



Irrigation Levels and Anti-Transpirants Impact on Growth Attributes and Phenology of Different Varieties of Indian Mustard (*Brassica juncea* L.)

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Abstract: Field experiment was carried out during 2017-18 and 2018-19 at Regional Research Station, Bawal, Haryana, India to examine the consequences of different levels of irrigation and anti-transpirants application on mustard crop. The experiment had three irrigation levels (I1: control, I2: one irrigation at 40 DAS, I3: two irrigation at 40 and 75 DAS), and two varieties (V1: RH-725, V2: RH-749) in main plots, whereas, four anti-transpirants (A1: control, A2 : PMA @ 250 ppm at 45 and 90 DAS, A3 : 6 % kaolin at 45 and 90 DAS and A4: PMA @ 250 ppm + 6% kaolin at 45 and 90 DAS) in sub plots. The different irrigation levels and anti-transpirants significantly influenced the performance of RH-749 and RH-725 mustard varieties. Growth attributes such as plant height, number of primary and secondary branches per plant, dry matter accumulation, crop growth rate, relative growth rate, leaf area index, leaf area duration and number of days for maturity of mustard significantly in two irrigation at 40 and 75 DAS (At pre-bloom + pod filling stage) as compared to control (no post-sowing irrigation) irrigation level. In the case of anti-transpirants, highest growth attributes and number of days taken to physiological maturity of mustard was recorded in A4 as compared to A1 but it was at par with A3 anti-transpirants. Among the varieties, RH-749 performed better compared to RH-725 variety under different treatments. The interaction between I3 irrigation level and A4 anti-transpirants was significantly superior as compared to others. Moreover, mustard yield was significantly and positive correlated with different growth attributes.

Keywords: Anti-transpirants, Indian mustard, Interaction, Irrigation, Varieties, Correlation, Yield, Levels

Mustard (*Brassica juncea* L.) is a very important *rabi* season oilseed crop of India. It is cultivated on 6.69 million hectares of area with 10.11 million tonnes production and 1511 kg/ha productivity in India during 2020-21, whereas in Haryana state, crop grown on 0.61 million hectares area and produce 1.28 million tonnes with average productivity of 2098 kg/ha (Anonymous 2021). India is a key player in the global oilseeds scenario with 12-15 per cent of oilseeds area, 6-7 per cent of vegetable oils production, 9-11 per cent of the total edible oils consumption and 14 per cent of vegetable oil imports (Bhukhar et al 2022). The average productivity of Indian mustard in India during last one and half decade, oscillating between 1.0 to 1.2 tonnes/ha, which is much below the world average of 1.98 tonnes/ha. Moreover, there is wider yield gaps when productivity of India is compared with countries like Germany (4.3 tonnes/ha), France (3.8 tonnes/ha) and UK (3.4 tonnes/ha).

The production of mustard is not being fully exploited because of the lack of proper information of water requirement. It is well known that water management is one of the major factors responsible for achieving better harvest in crop production. Efficient irrigation through timely supply of

water in desirable amount and with proper irrigation method not only improves the crop yields but also improve water use efficiency. Research studies indicated the beneficial effect of irrigation on performance of mustard. Kumar and Dhillon (2023) reported three irrigations at branching, flowering and siliqua-formation stages resulted in significantly higher seed yield, oil content, oil yield and protein content. Piri et al (2019) concluded that application of two irrigations at 45 and 90 DAS significantly increased higher growth yield attributes and yield of mustard. Applications of two irrigations significantly increased seed yield by 52.8% over one irrigations. Ray et al (2016) observed that two irrigations at 30 and 60 DAS resulted in highest gross and net returns. Adequate supply of moisture in soil helps in proper utilization of plant nutrients, resulting in proper growth and high yield. Therefore, there is need for appropriate solution to fulfil the irrigation requirement of mustard crop. For increasing the productivity of mustard crop the improved varieties which are capable of giving high yields need to be cultivated.

Recently, antitranspirants are used in agricultural field which reduce transpiration rate from plant leaves by reducing the size and number of stomata and gradually hardening

them to stress. Antitranspirants which minimize transpiration could possibly outcome of higher food production by realizing yield potential of different varieties. The application of anti-transpirants foliar spray may be an option to improve the biometric parameters. Rajput (2012) concluded that combined spray of PMA @ 250 ppm + kaolin (6%) at 45 and 90 days after sowing recorded significantly higher yield, net returns and water use efficiency. Kumar et al (2018) reported that application of PMA @ 250 PPM + kaoline (6%) at 45 and 90 DAS recorded significantly higher seed yield and net return. The present investigation was aimed to evaluate the Indian mustard varieties under different irrigation level and anti-transpirants.

MATERIAL AND METHODS

Site specifications: The experiment was conducted at Regional Research Station, Bawal of Chaudhary Charan Singh Haryana Agricultural University, Hisar during 2017-18 and 2018-19. The site is located in south-west (SW) zone of Haryana which comes under arid and semi-arid region having latitude and longitude of 28.10N, 76.50 E, respectively above mean sea level of 266 meters. The climate is arid and semi-arid type, with severe cold days in winter and hot sunny days in summer season. The experimental soil was sandy loam in texture. The mean maximum temperature touches as high as 48°C during summer season. However, minimum temperature of 2-3°C is recorded during winter months. The south-west monsoon (SWM) brings rain from July-September providing 80-85 % of total annual rainfall of the region. The weather remains dry except light rainfall during the months From October-April. However, the high temperature is prevailing in June.

Experimental details: The experiment was laid out in split plot design having twenty-four treatment combinations with three replications by keeping levels of irrigation and varieties as main plot and anti-transpirants in sub plots. The pH of the experimental soil was alkaline in nature (8.24) having electrical conductivity of 0.19 ds/m. The organic carbon, available nitrogen, available phosphorus and available potassium content were 0.23 %, 148 kg/ha, 14.22 kg/ha and 208 kg/ha, respectively (Jackson, 1973, Rechar 1954, Walkely and Black 1947, Subbaiah and Asija 1956, and Olsen et al 1954). The pre-sowing irrigation was applied before seed bed preparation to ensure adequate moisture at the time of planting. To have a good soil tilth and well pulverized seed bed, the field was ploughed twice with the help of disc harrow, once with cultivator followed by planking. Layout was done by using rope and hand hoe. Mustard variety RH-749 and RH-725 was sown with row spacing of 30 cm by 'pora' method with hand plough. Irrespective of

treatments, thinning of extra plant was done 20 days after sowing by hand pulling to obtain the recommended intra-row spacing of 15 cm. To eliminate weeds in all the plots of experimental area, 1st hoeings was done at 25 days after sowing. Application of irrigation as per the treatment and crop was harvested at ground level with the help of sickle. The above ground harvested biomass from each plot was tied in bundles, tagged and sun dried. Dry bundles of individual plots were weighed to have total biological yield. The crop was threshed by manual laborers and was weighed to get seed yield, stover yield and biological yield kg/plot. Thereafter, these yields were converted into kg/ha.

Observation recorded: The five plants were selected from each plot for recording various growth attributes such as plant height, number of primary and secondary branches per plant, dry matter accumulation, crop growth rate, relative growth rate, leaf area index and leaf area duration recorded at specified growth stages of crop. The harvesting of rows of net plot was done manually.

Crop growth rate (g/m²/day): Crop growth rate (CGR) indicates increase in dry weight (W) of plant in a unit time (T) per unit land area (P). CGR was calculated using the following formula (Reddy and Reddi 2009).

$$CGR = \frac{(W_2 - W_1)}{P (T_2 - T_1)}$$

Where, P is the land area per plant and W1 and W2 are dry weights of plant at T1 and T2 time, respectively.

Relative growth rate (g/g/day): Relative growth rate (RGR) indicates the amount of growing material per unit dry weight of plant per unit time was calculated (Reddy and Reddi 2009).

$$RGR = \frac{(\text{Loge}W_2 - \text{Loge}W_1)}{(T_2 - T_1)}$$

Where, W1 and W2 are dry weights of plant at T1 and T2 time, respectively.

Leaf area index (LAI): LAI was worked out with following formula (Watson 1952)

$$\text{Leaf area index} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Leaf area (cm}^2\text{)}}$$

Leaf area duration (LAD): Leaf area duration (LAD) express the magnitude and persistence of leaf area or leafiness during the period crop life (Hunt 1978).

$$LAD = \frac{LAI_1/LAI_2}{2} (t_2 - t_1)$$

Where, LAI1 and LAI2 are leaf area index at the time t1 and t2, respectively.

t2- t1 is the interval of observation in days.

Statistical analysis: Experimental data were statistically analyzed by using SPSS software.

RESULTS AND DISCUSSION

Effect of irrigation: The successive increase in number of irrigations (I1 to I3) at different phenological stages did not influence the plant stand at 20 DAS and at maturity as well as days to 50 % flowering of mustard but the mean plant height increased with advancement in age, but the increase in the height was faster up to 120 days as compared to later period of growth (Table 1). Application of two irrigations at 40 and 75 DAS significantly recorded the maximum plant height of at 60, 90, 120 DAS as well as harvest, and was at par with treatment one irrigation at different days after sowing except at harvest. The shortest plants were under control throughout the growth periods. Significantly higher number of primary and secondary branches per plant were under application of two irrigations at 40 and 75 days after sowing as compared to those receiving one irrigation at 40 DAS and over control. The significantly maximum dry matter accumulation was with application of two irrigations at 40 and 75 days after sowing and was at par with treatment I2 (one irrigation at 40 DAS) at harvest only, but significantly superior over control (Table 2). Percentage increase in dry matter accumulation at harvest with application of two irrigations at 40 and 75 DAS was 2.97 % over I2 and 6.62 % over I1. The increase in crop growth rate was observed with the advancement of crop age and maximum between 60-90 DAS in all three levels of irrigation. The application of two irrigations at 40 and 75 DAS significantly recorded the maximum crop growth rate at 30-60

and 60-90 DAS and was at par with treatment I2 (one irrigation at 40 DAS) at 60-90 DAS only during 2017-18, but significantly superior over control. Percentage increase in crop growth rate with application of two irrigations at 40 and 75 DAS was 7.18 and 10.30 % over I2 as well as 20.42 and 15.74 % over I1 at 30-60 and 60-90 DAS, respectively. The maximum relative growth rate was at 30-60, 60-90 and 90-120 DAS and was at par treatment one irrigation at 40 DAS, except at 60-90 DAS in 2018-19 (Table 3). The application of two irrigations at 40 and 75 days after sowing significantly recorded the maximum leaf area index at 60 and 90 DAS and was at par with one irrigation at 40 DAS during both years except at 90 DAS during 2018-19 (Table 4). Irrespective of different treatments application of two irrigations at 40 and 75 DAS recorded significantly higher leaf area at 60 and 90 DAS and was at par with one irrigation at 40 DAS. Wherever, more number of days taken to physiological maturity under application of two irrigations at 40 and 75 days after sowing as compared to over irrigation level I2 and I1. It is well known fact that where enough soil moisture for progressive plant growth is maintained by either providing irrigation or rainfall, it intends to better development of photosynthetic area and results in an accelerate photosynthetic rate. Thus, as a consequence plant growth accelerated and led to a better accumulation of dry matter.

Adequate and timely supply of irrigation water in I3 treatment ensured cell turgidity and consequently higher

Table 1. Plant population (000/ha) and plant height (cm) of Indian mustard as influenced by irrigation levels, varieties and anti-transpirants (Pooled of 2017-18 and 2018-19)

Treatment	Plant population (000/ha)		Plant height (cm)			
	20 DAS	At harvest	60 DAS	90 DAS	120 DAS	At harvest
Irrigation levels (I)						
I ₁ - Control (No post-sowing irrigation)	213.9	209.8	114.4	172.3	197.3	204.7
I ₂ - One irrigation at 40 DAS (At pre-bloom stage)	218.5	216.2	120.0	183.5	208.2	217.6
I ₃ - Two irrigation at 40 and 75 DAS (At pre-bloom + pod filling stage)	218.0	214.9	121.5	186.2	215.0	224.2
CD (p=0.05)	NS	NS	2.2	4.1	6.2	2.6
Varieties (V)						
V ₁ -RH-725	218.5	214.9	117.1	178.4	203.6	213.7
V ₂ -RH-749	215.1	212.4	120.2	182.9	210.2	217.3
CD (p=0.05)	NS	NS	1.8	3.3	5.1	2.2
Anti-transpirants (A)						
A ₁ - Control	218.1	217.7	115.2	178.4	202.8	211.1
A ₂ - PMA @ 250 ppm at 45 and 90 DAS	215.1	211.9	117.5	179.1	204.9	214.0
A ₃ - Kaolin 6 % at 45 and 90 DAS	213.0	209.5	119.1	181.1	207.9	216.0
A ₄ - PMA @ 250 ppm + Kaolin (6%) at 45 and 90 DAS	221.1	215.4	122.8	183.9	212.0	220.9
CD (p=0.05)	NS	NS	3.1	2.5	3.6	4.4

meristematic activity leading to more foliage development, greater photosynthetic rate, higher nutrient uptake and better growth of plant. The increased turgidity in optimum irrigated condition results in higher stomatal conductance and photosynthesis which favoured improved morphological parameters like plant height, leaf area and better allocation of dry biomass in different plant parts. The moisture deficit in no-post sowing irrigation and one irrigation at 40 DAS treatments resulted in dehydration of protoplasm which decreased the turgor potential and turgor driven physiological processes viz., cell division and cell elongation which affected the plant growth (height, number of leaves, branches) and ultimately the total dry matter accumulation. The results are in agreement with earlier studies (Tyagi and Upadhyay 2017, Shivran et al 2018, Mishra et al 2019, Piri et al 2019, Kumar and Dhillon 2023).

Effect of variety: Appreciable effect of different varieties on growth and phenological attributing characters was observed but did not exhibit any influence on plant population at initial and harvest. Between varieties, significantly higher plant height of 120.2, 182.9, 210.2, 217.3 cm at 60, 90, 120 DAS as well as harvest observed with variety RH-749, respectively and was at par with RH-725 at harvest only during 2017-18. Significantly the higher number of primary branches and secondary branches per plant were in RH-749 as compared to RH-725, respectively in both the years (Table 1). The significantly higher number of primary branches and

secondary branches per plant as well as dry matter accumulation of at 60, 90, 120 DAS as well as harvest recorded under variety RH-749 as compared to RH-725 (Table 2). The significantly higher crop growth rate at 30-60 and 60-90 DAS and relative growth rate at 30-60, 60-90 and 90-120 DAS observed with y RH-749 as compared to RH-725, respectively (Table 3). There was significantly higher leaf area index as well as leaf area duration at 60-90 and 90-129 DAS observed in RH-749 as compared to RH-725, respectively (Table 4). Percentage increase in leaf area index with RH-749 was 12.12 % and 7.31 % over RH-725 at 60-90 and 90-120 DAS during both year. Significantly more number of days were taken to 50 % flowering and physiological maturity by RH-749 and least number of days were taken to 50 % flowering and physiological maturity by RH-725. This might be due to the genetic makeup of different varieties. Inherent characteristic of particular variety plays a vital role on growth and development of crop, which might be responsible for plant growth in terms of plant height, number of branches per plant, dry matter accumulation, crop growth rate, relative growth rate, leaf area index, leaf area duration etc. These findings are in accordance with the results reported earlier research (Singh et al 2017, Meena et al 2017, Kumar et al 2018, Yadav et al 2018, Jaiswal et al 2019, Rajyalakshmi et al 2019, Maurya et al 2022).

Effect of anti-transpirants: Marked effect of various anti-transpirants was observed on growth attributing characters

Table 2. Number of primary and secondary branches per plant at harvest and dry matter accumulation (g/plant) of Indian mustard as influenced by irrigation levels, varieties and anti-transpirants (Pooled of 2017-18 and 2018-19)

Treatment	Number of primary branches per plant	Number of secondary branches per plant	Dry matter accumulation (g/plant)			
			60 DAS	90 DAS	120 DAS	At harvest
Irrigation levels (I)						
I ₁	4.6	11.4	17.0	43.8	120.0	134.0
I ₂	5.7	14.0	20.6	52.9	132.5	143.5
I ₃	6.3	15.4	22.3	57.7	139.9	147.9
CD (p=0.05)	0.3	0.7	1.0	1.3	3.4	4.3
Varieties (V)						
V ₁	5.4	13.1	19.4	49.8	127.5	138.9
V ₂	5.7	14.1	20.5	53.1	134.0	144.7
CD (p=0.05)	0.2	0.5	0.8	1.1	2.8	3.5
Anti-transpirants (A)						
A ₁	5.1	12.7	19.1	48.4	124.5	138.4
A ₂	5.3	13.3	19.6	50.8	129.0	141.3
A ₃	5.7	13.9	20.2	52.5	132.9	142.5
A ₄	6.1	14.5	21.0	54.1	136.7	145.1
CD (p=0.05)	0.3	0.8	0.6	1.5	3.5	2.9

See Table 1 for treatment details

but did not exhibit any influence on plant population at initial and harvest as well as days to attain 50 % flowering. Significantly taller plants were recorded with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS and was at par with application of kaolin (6 %) at 45 and 90 DAS over PMA @ 250 ppm at 45 and 90 DAS and control, respectively. There were significantly more number of primary and secondary branches per plant with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS and was at par with application of kaolin (6 %) at 45 and 90 DAS but significantly superior over PMA @ 250 ppm at 45 and 90 DAS and control (Table 2). Significantly higher dry matter accumulation with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A₄) at 60, 90, 120 DAS as well as harvest and was at par with application of kaolin (6 %) at 45 and 90 DAS, but significantly superior over PMA @ 250 ppm at 45 and 90 DAS and control.

The significantly higher crop growth rate with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS at 30-60 and 60-90 and 90-120 DAS and was at par with application of kaolin (6 %) at 45 and 90 DAS, but significantly superior over PMA @ 250 ppm at 45 and 90 DAS and control (Table 3). Significantly higher relative growth rate at 30-60, 60-90 and 90-120 DAS was with both application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS and with application of kaolin (6 %) at 45 and 90 DAS and was at par with application of kaolin (6 %) at 45 and 90 DAS at 60-90 DAS and PMA @ 250 ppm at 45 and 90 DAS during. There was significantly higher leaf

area index and leaf area duration at 60-90 and 90-120 DAS recorded with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS and was at par with both application of kaolin (6 %) at 45 and 90 DAS and PMA @ 250 ppm at 45 and 90 DAS (Table 4). Foliar sprays of PMA @ 250 ppm and kaolin (6%) markedly increase all growth parameters and relative water content and reduce transpiration thus decreasing the loss of water vapour from the leaves and gradually hardening them to stress by closing the stomata for 2-3 days when sprayed on the leaves. Film forming anti-transpirants produce an external physical barrier to retard the escape of water vapour. Another approach to reduce the transpiration rate is by coating the leaf surface with white reflecting materials and kaolin at 6% helps to lower the leaf temperature and reduce the transpiration when applied on foliage which might be responsible for plant growth in terms of plant height, number of branches per plant and dry matter accumulation. Results are in concurrence with those of earlier reports (Badukale et al 2015, Kumar et al 2017, Kumar et al 2018, Mphande et al 2020).

Relationship of different growth attributes with seed yield of mustard crop: The correlation analysis between seed yield and growth attributing characters revealed that seed yield was significantly and positively correlated with growth parameter viz. plant height at harvest, number of primary and secondary branches per plant, dry matter accumulation at harvest and crop growth rate (Table 6).

Table 3. Effect of irrigation levels, varieties and anti-transpirants on crop growth and relative growth of Indian mustard (Pooled of 2017-18 and 2018-19)

Treatment	Crop growth rate (g/m ² /day)			Relative growth rate (g/g/day)		
	30-60	60-90	90-120	30-60	60-90	90-120
Irrigation levels (I)						
I ₁	11.3	19.8	56.3	0.041	0.054	0.069
I ₂	14.2	23.5	59.3	0.044	0.057	0.071
I ₃	15.3	26.2	60.9	0.045	0.059	0.071
CD (p=0.05)	0.6	1.2	2.4	0.001	0.000	0.001
Varieties (V)						
V ₁	13.2	22.4	57.3	0.043	0.056	0.070
V ₂	14.0	24.0	60.4	0.043	0.057	0.071
CD (p=0.05)	0.5	1.0	1.9	0.001	0.000	0.001
Anti-transpirants (A)						
A ₁	12.9	21.7	55.9	0.042	0.056	0.069
A ₂	13.4	22.6	58.0	0.043	0.056	0.070
A ₃	13.8	23.9	59.6	0.043	0.057	0.071
A ₄	14.4	24.6	61.9	0.044	0.057	0.071
CD (p=0.05)	0.4	1.3	3.0	0.000	0.001	0.001

See Table 1 for treatment details

Table 4. Effect of irrigation levels, varieties and anti-transpirants on crop growth and relative growth of Indian mustard (Pooled of 2017-18 and 2018-19)

Treatment	Leaf area index (DAS)		Leaf area duration (DAS)		Days taken to 50% flowering	Days taken to physiological maturity
	60-90	90-120	60-90	90-120		
Irrigation levels (I)						
I ₁	2.7	3.7	55.6	95.7	43.7	139.0
I ₂	3.3	4.4	65.9	115.0	44.9	141.0
I ₃	3.4	4.7	68.0	121.4	45.0	142.4
CD (p=0.05)	0.4	0.4	6.8	10.6	NS	1.4
Varieties (V)						
V ₁	2.9	4.1	60.1	105.3	43.0	138.7
V ₂	3.3	4.4	66.2	116.2	46.0	143.0
CD (p=0.05)	0.4	0.3	5.5	8.7	0.9	1.2
Anti-transpirants (A)						
A ₁	2.8	3.9	58.0	100.9	44.4	139.5
A ₂	3.2	4.0	63.8	108.6	43.9	140.8
A ₃	3.3	4.3	64.8	113.7	44.7	141.1
A ₄	3.3	4.7	66.0	119.8	45.1	141.9
CD (p=0.05)	0.4	0.5	5.7	8.7	NS	1.5

See Table 1 for treatment details

Table 5. Correlation coefficient between seed yield and growth attributes (Pooled of 2017-18 and 2018-19)

Characters	Correlation coefficient 'r'
Plant height	0.7455**
Number of primary branches per plant	0.8226**
Number of secondary branches per plant	0.6943**
Dry matter accumulation	0.7658**
Crop growth rate (g/m ² /day)	0.8160**

***=Significant at 5 and 1 per cent level

CONCLUSIONS

The higher growth and growth traits could be obtained when mustard crop is grown with two irrigations, at 40 and 75 DAS. The variety RH-749 proved to be better as compared to RH-725 in terms of all yield traits. The application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS recorded significantly higher growth and growth parameters. Thus, higher growth and growth parameters can be achieved with mustard variety RH-749 along with application of two irrigations at 40 and 75 DAS and PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS on loamy sand soils.

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