



Productivity and profitability of mustard (*Brassica juncea* L.) as influenced by plant growth regulators and irrigation levels

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Abstract

The field study was carried out during *rabi* 2020-21 to assess the effect of plant growth regulators and irrigation levels on seed yield and economic feasibility of Indian mustard. There were three irrigation levels in main plots *viz.*, no irrigation, one irrigation at 40 days after sowing (DAS) and two irrigations (at 40 and 75 DAS) with six treatments *viz.*, control, naphthalene acetic acid (NAA) @ 100 ppm, gibberellic acid @ 50 ppm, salicylic acid @ 100 ppm, thiourea @ 0.1% and indole acetic acid @ 50 ppm at 30 and 60 DAS were allotted to sub-plots. Results revealed that maximum growth, number of branches/plant and plant dry weights were found under the application of two irrigations with salicylic acid. Further, yield and its attributes such as number of siliquae/plant, siliquae length, number of seeds/siliquae, seed and stover yield were recorded higher in salicylic acid with two irrigations. The maximum B-C ratio (2.47) was calculated in two irrigations with application of salicylic acid (2.36). Thus, it can be concluded that application of two irrigations with the use of salicylic acid could be beneficial for getting higher yield of Indian mustard under semi-arid region of Rajasthan.

Keywords: Indian mustard, irrigation levels, plant growth regulators, yield attributes and yield

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] mostly grown in rainfed ecologies using conserved monsoonal rainwater supported by a few wintry showers. India is the fourth largest vegetable oil economy in the world next to USA, China and Brazil. Oilseeds are the second largest contributor in Indian agricultural economy after the cereals. Being second largest grower (21.1%) after Canada, and third largest producer (12.6%) after Canada and China, India plays a key role in global rapeseed-mustard industry (FAOSTAT, 2022). Effective irrigation water management in rapeseed-mustard has an enormous impact on seed and oil products and also on response to other applied inputs (Rathore *et al.*, 2019). Besides efficient irrigation water management, improved rainwater and soil moisture conservation help in enhancing crop growth and yield as well. The successful cultivation of the crops in semi-arid areas during *Rabi* (winter season) is mainly dependent upon the conserved soil moisture of previous *Kharif* (rainy season) crop. Yield of Indian mustard is greatly influenced by irrigation and better results both in terms of biometric components and seed yield can be achieved by the application of optimum irrigation (Choudhary *et al.*, 2021). Due to scarcity of winter rainfall mustard shows better response to irrigation. This crop is more sensitive to water fluctuation and more or less at critical growth stages, which adversely influence the yield (Choudhary *et al.*, 2023; Langadi *et al.*, 2021). The irrigation at critical stages increases the yield of the Indian mustard because of more

availability of nutrients and more efficient metabolic activities of the plant. Increase in the amount of water by increasing the number of irrigations augmented the leaf water potential, stomatal conductance, light absorption, and leaf area index which ultimately increased growth, yield attributes (Ray *et al.*, 2014).

Plant growth regulators have great potential in increasing agricultural production and help in removing many of the barriers imposed by genetics and environment. They play an important role in mitigating stress, increasing flower set, yield and physiological efficiency of the crop. Salicylic acid (SA) as a potent signaling molecule in plants is involved in defense mechanisms by regulating physiological and biochemical functions and has diverse effects on tolerance to biotic and abiotic stress factors (Nazar *et al.*, 2011). Exogenous SA application enhanced the growth and photosynthetic rate in wheat (Hussein *et al.*, 2007) under water stress, and increases photosynthetic activity and stomatal conductance under drought stress (Habibi, 2012). In addition, it has been found that plants treated with SA generally exhibited better resistance to drought stress and improved the seed yield of Indian mustard (Choudhary *et al.*, 2023). The exogenous application of SA has been reduced the negative effect of water stress (Choudhary *et al.*, 2023; Meena *et al.*, 2018) and spray of SA improve the growth of the plant (Hayat *et al.*, 2010). The gibberellins are known to play a significant role in the regulation of growth and development by enhancing cell elongation and cell differentiation thus augmenting plant height. They are

also known to control different physiological functions in plants by enhancing N-use efficiency and activities of nitrate reductase and carbonic anhydrase (Khan *et al.*, 2010). Thiourea, a sulphahydral compound, is known to improve oilseeds productivity and its role as a drought ameliorant is well established under the sub-tropical regions. It helps to play an important role in biosynthesis of some metabolites, such as chlorophyll and essential oils. Its application in rapeseed-mustard affects oil, protein and glucosinolate concentration (Singh *et al.*, 2017). As it is proven by several studies, sulphur is, therefore, actively involved in seed formation and oil synthesis in rapeseeds. Naphthalene acetic acid (NAA) is an important synthetic auxin. It is important to study the performance of NAA on the growth, yield and biochemical attributes of mustard plant varieties.

Consequently, the present study was based on the hypothesis that irrigation levels and plant growth regulators may enhance the growth and physiological parameters, yield attributes and yield of Indian mustard. Keeping above facts in view, the present study was planned with the aim to assess the effect of plant growth regulators and irrigation levels on productivity and profitability of Indian mustard.

Materials and Methods

The field experiment was conducted at research farm of ICAR-Indian Institute of Rapeseed-Mustard Research (Earlier as Directorate of Rapeseed-Mustard Research), Bharatpur during 2020-21 located at 77°3' E longitude, 27°15' N latitude and at an altitude of 178.37 m AMSL. The region falls under Agro Climatic Zone III a (semi-arid eastern plain) with sub-tropical and semi-arid climate. The climate of this zone is typically semi-arid, characterized with wide range of temperature between summer and winter. High temperature with high wind velocity during summers and low temperature during winters are the characteristic features of climatic condition. The average rainfall of the locality is around 650 mm of which 85 % is contributed by SW monsoon during July to August. Weather parameters play a great role in affecting growth and development process of the crop; hence it is important to present climatic variables. The mean weekly maximum and minimum temperature during the crop growing season of mustard fluctuated between 18.6 to 39.5°C and 3.4 to 26.3°C. The mean daily evaporation from 'USWB class A' pan evaporimeter ranged from 0.9 to 11.8 mm per day. The average relative humidity fluctuated between 64.90 to 92.0 %. The bright sunshine hours varied from 1.1 to 9.7. Total rainfall received during entire crop season was 46.9 mm.

Physico-chemical properties of soil

The soil was randomly drawn from different spots of experimental site up to 15 cm depth before the start of experiment and composite sample was prepared after proper mixing, drying and sieving. The composite soil sample was analyzed for different physico-chemical characteristics of the experimental soil. Soil of experimental site was loamy sand in texture and slightly alkaline in reaction (pH 8.2). The soil was medium in organic carbon (0.35 %), low in available nitrogen (124.7 kg/ha), medium in available phosphorus (16.9 kg/ha) and medium in available potassium (152.5 kg/ha), while the available sulphur content of the soil (8.3 ppm) indicated its deficiency.

Treatment details and experimental setup

There were three irrigation levels in main plots *viz.*, no irrigation (I_0), One irrigation at 40 days after sowing (DAS) (I_1) and two irrigations at 40 and 75 DAS (I_2) with six treatments in sub plots; Control (M_0), NAA @ 100 ppm at 30 and 60 DAS (M_1), gibberellic acid (GA) @ 50 ppm at 30 and 60 DAS (M_2), salicylic acid (SA) @ 100 ppm at 30 and 60 DAS (M_3), thiourea (TU) @ 0.1% at 30 and 60 DAS (M_4), indole acetic acid (IAA) @ 50 ppm at 30 and 60 DAS (M_5). The experiment was laid out in split plot design with three replications. Date of sowing of crop was 23 October 2020. Spacing of line to line was 45 cm and plant to plant was 15 cm with 6×5 m² plot size. Variety 'Giriraj' was used as test crop.

Before sowing, the seeds of mustard were treated with bavistin @ 2 g/kg seed to prevent seed borne diseases. The seed rate was 4 kg/ha. Thinning was done in two phases, in first phase the dense emerging seedlings were thinned out at 15 days after sowing. At second phase thinning and gap filling was completed at 25 DAS in order to maintain plant to plant distance 10-15 cm. To eliminate weeds in all the plots of experimental area, one hoeing was done at 25 DAS. Irrigations were applied to the crop as per treatments. The crop was affected by some aphids during the maturity period of the crop. Therefore, no control measures were required in the mustard crop. The crop was harvested when the grains were fully ripened. At the time of harvesting, first of all border rows were harvested around the individual plots leaving the net plot. The crop from the net plots were harvested, bundled separately and tagged. The bundles of the harvested crop were weight after drying in the sun. The threshing was done manually by beating the bundles of produce with stick for yield measurements.

Observation recorded

The observations like plant dry weight, branches/plant,

siliquae per plant, siliquae length, number of seeds per siliquae were taken from both areas apart from net plot. Randomly three plants were selected for recording growth parameter from net plot area and tagged and recorded observations at 45, 60, 90 DAS and at harvest. Yield and yield attributing character were recorded at harvest. Total numbers of siliquae were counted and averaged them. Each bundle from net plot was threshed separately and after winnowing the seed yield was recorded from each plot. The seed yield per plot was converted to determine the yield per hectare (q/ha). Difference between biological yield and seed yield gives the value of stover yield. The economics of different treatments were worked out in terms of cost of cultivation, gross monetary returns (GMR), net monetary returns (NMR), and benefit cost ratio (B:C) to ascertain the economic viability of the treatments.

Data on various parameters were analyzed using the techniques of the analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1967) and the treatment was tested by F test shown their significance. Critical difference (CD) at 5% level of significance was

determined for each character to compare the differences among treatment means.

Results and Discussion

Growth and dry matter production

The number of branches (plant⁻¹) varied remarkable due to treatment at all crop growth stages (45,60,90 DAS and at harvest). The number of branches (plant⁻¹) was found to be higher at 90 DAS in all treatments (Table 1). It has been observed that significantly highest number of branches 9.12, 19.17 and 23.78 was recorded under the treatment I₂ (two irrigations at 40 and 75 DAS) at 45, 60 and 90 DAS followed by I₁ (one irrigation at 40 DAS) treatment. Similar findings were also reported by Dadhich *et al.* (2015). Dry matter production varied at all growth stages (45,60, 90 DAS and at harvest) under all treatments. The dry matter production (plant⁻¹) at harvest was found higher in I₂ (12.73-131.52 g) followed by I₁ at all stages of crop growth which was increased significantly by 8.4 and 3.4% over no irrigation and one irrigation treatments, respectively at the harvest. Similar findings were also reported by Panda *et al.* (2004).

Table 1: Effect of irrigation levels and plant growth regulators on growth and dry matter production of mustard

Treatments	Plant dry weight (g)				Branches/plant (no.)		
	45 DAS	60 DAS	90 DAS	At harvest	45 DAS	60 DAS	90 DAS
A. Irrigation levels							
No irrigation	11.29	20.12	108.70	121.36	7.58	17.44	21.37
One irrigation (at 40 DAS)	11.74	27.60	121.14	127.19	7.91	19.07	22.27
Two irrigations (at 40 and 75 DAS)	12.73	31.12	129.53	131.52	9.12	19.37	23.78
SEm(±)	0.07	0.33	0.36	0.36	0.06	0.05	0.09
LSD (p=0.05)	0.27	1.31	1.40	1.41	0.24	0.21	0.37
B. Plant growth regulators							
Control	10.80	21.32	110.59	122.40	7.58	17.34	21.27
NAA @ 100 ppm at 30 and 60 DAS	11.56	25.27	116.77	125.50	7.99	18.38	22.28
Gibberellic acid @ 50 ppm at 30 and 60 DAS	11.98	27.30	121.17	127.53	8.22	18.84	22.69
Salicylic acid @ 100 ppm at 30 and 60 DAS	13.26	31.76	130.57	131.68	9.11	20.02	23.73
Thiourea @ 0.1% at 30 and 60 DAS	12.69	29.58	125.28	129.31	8.56	19.33	23.13
IAA @ 50 ppm at 30 and 60 DAS	11.24	22.44	114.39	123.71	7.77	17.83	21.76
SEm(±)	0.10	0.21	0.60	0.38	0.05	0.13	0.10
LSD (p=0.05)	0.28	0.61	1.75	1.11	0.13	0.37	0.28

Effect of irrigation levels on yield attributes and yield

Among different treatments, number of siliquae plant⁻¹ were found more in two irrigations; one at 40 DAS and another at 75 DAS in treatment I₂ followed by treatment I₁. Treatment I₂ recorded significantly highest number of siliquae plant⁻¹ i.e. 323.23 as compared to no irrigation (265.62) and one irrigation (305.94) treatment. Similar findings were also reported by Piri *et al.* (2008). The

longest siliquae (4.44 cm) was recorded with two irrigations which was significantly higher over no irrigation (4.01 cm), but remained at par with one irrigation (4.33) (Table 2). Similar findings were also reported by Alamin *et al.* (2018). Further, data revealed that treatment I₂ recorded significantly highest number of seeds per siliquae (15.31 cm) followed by I₁ treatment (14.11). Similar findings were also reported by Dadhich *et al.* (2015). The maximum seed yield was recorded with two irrigations (19.16 q/ha) which was significantly higher by 20.3% and

Table 2: Effect of irrigation levels and plant growth regulators on yield and yield attributes of mustard

	Siliquae/ plant (no.)	Siliquae length (cm)	Seeds/ siliquae (no.)	Seed yield (q/ha)	Stover yield (q/ha)
A. Irrigation levels					
No irrigation	265.62	4.01	13.93	15.93	43.92
One irrigation (at 40 DAS)	305.94	4.33	14.11	17.71	46.91
Two irrigations (at 40 and 75 DAS)	323.23	4.44	15.31	19.16	48.49
SEm(±)	0.69	0.03	0.06	0.32	0.10
LSD (p=0.05)	2.69	0.13	0.23	1.25	0.39
B. Plant growth regulators					
Control	301.40	3.88	13.80	15.39	45.64
NAA @ 100 ppm at 30 and 60 DAS	306.30	4.26	14.29	16.78	47.34
Gibberellic acid @ 50 ppm at 30 and 60 DAS	310.59	4.34	14.62	17.41	48.12
Salicylic acid @ 100 ppm at 30 and 60 DAS	285.51	4.59	15.21	19.47	52.83
Thiourea @ 0.1% at 30 and 60 DAS	281.99	4.47	14.76	18.16	49.89
IAA @ 50 ppm at 30 and 60 DAS	303.80	4.01	14.01	16.46	47.24
SEm(±)	0.42	0.06	0.06	0.11	0.56
LSD (p=0.05)	1.22	0.17	0.17	0.33	1.62

8.2%, respectively over no irrigation and one irrigation. Seed yield was significantly decreased by 10.0-16.9% under no irrigation than irrigated treatments due to moisture stress. Similar findings were also reported by Alamin *et al.* (2018); Verma *et al.* (2014) and Dadhich *et al.* (2015). The maximum stover yield was recorded with two irrigations (48.49 q/ha) which was increased significantly by 10.4% and 3.4% over no irrigation and one irrigation, respectively. The maximum biological yield was recorded with two irrigations (67.65 q/ha), increased significantly by 13.0% and 4.7% over no irrigation and one irrigation, respectively.

Effect of irrigation levels on economic viability of treatments

The common cost of cultivation was 32775 Rs./ha. The cost of cultivation was influenced substantially due to different irrigation levels. The maximum cost of cultivation was recorded with two irrigations followed by one irrigation and the least found under no irrigation. The present market value of seed and stover was considered for determination of economic viability of the treatments. The GMR influenced substantially due to different levels of irrigation. The maximum GMR was recorded with two irrigations followed by one irrigation and the least under no irrigation. The net monetary returns were calculated by subtracting the cost involved into the gross monetary returns. The maximum NMR (52675 Rs./ha) was fetched with two irrigations which was increased by 70.2 and 28.3% over no irrigation and one irrigation, respectively (Table 3). Benefit-cost ratio refers to the monetary gain over on each rupee of investment and expressed as profitability of a treatment. The maximum BC ratio was

recorded with two irrigations (2.47) followed by one irrigation (2.20) with least under no irrigation (1.94). The results are in line with the findings of Dadhich *et al.* (2015) and Piri *et al.* (2011).

Effect of PGRs on growth and dry matter production

Irrespective of the treatments, the number of branches per plant was increased with the days of the crop growth and recorded maximum at 90 DAS. Among the PGRs, maximum number of branches were recorded with SA which was significantly higher than rest of the treatments at all growth stages. Among the PGRs, irrespective of growth stages, significantly higher plant dry weight was recorded with SA (13.26-131.68 g) than rest of the PGRs (10.80-129.31 g). At harvest, plant dry weight was increased significantly by 1.8-7.6% with SA over rest of the treatments. Similar findings were also reported by Noor *et al.* (2017) and Meena *et al.* (2020).

Effect of PGRs on yield attributes and yield

Among the PGRs, maximum number of siliquae per plant was recorded with SA (310.59) which was significantly higher over rest of the PGRs by 1.4-10.3 %. Similar findings were also reported by Noor *et al.* (2017). In all PGRs treatments, SA being at par with TU produced the lengthiest siliquae. The maximum number of seeds per siliquae was recorded with SA (15.21) and proved significantly superior over other treatments (by 3.0-10.2 %). Similar findings were also reported by Aktar *et al.* (2007). Similarly, the maximum seed yield was recorded with SA (19.47 q/ha), followed by TU (18.16 q/ha), GA

Table 3: Economics of the treatments under different irrigation levels and plant growth regulators of mustard

Treatments	Cost of cultivation (Rs./ha)	Gross monetary returns (Rs./ha)	Net monetary returns (Rs./ha)	B:C
A. Irrigation levels				
No irrigation	32775	63720	30945	1.94
One irrigation (at 40 DAS)	34350	75400	41050	2.20
Two irrigations (at 40 and 75 DAS)	35925	88600	52675	2.47
SEm(±)				
LSD (p=0.05)	32775	61560	28785	1.88
B. Plant growth regulators				
Control	33075	67120	34045	2.03
	33625	69640	36015	2.07
NAA @ 100 ppm at 30 and 60 DAS	32997	77880	44883	2.36
Gibberellic acid @ 50 ppm at 30 and 60 DAS	33075	72640	39565	2.20
Salicylic acid @ 100 ppm at 30 and 60 DAS	33125	65840	32715	1.99

(17.41 q/ha), NAA (16.78 q/ha), IAA (16.46 q/ha) and least under control (15.39 q/ha). Seed yield with SA was significantly improved by 24.7 and 7.2-18.3% over the control and rest of the PGRs, respectively. In addition to SA, seed yield was also improved significantly by 7.0-18.0% with other PGRs (TU, GA, NAA and IAA) over control. Similar findings were also reported by Sharma *et al.* (2017) and Meena *et al.* (2020). The stover yield was recorded higher with SA (52.83 q/ha), which was significantly higher than rest of the PGRs by 5.9-15.7 %.

Effect of PGRs on economic viability of treatments

Among the PGRs, the maximum cost of cultivation was recorded with GA followed by IAA, NAA and TU. The least cost of cultivation was observed with the control followed by SA. The maximum GMR was recorded with SA followed by TU and minimum with the control followed by IAA. The GMR with SA was improved by 26.5% and 7.2-18.3% over the control and rest of the PGRs, respectively. Maximum NMR was recorded with SA (44883 Rs./ha) followed by TU (39565 Rs./ha) and the minimum with the control (28785 Rs./ha) followed by IAA. The NMR with SA was improved by 55.9% and 13.4-37.2% over the control and rest of the PGRs, respectively. Findings related to this study were also reported by Mishra and Kushwaha, 2015 and Soni *et al.* (2016). Among the PGRs, maximum B:C was recorded with SA (2.36) followed by TU (2.20) and the minimum B:C ratio was recorded with the control (1.88) followed by the IAA (1.99). The B:C with SA was improved by 25.5% and 7.3-18.6% over the control and rest of the PGRs, respectively. Findings related to this study were also reported by Singh and Singh, 2018; Mishra and Kushwaha, 2015 and Meena *et al.* (2020).

Conclusion

Growth parameters including branches per plant and plant

dry weight were found maximum with application of irrigation at 40 & 75 DAS with application of salicylic acid @ 100 ppm at 30 and 60 DAS. Further, results also revealed that yield and yield attributes like number of siliquae per plant, siliquae length, seeds per siliquae, seed and stover yield were found highest in salicylic acid treatment with two irrigations. The NMR and BC ratio was higher in the application of irrigation at 40 and 75 DAS with application of salicylic acid @ 100 ppm at 30 and 60 DAS. Therefore, from this study it can be concluded that application of irrigation at 40 and 75 DAS with application of salicylic acid @ 100 ppm at 30 and 60 DAS could be beneficial for getting higher productivity and profitability of Indian mustard under semi-arid region of Rajasthan.

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