter accumulation was found to be significant at 90 DAS and harvest. Perusal of the results revealed that mustard hybrid 'NRCHB-506' with irrigation at 0.8 IW/CPE and fertilized with 60 kg S ha^{-1}recorded significantly the highest dry matter accumulation at 90 DAS ascompared to other treatment combinations during 2015-16. While, mustard hybrid 'PAC 432' irrigated with 0.8 IW/CPE reported highest dry matter accumulation at 90 DAS during second year of trial and at harvest during both the years. The lowest dry matter accumulation was observed with 'NRCHB-506' under irrigation at 0.4IW/CPE with no sulphur application during both the years. Cumulative effect of higher frequency of irrigation associated with high IW/CPE ratio, improved variety and better nutritional status of soil as well as plant might have resulted in said performance of the treatment combinations as also evident in the studies conducted by Yadav *et al.* (2010) and Verma *et al.* (2018).

Conclusion

On the basis of two-year experimentation, it was revealed that irrigation at 0.8 IW/CPE to mustard produced maximum dry matter accumulation as well as improved growth indices in comparison to 0.6 and 0.4 IW/CPE. Among the treatment variables tested, hybrid 'PAC 432' and application of 60 and 30 kg S ha^{-1} was significantly superior to 'NRCHB-506' and no sulphur application, respectively in relation to studied parameters. Mustard hybrid 'PAC 432' coupled with 0.8 or 0.6 IW/CPE and 30 or 60 kg S ha^{-1} performed better in comparison to rest of the treatment combinations with respect to dry matter production during course of the trial. Thus, it is concluded that Indian mustard 'PAC 432' may be irrigated at 0.6 and 0.8 IW/CPE and fertilized with 30 and 60 kg S ha^{-1}for optimum growth and development.

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