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Effect of plant growth regulators and irrigation levels on growth, physiological parameters and yield of Indian mustard

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Abstract

A field experiment was conducted during 2020-21 to assess the effects of plant growth regulators and irrigation levels on growth, yield attributes and yield 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%, indole acetic acid @ 50 ppm applied at 30 and 60 DAS were allotted to sub-plots. Results revealed that maximum growth parameters including plant height, number of leaves/plant, number of branches and physiological parameters like SPAD reading, leaf area index were found under the application of two irrigations with salicylic acid. Further, yield and its attributes like test weight, stem girth, number of primary and secondary branches, seed and stover yield, biological yield and harvest index were found highest in salicylic acid with two irrigations. Thus, it can be concluded that application of two irrigations with use of salicylic acid could be beneficial for getting higher productivity 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.] shares the major area occupied by this group of crops and anchoring the livelihood of the majority of the farmers in the semi-arid regions of India. It is 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).

Efficient 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. 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 influenced the yield (Choudhary *et al.,* 2023; Langadi *et al.,* 2021). The irrigation at critical stages increased the yield of the Indian mustard this might due to the more availability of the nutrient and more efficient metabolic activities of the plant (Mehta, 2004). 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 (Yamamoto and Yamamoto, 1998). 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 growth, yield attributes and yield of Indian mustard.

Materials and Methods

The field experiment was conducted at research farm of ICAR-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.

Physio-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 physio-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 management of the experiment

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 @ 50 ppm at 30 and 60 DAS (M_2), salicylic acid @ 100 ppm at 30 and 60 DAS (M_3), thiourea @ 0.1% at 30 and 60 DAS (M_4), indole acetic acid @ 50 ppm at 30 and 60 DAS (M_5). The experiment was laid down in split plot design with three replications. Date of sowing of this experiment was 23 October 2020. Spacing of line to line was 45 cm and plant to plant was 15 cm with 6 × 5 m plot size. Variety 'Giriraj' was used for sowing purpose.

Before sowing, the seeds of mustard were treated with bavistin @ 2 g/kg seed to prevent seed born 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 height, leaf area index, chlorophyll content by SPAD meter and number of primary and secondary branches per plant were taken from both areas apart from net plot. For recording growth parameter of 3 plants from both net plot area was selected randomly and tagged and their observation were recorded at 45, 60, 90 DAS and at harvest. Yield and yield attributing character were recorded after harvest. Plant height of three randomly tagged plants was measured from base of plant up to the growing tips of main stem of randomly tagged plants and average height was recorded in cm. The leaf area of three plants was measured by leaf area meter and leaf area index (LAI) was calculated by the following formula and by using formula.

LAI = Leaf area per plant/Land area occupied per plant

The number of functional green leaves per plant were counted on the three representative plants and expressed as average number of leaf per plant. The total number of branches were recorded at 45, 60 and 90 DAS. Three randomly tagged plants were used for the number of primary and secondary branches were counted at maturity stage from the same three tagged plants (used for plant height) and average was worked out. The chlorophyll content was measured with SPAD chlorophyll meter reading (SCMR) at 45, 60 and 90 DAS. SCMR data were recorded on top, middle and bottom leaf each representative plant, between 9.00 to 11.00 am of the day. Reading form three tagged plants per plot were taken. After threshing and cleaning seed were taken without any bias from the total seeds of the plot. One thousand grains from each plot sample were counted and weighed on electronic balance and their weight was expressed in grams. Each bundle from the net plot was threshed separately and after winnowing the seed yield (kg) of each plot. The seed yield of per plot was converted to determine the yield per hectare in quintal/ha. The difference between the total biological yield and grain yield gives the value of stover yield, represented in quintal/ha. The weight of the thoroughly sun-dried harvested produce of each net plot was recorded separately before threshing as biological yield. This was converted in to quintal/ha. Harvest index was calculated by the formula given below:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (q/ha)}}{\text{Biological yield (q/ha)}} \times 100$$

Where; Economic yield = seed yield (q/ha), Biological yield = seed yield + stover yield (q/ha)

The data obtained on various observations were tabulated and analyzed in split-plot design with three replications by 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 where critical difference (CD) at 5% level of significance was determined for each character to compared the differences among treatment means.

Results and Discussion

Effect of irrigation levels on growth and physiological parameters

Growth of a plant can be manifested in many ways. Simple way to measure the growth is by recording height. The height is controlled genetically and it can be modified by environment and application of irrigation water. Data on plant height recorded at 45, 60, 90 and at harvest are presented in Table 1. Plant height gradually increased with the advancement in the growth stage up to 90 DAS under all treatments. The plant height marginally reduced at maturity over preceding stage under all treatments because of conversion of photosynthesis and food materials into development of seeds. The senescence of plant might be also the reason for a little reduction in plant height at maturity stage. The treatment I_2(two irrigations; one at 40 DAS and one at 75 DAS) recorded significantly highest plant height 59.8, 139.3, 210.8 and 209.9 cm recorded at 45, 60 and 90 DAS and harvest stage followed by I_1 (one irrigation at 40 DAS) treatment. Increase number of irrigations resulted increase in plant height. These findings are in close conformity with those reported by Singh and Meena (2020). Number of leaves indicates the assimilatory apparatus of plant. Determination of number of leaves provides the photosynthetic surface area. Higher number of leaves absorb more light interception. Lower the number of leaves apparently brings production as net assimilation is relatively low.

The data on number of leaves per plant had increased with the advanced in the growth stage up to 90 DAS. The emergence of new leaves almost stopped after 90 DAS because the conversion of vegetative phase of crop into reproductive phase by the time. The highest number of leaves were recorded in treatment I_2(two irrigations; one at 40 DAS and one at 75 DAS) at 45, 60 and 90 DAS followed by I_1 (one irrigation at 40 DAS) treatment (Table 1). Increase number of irrigations resulted increase in number of leaves at all growth stages of the crop. Similar results were also observed by Alamin *et al.* (2018). Chlorophyll content of leaves recorded by SPAD meter. Among different treatments, treatment I_2 (two irrigations; one at 40 DAS and one at 75 DAS) recorded significantly highest chlorophyll content 41.0, 45.0 and 44.6 % recorded at 45, 60 and 90 DAS followed by I_1 (one irrigation at 40 DAS) treatment due to increase the size of leaves and more photosynthesis at this stage (Table 2). The maximum SPAD readings were recorded two irrigations (44.6) which was increased significantly by 4.9 and 2.7 % over the no irrigation and one irrigation

Table 1: Effect of irrigation levels and plant growth regulators on growth parameters of mustard

Treatments	Plant height (cm)				Number of leaves		
	45 DAS	60 DAS	90 DAS	At harvest	45 DAS	60 DAS	90 DAS
A. Irrigation levels							
No irrigation	57.4	127.3	195.9	195.2	12.6	27.6	42.0
One irrigation at 40 DAS	58.7	133.3	200.2	199.6	13.2	28.0	43.1
Two irrigations (40 and 75 DAS)	59.8	139.3	210.8	209.9	14.5	31.0	45.2
SEm±	0.2	0.5	0.8	0.8	0.1	0.1	0.1
CD at 5%	0.6	1.9	2.9	3.0	0.5	0.6	0.3
B. Plant growth regulators							
Control	57.4	126.8	195.9	195.3	12.2	26.8	41.5
NAA @ 100 ppm at 30 and 60 DAS	58.1	131.8	201.4	200.5	13.1	28.3	43.2
Gibberellic acid @ 50 ppm at 30 and 60 DAS	58.6	134.4	203.6	203.0	13.5	28.9	43.4
Salicylic acid @ 100 ppm at 30 and 60 DAS	60.5	139.9	209.2	208.5	14.9	31.5	45.8
Thiourea @ 0.1% at 30 DAS and 60 DAS	59.4	137.1	205.2	204.7	14.1	29.9	44.2
IAA @ 50 ppm at 30 and 60 DAS	57.8	129.6	198.4	197.5	12.7	27.5	42.3
SEm±	0.1	0.4	0.5	0.5	0.2	0.2	0.2
CD at 5%	0.4	1.2	1.4	1.6	0.4	0.6	0.5

Table 2: Effect of irrigation levels and plant growth regulators on physiological parameters of mustard

Treatments	SPAD reading			Leaf area index		
	45 DAS	60 DAS	90 DAS	45 DAS	60 DAS	90 DAS
A. Irrigation levels						
No irrigation	37.9	40.7	42.5	2.34	3.49	3.37
One irrigation at 40 DAS	39.6	42.6	43.4	2.56	3.72	3.56
Two irrigations (40 and 75 DAS)	41.0	45.0	44.6	2.84	4.14	3.92
SEm±	0.0	0.2	0.1	0.04	0.05	0.05
CD at 5%	0.2	0.8	0.5	0.14	0.20	0.19
B. Plant growth regulators						
Control	37.7	40.6	42.0	2.07	3.22	3.07
NAA @ 100 ppm at 30 and 60 DAS	39.1	42.2	43.1	2.50	3.66	3.52
Gibberellic acid @ 50 ppm at 30 and 60 DAS	39.8	43.0	43.7	2.67	3.84	3.76
Salicylic acid @ 100 ppm at 30 and 60 DAS	41.6	45.4	45.6	3.12	4.41	4.19
Thiourea @ 0.1% at 30 and 60 DAS	40.7	43.8	44.2	2.87	4.10	3.90
IAA @ 50 ppm at 30 and 60 DAS	38.3	41.6	42.6	2.27	3.49	3.28
SEm±	0.1	0.2	0.2	0.07	0.05	0.06
CD at 5%	0.4	0.5	0.6	0.20	0.16	0.17

Table 3: Effect of irrigation levels and plant growth regulators on yield attributes and yield of mustard

Treatments	Primary branches	Secondary branches	Stem girth (cm)	Test weight (g)	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest Index (%)
A. Irrigation levels								
No irrigation	5.9	14.0	6.09	5.04	15.93	43.92	59.85	26.6
One irrigation at 40 DAS	6.2	14.6	6.27	5.19	17.71	46.91	64.62	27.4
Two irrigations (40 and 75 DAS)	6.8	15.7	6.59	5.36	19.16	48.49	67.65	28.3
SEm±	0.0	0.1	0.02	0.03	0.32	0.10	0.37	0.4
CD at 5%	0.1	0.3	0.07	0.10	1.25	0.39	1.45	NS
B. Plant growth regulators								
Control	5.5	13.4	5.61	4.59	15.39	45.64	61.03	25.2
NAA @ 100 ppm at 30 and 60 DAS	6.0	14.3	6.24	5.08	16.78	47.34	64.12	26.2
Gibberellic acid @ 50 ppm at 30 and 60 DAS	6.4	14.9	6.50	5.36	17.41	48.12	65.53	26.6
Salicylic acid @ 100 ppm at 30 and 60 DAS	7.4	16.6	7.00	5.87	19.47	52.83	72.3	26.9
Thiourea @ 0.1% at 30 and 60 DAS	6.8	15.6	6.73	5.53	18.16	49.89	68.05	26.7
IAA @ 50 ppm at 30 and 60 DAS	5.8	13.7	5.81	4.77	16.46	47.24	63.7	25.8
SEm±	0.1	0.1	0.04	0.06	0.11	0.56	0.58	0.3
CD at 5%	0.2	0.3	0.12	0.18	0.33	1.62	1.69	0.8

treatments, respectively at 90 DAS. Similar findings were also reported by Panda *et al.* (2004).

Leaf area index (LAI) was recorded at 45, 60 and 90 DAS (Table 2). LAI was found to be higher at 60 DAS and marginally decrease after 60 DAS in all treatments. It is indicated that treatment I_2 (two irrigations; one at 40 DAS and one at 75 DAS) recorded significantly highest LAI 2.84, 4.14 and 3.92 recorded at 45, 60 and 90 DAS followed by I_1 (one irrigation at 40 DAS) treatment. Results indicate that treatment I_2 significantly increased LAI over I_1 and I_0 at 45, 60 and 90 DAS respectively. Similar findings were also reported by Panda *et al.* (2004). Treatment I_2 (two irrigations; one at 40 DAS and one at 75 DAS) recorded significantly highest number of primary branches i.e. 6.8 followed by I_1. Treatment I_2 recorded significantly highest number of secondary branches i.e. 15.7 followed by I_1 treatment. Similar findings were also reported by Dadhich *et al.* (2015).

Effect of plant growth regulators on growth and physiological parameters

Plant height was influenced significantly due to different plant growth regulators (PGRs). Among the PGRs, the maximum plant height was recorded with salicylic acid (SA) closely followed by thiourea (TU), gibberellic acid (GA), NAA and IAA and the least under the control treatment. At harvest, plant height was increased significantly by 1.9-6.8 % with the SA over the rest of the treatments (Table 1). Similar findings were also reported by Singh and Meena (2020). Number of leaves increased with the days of the crop growth and recorded the maximum at 90 DAS. Among the PGRs, the maximum number of leaves were recorded with SA closely followed by the TU, GA, NAA and IAA and the least under the control treatment. At 90 DAS, number of leaves were increased significantly by 3.5-10.4 % with the SA over the rest of the treatments. Similar findings were also reported by Khan *et al.* (2002). Among the PGRs, the maximum LAI was recorded with SA which was significantly higher than rest of the PGRs at all the growth stages (Table 2). The LAI was increased by 7.4-36.5 % with SA over the rest of the PGRs at 90 DAS. Similar findings were also reported by Shah (2007). Among the PGRs, the maximum numbers of primary and secondary branches were recorded with SA which were also significantly higher than the rest of the treatments.

Effect of irrigation levels on yield attributes and yield of mustard crop

The maximum plant girth (6.59 cm) was recorded with two irrigations which was also significantly higher than no irrigation (6.09 cm) and one irrigation (6.27 cm) treatments (Table 3). The maximum test weight was recorded with two irrigations (5.36 g) which was also significantly higher than no irrigation (5.04 g) and one irrigation (5.19 g) treatments. Similar findings were also reported by Piri (2008). The maximum seed yield (19.16 q/ha) was recorded with two irrigations which was improved significantly by 20.3 and 8.2 % over the no irrigation and one irrigation treatments, respectively (Table 3). Seed yield was significantly decreased by 10.0-16.9 % under no irrigation treatment than the irrigated treatments due to moisture stress. Similar findings were also reported by Choudhary *et al* (2021, 2023), Alamin *et al.* (2018), Verma *et al.* (2014) and Dadhich *et al.* (2015). The maximum stover yield (48.49 q/ha) was recorded with two irrigations which was improved significantly by 10.4 and 3.4 % over the no irrigation and one irrigation treatments, respectively. The maximum biological yield (67.65 q/ha) was recorded with two irrigations which was increased significantly by 13.0 and 4.7 % over the no irrigation and one irrigation treatments, respectively (Table 3). The harvest index did not influence significantly due to different levels of irrigation. However, it was recorded comparatively higher with two irrigations (28.32 %) over the no irrigation (26.62 %) and one irrigation (27.41 %). Similar findings were also reported by Piri *et al.* (2011) and Alamin *et al.* (2018).

Effect of plant growth regulators on yield attributes and yield of mustard

Among the PGRs, the maximum plant girth was recorded with SA which was significantly higher than rest of the PGRs by 4.0-24.8 %. Among the PGRs, the maximum test weight was recorded with SA (5.87 g) which was significantly higher than rest of the PGRs by 6.1-27.9 % (Table 3). Similar findings were also reported by Mishra and Kushwaha (2015). Among the PGRs, the maximum seed yield was recorded with SA (19.47 q/ha), followed by the TU (18.16 q/ha), GA (17.41 q/ha), NAA (16.78 q/ha), IAA (16.46 q/ha) and least under the control (15.39 q/ha) treatment. 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 the control. Similar findings were also reported by Choudhary *et al.* (2023) and Sharma *et al.* (2017). Among the PGRs, the maximum stover yield was recorded with SA (52.83 q/ha), which was recorded significantly higher than rest of the PGRs by 5.9-15.7 %. In addition to SA, stover yield was also improved significantly by 3.6-9.3 % with other PGRs (TU, GA, NAA and IAA) over the control. Among the PGRs, the maximum biological yield was recorded with SA (72.3 q/ha), which was recorded significantly higher than rest of the PGRs by 6.2-18.5 % (Table 3). The biological yield was also improved significantly by 4.4-11.5 % with other PGRs (TU, GA, NAA and IAA) over the control. Harvest index was differed significantly with different PGRs. SA being on par with TU registered the maximum harvest index which was found significantly greater than rest of the treatments. Harvest index with SA was significantly improved by 1.4-6.8 % over the control and rest of the PGRs. In addition to SA, harvest index was also improved significantly with other PGRs (TU, GA, NAA and IAA) over the control. Similar findings were also reported by Aktar *et al.* (2007) and Noor *et al.* (2017).

Conclusion

Maximum growth parameters including plant height, number of leaves/plant and physiological parameters like SPAD reading, leaf area index were found maximum in application of irrigation at 40 and 75 DAS with application of salicylic acid @ 100 ppm at 30 and 60 DAS. Further results also revealed that; yield and its attributes like test weight, stem girth, number of primary and secondary branches, seed and stover yield, biological yield and harvest index were found highest in salicylic acid treatment with two irrigations. 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 of Indian mustard under semi-arid region of Rajasthan.

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