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Growth and phenological responses of Indian mustard (*Brassica juncea* L.) to different irrigation levels, varieties and antitranspirants

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Abstract
A field experiment was conducted on loamy sand soil during 2017-18 and 2018-19 at Regional Research Station, Bawal, CCS Haryana Agricultural University, Hisar. Twenty-four treatment combinations comprising of three levels of irrigation *viz*., Control (I_1), one irrigation at 40 DAS (I_2), two irrigation at 40 and 75 DAS (I_3), two varieties *viz*., RH-725 (V_1) and RH-749 (V_2) and four levels of antitranspirants *viz*., Control (A_1), PMA @ 250 ppm at 45 and 90 DAS (A_2), kaolin (6%) at 45 and 90 DAS (A_3) and PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) were evaluated in split plot design with three replications by keeping levels of irrigation and varieties as main plot and antitranspirants in sub plots. From the results of two-year field investigation concluded that, irrigation schedule of two at 40 and 75 days after sowing (I_3) to mustard was found significantly superior in terms of all the growth parameter as well as more number of days taken to physiological maturity, respectively during both years of experimentation. The genotype RH-749 proved to be best as compared to RH-0725 in terms of all growth traits and recorded significantly more number of days were taken to 50% flowering and days were taken to physiological maturity by RH-749 (V_2) than RH-725 (V_1), during both years. Whereas, application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) found to be superior in terms of all growth parameters followed by kaolin (6%) at 45 and 90 DAS (A_3), PMA @ 250 ppm at 45 and 90 DAS (A_2) and superior over control (A_1), respectively during both years of experimentation. Thus, higher growth traits can be achieved by sowing the 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 under the agro-climatic condition of Bawal, Rewari, Haryana.

Keywords: Antitranspirants, growth, Indian mustard, irrigation, phenology, varieties

1. Introduction
Indian mustard (*Brassica juncea* L.) is one of the most important winter oil seed crop grown in northern parts of India. It is commonly known as Sarson (Hindi, Urdu, and Punjabi), Shorshe (Bengali), Raai (Gujarati), Mohari (Marathi), Aavalu (Telugu), Kadugu (Tamil), Sasive (Kannada) and Kadugu (Malayalam). It is native of China and belonging to the family of Cruciferae (Brassicaceae). China, India, Canada, Australia, France, Germany is major mustard growing countries. The area, production and productivity of mustard in India during 2018-2019 were 6.23 million hectares, 9.34 million tonnes and 1499 kg ha^{-1}, respectively (DAC, 2019) [1]. In India, it is mainly cultivated in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat. Among these states, Rajasthan, Uttar Pradesh, Haryana and Madhya Pradesh are the major rapeseed-mustard growing states with 45.5%, 13.1%, 11.8% and 11.1% contribution, respectively to the national acreage during the last five years. Haryana produced 1.25 million tonnes (13.42 percent to all India) from 0.61 million hectares area (9.78 percent of total area of India) with average productivity of 2058 kg ha^{-1} (DAC, 2019) [1].
Mustard seeds are tiny round structures derived from a mustard plant, have been used from time immemorial as a condiment in food at regions all over the world. The seeds are high in essential oils as well as plant sterols and excellent source of essential B-complex vitamins such as folates, niacin, thiamin, riboflavin, pyridoxine (vitamin B-6), pantothenic acid. These B-complex groups of vitamins help in enzyme synthesis, nervous system function and regulating body metabolism. The 100 g of mustards provide 4.733 mg of niacin (vitamin B-3). Niacin is a part of nicotinamide co-enzymes that help lower blood cholesterol and triglyceride levels and the seeds are an excellent source of vitamin-E, gamma tocopherol; contain about 19.82 mg per 100 g of seed. Oilcake is a by-product left after extraction of oil, is used as manure, which is

rich in nitrogen. It acts as nematicide and also as cattle and poultry feed.

Yield of 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. Non-availability of sufficient irrigation water as per requirements of mustard crop causes moisture stress at critical stages of growth and development. Under such circumstances to find out some appropriate solution for minimizing the irrigation requirement of mustard crop without sacrificing yield should receive top most priority. Selection of high yielding variety resistant to biotic and abiotic stress and suitable for particular environment plays a key role for attaining the desired level of productivity. Antitranspirants are the chemical compound which favours reduction in rate of transpiration from plant leaves by reducing the size and number of stomata and gradually hardening them to stress. The application of antitranspirants *i.e.* PMA and kaolin alone and in combination through foliar spray may be an option to improve the biometric parameters. Keeping above points in view, the present investigation was aimed to evaluate the Indian mustard varieties according to response of irrigation level and antitranspirants and effect of different irrigation levels and antitranspirants on growth and phenology of Indian mustard.

2. Materials and Methods

A field was conducted at Regional Research Station, Bawal, CCS Haryana Agricultural University, Hisar during 2017-18 and 2018-19. Twenty-four treatment combinations comprising of three levels of irrigation *viz*., Control (I_1), One irrigation at 40 DAS (I_2), Two irrigation at 40 and 75 DAS (I_3), two varieties *viz*., RH-725 (V_1) and RH-749 (V_2) and four levels of antitranspirants *viz*., Control (A_1), PMA @ 250 ppm at 45 and 90 DAS (A_2), kaolin 6% at 45 and 90 DAS (A_3) and PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) were evaluated in split plot design with three replications by keeping levels of irrigation and varieties as main plot and antitranspirants in sub plots.

The climate of this region is characterized by extreme arid and semi-arid with severe cold days during winter season and hot sunny days coupled with desiccating winds during summer which is situated with latitude of 28.1^0N, longitude of 76.5^0E and 266 meters above mean sea level in south-west zone of Haryana. The results of mechanical and chemical analysis of soil indicates that the soil of the field was having 78% sand, 12% silt and 10% clay; classified as sandy loam in texture having alkaline pH (8.24), EC (0.19 ds/m), low in organic carbon (0.23) and available nitrogen (148 kg ha^{-1}), medium in available phosphorus (14.22 kg ha^{-1}) and high in available potassium (208 kg ha^{-1}). International Pipette method, Piper, 1966 [10] for physical properties, Schofield method (Jackson, 1973) [5] for EC, Potentiometric method (Jackson, 1973) [5] for soil pH, Walkley and Black's method (Jackson, 1973) [5] for organic carbon, Alkaline Potassium Permanganate method (Jackson, 1973) [5] for available nitrogen, Olsen's method (Olsen *et al.*, 1954) [9] for available phosphorus and Flame Photometer method (Jackson, 1973) [5] for available potash. Recommended doses of nitrogen (80 kg N ha^{-1}), phosphorus (30 kg P_2O_5 ha^{-1}), potassium (20 kg k_2O ha^{-1}), zinc sulphate (5 kg ha^{-1}) and 40 kg S ha^{-1} in the form of gypsum were applied. The five plants were selected from each plot for recording various growths attributes and recorded at specified growth stages of crop. The statistical analysis of data for each character studied in the experiment was carried out as per design of the experiment.

2.1 Formula of crop growth analysis

2.1.1 Crop growth rate ($gm^{-2}day^{-1}$)

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 by using the following formula (Reddy and Reddi, 2009) [12]:

$$CGR \frac{(W2 - W1)}{P(T2 - T1)}$$

Where, P is the land area per plant and W_1 and W_2 are dry weights of plant at T_1 and T_2 time, respectively.

2.1.2 Relative growth rate (gg^{-1} day^{-1})

Relative growth rate (RGR) indicates the amount of growing material per unit dry weight of plant per unit time. RGR was calculated by the following formula (Reddy and Reddi, 2009) [12]:

$$RGR = \frac{LogeW2 - LogeW1}{T2 - T1}$$

Where, W_1 and W_2 are dry weights of plant at T_1 and T_2 time, respectively.

2.1.3 Leaf area index (LAI)

LAI was worked out with the help of the following formula (Watson, 1952):

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

2.1.4 Leaf area duration (LAD)

Leaf area duration (LAD) express the magnitude and persistence of leaf area or leafiness during the period crop life. It was calculated by the formula given by Hunt (1978) [4].

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

Where,

LAI_1 and LAI_2 are leaf area index at the time t_1 and t_2, respectively.

$t_2 - t_1$ is the interval of observation in days.

3. Results and Discussion

3.1 Effect of irrigation

The data presented in Table 1 revealed that successive increase in number of irrigations (I_1 to I_3) at different phenological stages did not influence the plant stand at 20 DAS and at maturity and 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. Application of two irrigations at 40 and 75 DAS (I_3) significantly recorded the maximum plant height of 122.4, 186.6, 214.1, 221.5 cm and 120.6, 185.7, 216.0, 227.0 cm at 60, 90, 120 DAS as well as harvest, respectively during 2017-18 and 2018-19 and was at par with treatment one irrigation at different days after sowing except at harvest. The shortest plants were recorded under control (I_1) throughout the growth periods. The results in

(Table 2) revealed that significantly higher number of primary (6.2 and 6.4) and secondary (15.5 and 15.3) branches per plant were noted under application of two irrigations at 40 and 75 days after sowing (I_3) as compared to those receiving one irrigation at 40 DAS (I_2) and over control (I_1) in both the years.

The data presented in Table 2 revealed that application of two irrigations at 40 and 75 days after sowing significantly recorded the maximum dry matter accumulation of 23.2, 59.4, 142.0, 149.0 and 21.4, 56.1, 137.8, 146.8 g plant^{-1} at 60, 90, 120 DAS as well as harvest, respectively and was at par with treatment I_2 (one irrigation at 40 DAS) at harvest only, but significantly superior over control (I_1), respectively during 2017-18 and 2018-19. Percentage increase in dry matter accumulation at harvest with application of two irrigations at 40 and 75 DAS was 3.47% and 2.65% over I_2 as well as 11.61% and 9.06% over I_1, respectively during both years of experimentation.

An increase in crop growth rate was observed with the advancement of crop age and reached maximum between 60-90 DAS in all three levels of irrigation. The results in Table 3 revealed that application of two irrigations at 40 and 75 DAS significantly recorded the maximum crop growth rate of 16.0, 14.6 and 26.7, 25.7 g m^{-2}day^{-1} at 30-60 and 60-90 DAS, respectively, during both years and was at par with treatment I_2 (one irrigation at 40 DAS) at 60-90 DAS only during 2017-18, but significantly superior over control (I_1). Percentage increase in crop growth rate with application of two irrigations at 40 and 75 DAS was 9.58%, 5.79% and 8.53, 14.22% over I_2 as well as 41.59%, 28.07% and 28.98%, 35.26% over I_1 at 30-60 and 60-90 DAS, respectively, during both years of experimentation.

The data presented in Table 3 revealed that application of two irrigations at 40 and 75 DAS significantly recorded the maximum relative growth rate of 0.045, 0.059, 0.072 g g-1 day-1 and 0.044, 0.058, 0.071 g g-1 day^{-1} at 30-60, 60-90 and 90-120 DAS and was at par treatment one irrigation at 40 DAS (I_2), respectively during both years except at 60-90 DAS in 2018-19. Application of two irrigations at 40 and 75 days after sowing (I_3) significantly recorded the maximum leaf area index of 3.36. 4.73 and 3.43, 4.67 at 60 and 90 DAS and was at par with one irrigation at 40 DAS (I_2) during both years except at 90 DAS during 2018-19. Irrespective of different treatments application of two irrigations at 40 and 75 DAS (I_3) significantly recorded the maximum leaf area duration of 67.4, 121.4 and 68.5, 121.5 at 60 and 90 DAS and was at par with one irrigation at 40 DAS (I_2), respectively during 2017-18 and 2018-19 (Table 4). 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 I_3 (at 40 and 75 DAS) treatment ensured cell turgidity and consequently higher 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. On the other hand, moisture deficit in I_1 (no-post sowing irrigation) and I_2 (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 etc.) and ultimately the total dry matter accumulation. The results are in full agreement with those of Meena *et al.* (2017) [8], Hossain *et al.* (2013) [3], Verma *et al.* (2014) [14] and Tyagi and Upadhyay (2017) [13].

3.2 Effect of variety

Appreciable effect of different varieties on growth and phonological attributing characters. Between varieties, significantly higher plant height of 120.9, 182.4, 208.1, 215.4 cm and 119.5, 183.5, 212.2, 219.2 cm at 60, 90, 120 DAS as well as harvest observed with variety RH-749 (V_2), respectively during 2017-18 and 2018-19 and was at par with treatment RH-725 (V_1) at harvest only during 2017-18. (Table 1). Significantly the higher number of primary branches (5.7 and 5.8) and secondary (14.2 and 13.9) branches per plant were found under RH-749 (V_2) as compared to RH-725 (V_1), respectively in both the years (Table 2).

The results in Table 2 revealed that the significantly higher dry matter accumulation of 21.0, 54.6, 135.2, 145.4 and 20.0, 51.6, 132.8, 144.0 g plant^{-1} at 60, 90, 120 DAS as well as harvest, respectively during 2017-18 and 2018-19 observed with variety RH-749 (V_2) as compared to RH-725 (V_1). Significantly higher crop growth rate of 14.4, 13.6 and 24.7, 23.4 g m^{-2}day^{-1} at 30-60 and 60-90 DAS observed with variety RH-749 (V_2) as compared to RH-725 (V_1), respectively during both years. Percentage increase in crop growth rate with RH-749 (V_2) were 6.66%, 5.42% and 24.7%, 23.4% over RH-725 (V_1) at 30-60 and 60-90 DAS, respectively during 2017-18 and 2018-19 (Table 3)

The data presented in Table 3 revealed that the significantly higher relative growth rate of 0.044, 0.058, 0.071 and 0.043, 0.057, 0.071 g g^{-1} day^{-1} at 30-60, 60-90 and 90-120 DAS observed with variety RH-749 (V_2) as compared to RH-725 (V_1), respectively during both years. Significantly higher leaf area index of 3.30, 4.43 and 3.34, 4.42 at 60 and 90 DAS observed with variety RH-749 (V_2) as compared to RH-725 (V_1), respectively during both years. Percentage increase in leaf area index with RH-749 (V_2) were 14.18%, 8.31% and 13.22%, 8.86% over RH-725 (V_1) at 60 and 90 DAS during 2017-18 and 2018-19 (Table 4).

The results in Table 4 revealed that significantly higher leaf area duration of 65.6, 115.9 and 66.8 and 116.5 at 60 and 90 DAS observed with variety RH-749 (V_2) as compared to RH-725 (V_1), respectively during both years of experimentation. Significantly more number of days 46.1 and 45.9 were taken to 50% flowering and 142.8 and 143.1 were taken to physiological maturity by RH-749 (V_2) and least number of days 42.6 and 43.4 were taken to 50% flowering and 138.5 and 138.8 were taken to physiological maturity by RH-725 (V_1), respectively during 2017-18 and 2018-19 (Table 5). This result 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 by Kumar *et al.* (2017) [7].

3.3 Effect of antitranspirants

Marked effect of various antitranspirants was noted on growth attributing characters but did not exhibit any influence on plant population at initial and harvest, days to attain 50% flowering and days to physiological maturity. Data exhibited in Table 1 inferred that significantly taller plants were recorded with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) and was at with application of kaolin (6%) at 45 and 90 DAS (A_3), respectively during 2017-18 and 2018-19 except at harvest during 2017-18 but significantly superior over PMA @ 250 ppm at 45 and 90 DAS (A_2) and control (A_1). The perusal of data presented in Table 2 revealed that significantly more number of primary branches per plant of 6.2 and 6.0 with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4), respectively during 2017-18 and 2018-19 and was at par with application of kaolin (6%) at 45 and 90 DAS (A_3) only during 2018-19. Whereas, significantly maximum number of secondary branches per plant of 14.8 and 14.1 with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) and was at par with application of kaolin (6%) at 45 and 90 DAS (A_3), respectively, during 2017-18 and 2018-19, but significantly superior over PMA @ 250 ppm at 45 and 90 DAS (A_2) and control (A_1).

The data presented in Table 2 revealed that significantly higher dry matter accumulation of 21.4, 55.2, 137.6, 145.7 and 20.5, 53.1, 135.4, 144.5 g plant^{-1} with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) at 60, 90, 120 DAS as well as harvest and was at with application of kaolin (6%) at 45 and 90 DAS (A_3), but significantly superior over PMA @ 250 ppm at 45 and 90 DAS (A_2) and control (A_4) during both years. The results in Table 3 revealed that the significantly higher crop growth rate of 14.7, 14.0 and 25.0, 24.1 g m^{-2}day^{-1} with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) at 30-60 and 60-90 and was at par with application of kaolin (6%) at 45 and 90 DAS (A_3), but significantly superior over PMA @ 250 ppm at 45 and 90 DAS (A_2) and control (A_1) during both years. Data exhibited in Table 3 inferred that significantly higher relative growth rate at 30-60, 60-90 and 90-120 DAS recorded with both application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) and with application of kaolin (6%) at 45 and 90 DAS (A_3), respectively during 2017-18 and 2018-19 and was at par with application of kaolin (6%) at 45 and 90 DAS (A_3) at 60-90 DAS and PMA @ 250 ppm at 45 and 90 DAS (A_2) at 30-60, 60-90 and 90-120 DAS during both years except at 60-90 DAS during 2018-19.

The data presented in Table 4 revealed that significantly higher leaf area index and leaf area duration at 60 and 90 DAS recorded with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) and was at par with both application of kaolin (6%) at 45 and 90 DAS (A_3) and PMA @ 250 ppm at 45 and 90 DAS (A_2) during both years.

Foliar sprays of PMA @ 250 ppm and kaolin (6%) markedly increase all growth parameters and relative water content and may 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 antitranspirants 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 etc. Results are in concurrence with those of reported earlier by Rajput (2012) [11], Badukale *et al.* (2015) [2], Kumar *et al.* (2017) [7] and Kumar *et al.* (2018) [6].

4. Interaction effect

Interaction effect between irrigation levels and antitranspirants was found significance on plant height at harvest during 2018-19 (Table 5). The maximum plant height (232.1 cm) was recorded when application of two irrigations at 40 and 75 DAS (I_3) with kaolin (6%) at 45 and 90 DAS (A_3) and was statistically at par with treatment combinations of I_3A_4 and I_2A_4 but significantly superior over rest of the treatment combinations.

5. Correlation between seed yield (kg ha^{-1}) and growth characters

The correlation analysis between seed yield and growth attributing characters (Table 6) revealed that seed yield was significantly and positively correlated with growth parameter *viz.* plant height at harvest (0.7864** and 0.7047**), number of primary (0.8434** and 0.8019**) and secondary (7585** and 0.6301**) branches per plant, dry matter accumulation at harvest (0.8328** and 0.6989**), crop growth rate (0.8024** and 0.8296**), leaf area index (0.7661** and 0.6718**) and leaf area duration (0.8034** and 0.7143**), respectively during 2017-18 and 2018-19.

Table 1: Plant population (000 ha^{-1}) and plant height (cm) of Indian mustard as influenced by irrigation levels, varieties and antitranspirants

Treatment	Plant population (000 ha^{-1})				Plant height (cm)									
	20 DAS		At harvest		30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation levels (I)														
I_1 - Control (No post-sowing irrigation)	214.3	213.6	210.3	209.3	21.1	20.9	115.6	113.2	172.2	172.3	195.8	198.9	203.1	206.2
I_2 - One irrigation at 40 DAS (At pre-bloom stage)	218.0	219.0	216.8	215.7	21.1	21.1	120.2	119.8	182.6	184.4	207.1	209.3	216.5	218.8
I_3 - Two irrigation at 40 and 75 DAS (At pre-bloom + pod filling stage)	217.2	218.8	216.0	213.8	21.7	21.2	122.4	120.6	186.6	185.7	214.1	216.0	221.5	227.0
S.Em.±	2.8	3.8	3.6	3.8	0.2	0.2	1.0	1.2	1.4	1.8	1.8	3.0	1.3	1.4
C.D. at 5%	NS	NS	NS	NS	NS	NS	3.2	3.7	4.6	5.6	5.6	9.3	4.1	4.4
Varieties (V)														
V_1-RH-25	217.1	219.9	216.3	213.6	21.2	21.2	118.0	116.3	178.5	178.2	203.2	203.9	212.0	215.5
V_2-RH-749	215.8	214.4	212.4	212.3	21.4	20.9	120.9	119.5	182.4	183.5	208.1	212.2	215.4	219.2
S.Em.±	2.3	3.1	2.9	3.1	0.1	0.1	0.8	1.0	1.2	1.4	1.5	2.4	1.1	1.2
C.D. at 5%	NS	NS	NS	NS	NS	NS	2.6	3.0	3.7	4.6	4.6	7.6	3.4	3.6

Antitranspirants (A)														
A_1 - Control	216.3	219.9	219.5	216.0	21.5	21.0	117.5	113.0	179.0	177.9	201.8	203.8	209.5	212.7
A_2 - PMA @250 ppm at 45 and 90 DAS	215.9	214.2	213.2	210.7	21.3	20.9	118.4	116.5	179.4	178.9	203.2	206.5	211.9	216.2
A_3 - Kaolin 6% at 45 and 90 DAS	214.2	211.8	209.3	209.7	21.0	21.0	119.1	119.1	181.4	180.9	206.4	209.4	213.6	218.4
A_4 - PMA @250 ppm + Kaolin (6%) at 45 and 90 DAS	219.6	222.6	215.4	215.4	21.6	21.3	122.7	122.9	182.1	185.7	211.3	212.6	219.8	222.0
S.Em.±	3.3	3.4	3.0	3.0	0.3	0.2	1.3	2.2	0.9	1.6	1.9	1.9	2.1	1.4
C.D. at 5%	NS	NS	NS	NS	NS	NS	3.9	6.2	2.6	4.5	5.4	5.4	5.9	3.9

Table 2: Primary and secondary branches per plant at harvest and dry matter accumulation (g plant^{-1}) of Indian mustard as influenced by irrigation levels, varieties and antitranspirants

Treatment	Primary branches per plant at harvest		Secondary branches per plant at harvest		Dry matter accumulation (g plant^{-1})									
					30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation levels (I)														
I_1 - Control (No post-sowing irrigation)	4.6	4.5	11.8	11.0	1.60	1.68	16.9	17.1	44.8	42.8	121.8	118.3	133.5	134.6
I_2 - One irrigation at 40 DAS (At pre-bloom stage)	5.7	5.8	13.8	14.1	1.42	1.51	21.1	20.1	55.3	50.4	133.0	131.9	144.0	143.0
I_3 - Two irrigation at 40 and 75 DAS (At pre-bloom + pod filling stage)	6.2	6.4	15.5	15.3	1.67	1.74	23.2	21.4	59.4	56.1	142.0	137.8	149.0	146.8
S.Em.±	0.1	0.2	0.34	0.35	0.08	0.08	0.4	0.3	0.5	0.7	1.1	1.6	1.7	1.5
C.D. at 5%	0.3	0.5	1.08	1.10	NS	NS	1.3	1.1	1.5	2.1	3.5	4.9	5.2	4.8
Varieties (V)														
V_1-RH-725	5.4	5.4	13.2	13.0	1.56	1.68	19.8	19.0	51.7	48.0	129.3	125.8	138.9	139.0
V_2 -RH-749	5.7	5.8	14.2	13.9	1.57	1.61	21.0	20.0	54.6	51.6	135.2	132.8	145.4	144.0
S.Em.±	0.1	0.1	0.28	0.29	0.06	0.07	0.3	0.3	0.4	0.5	0.9	1.3	1.3	1.2
C.D. at 5%	0.3	0.4	0.88	0.90	NS	NS	1.1	0.9	1.2	1.7	2.9	4.0	4.2	3.9
Antitranspirants (A)														
A_1-Control	4.9	5.2	12.8	12.5	1.69	1.64	19.4	18.8	49.5	47.3	127.6	121.4	139.5	137.3
A_2 - PMA @250 ppm at 45 and 90 DAS	5.2	5.5	13.2	13.5	1.46	1.61	20.2	19.0	53.7	47.8	130.3	127.6	140.7	141.8
A_3 - Kaolin 6% at 45 and 90 DAS	5.7	5.6	14.0	13.8	1.58	1.65	20.7	19.8	54.1	50.9	133.5	132.4	142.7	142.4
A_4 - PMA @250 ppm + Kaolin (6%) at 45 and 90 DAS	6.2	6.0	14.8	14.1	1.52	1.68	21.4	20.5	55.2	53.1	137.6	135.9	145.7	144.5
S.Em.±	0.1	0.1	0.43	0.41	0.06	0.05	0.3	0.3	0.6	0.9	1.6	2.0	1.5	1.8
C.D. at 5%	0.4	0.4	1.24	1.17	NS	NS	0.8	1.0	1.8	2.5	4.6	5.7	4.4	5.1

Table 3: Crop growth rate (gm^{-2}day^{-1}) and relative growth rate (gg^{-1} day^{-1}) of Indian mustard as influenced by irrigation levels, varieties and antitranspirants

Treatment	Crop growth rate (gm^{-2}day^{-1})						Relative growth rate (gg^{-1}day^{-1})					
	0-30 DAS		30-60 DAS		60-90 DAS		30-60 DAS		60-90 DAS		90-120 DAS	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation levels (I)												
I_1 - Control (No post-sowing irrigation)	1.19	1.25	11.3	11.4	20.7	19.0	0.041	0.041	0.055	0.054	0.069	0.068
I_2 - One irrigation at 40 DAS (At pre-bloom stage)	1.05	1.12	14.6	13.8	24.6	22.5	0.044	0.043	0.058	0.056	0.071	0.070
I_3 - Two irrigation at 40 and 75 DAS (At pre-bloom + pod filling stage)	1.23	1.29	16.0	14.6	26.7	25.7	0.045	0.044	0.059	0.058	0.072	0.071
S.Em.±	0.06	0.06	0.3	0.2	0.4	0.5	0.000	0.000	0.000	0.000	0.000	0.000
C.D. at 5%	NS	NS	0.9	0.7	1.4	1.6	0.001	0.001	0.001	0.001	0.001	0.001
Varieties (V)												
V_1-RH-725	1.15	1.24	13.5	12.9	23.3	21.4	0.043	0.042	0.057	0.055	0.070	0.069
V_2-RH-749	1.16	1.20	14.4	13.6	24.7	23.4	0.044	0.043	0.058	0.057	0.071	0.071
S.Em.±	0.05	0.05	0.2	0.2	0.4	0.4	0.000	0.000	0.000	0.000	0.000	0.000
C.D. at 5%	NS	NS	0.7	0.6	1.1	1.3	0.001	0.001	0.001	0.001	0.001	0.001
Antitranspirants (A)												
A_1-Control	1.25	1.21	13.1	12.7	22.3	21.1	0.043	0.042	0.056	0.055	0.069	0.068
A_2 - PMA @250 ppm at 45 and 90 DAS	1.08	1.19	13.9	12.9	23.9	21.4	0.043	0.042	0.057	0.055	0.070	0.070
A_3 - Kaolin 6% at 45 and 90 DAS	1.17	1.23	14.1	13.4	24.7	23.0	0.044	0.043	0.057	0.056	0.071	0.071
A_4 - PMA @ 250 ppm + Kaolin (6%) at 45 and 90 DAS	1.13	1.24	14.7	14.0	25.0	24.1	0.044	0.043	0.058	0.057	0.071	0.071
S.Em.±	0.04	0.04	0.2	0.3	0.6	0.7	0.000	0.000	0.000	0.000	0.000	0.001
C.D. at 5%	NS	NS	0.6	0.7	1.6	2.1	0.001	0.001	0.001	0.001	0.001	0.001

Table 4: Leaf area index (LAI), Leaf area duration (LAD), days taken to 50% flowering and days taken to physiological maturity of Indian mustard as influenced by irrigation levels, varieties and antitranspirants

Treatment	Leaf area index (LAI)						Leaf area duration (LAD)						Days taken to 50% flowering		Days taken to physiological maturity	
	30-60 DAS		60-90 DAS		90-120 DAS		30-60 DAS		60-90 DAS		90-120 DAS					
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation levels (I)																
I_1 - Control (No post-sowing irrigation)	1.01	1.08	2.64	2.75	3.70	3.68	15.1	16.2	54.7	56.5	95.0	96.5	43.9	43.5	138.8	139.3
I_2 - One irrigation at 40 DAS (At pre-bloom stage)	1.04	1.10	3.28	3.34	4.35	4.36	15.7	16.5	64.9	67.0	114.5	115.5	44.6	45.3	141.3	140.8
I_3 - Two irrigation at 40 and 75 DAS (At pre-bloom + pod filling stage)	1.13	1.14	3.36	3.43	4.73	4.67	17.0	17.1	67.4	68.5	121.4	121.5	44.6	45.3	142.0	142.8
S.Em.±	0.03	0.02	0.15	0.13	0.11	0.14	0.5	0.3	2.2	2.2	3.5	3.3	0.2	0.8	0.42	0.8
C.D. at 5%	NS	NS	0.47	0.42	0.35	0.44	NS	NS	7.0	6.9	11.0	10.5	NS	NS	1.3	2.6
Varieties (V)																
V_1-RH-725	1.04	1.11	2.89	2.95	4.09	4.06	15.7	16.6	59.0	61.2	104.7	105.8	42.6	43.4	138.5	138.8
V_2-RH-749	1.08	1.11	3.30	3.34	4.43	4.42	16.2	16.6	65.6	66.8	115.9	116.5	46.1	45.9	142.8	143.1
S.Em.±	0.03	0.01	0.12	0.11	0.09	0.11	0.4	0.2	1.8	1.8	2.8	2.7	0.2	0.7	0.34	0.7
C.D. at 5%	NS	NS	0.38	0.34	0.29	0.36	NS	NS	5.7	5.6	9.0	8.6	0.5	2.1	1.09	2.1
Antitranspirants (A)																
A_1-Control	1.05	1.09	2.75	2.81	3.92	3.96	15.7	16.4	56.9	59.2	100.0	101.8	44.1	44.7	139.1	139.9
A_2 - PMA @250 ppm at 45 and 90 DAS	1.05	1.11	3.19	3.17	4.07	3.97	15.7	16.7	63.5	64.1	108.9	108.3	44.1	43.8	140.9	140.8
A_3 - Kaolin 6% at 45 and 90 DAS	1.04	1.10	3.21	3.29	4.32	4.33	15.6	16.6	63.8	65.9	113.0	114.3	44.6	44.8	141.1	141.1
A_4 - PMA @250 ppm + Kaolin (6%) at 45 and 90 DAS	1.11	1.12	3.23	3.32	4.72	4.69	16.6	16.8	65.1	66.8	119.3	120.2	44.8	45.5	141.7	142.1
S.Em.±	0.04	0.02	0.13	0.13	0.20	0.21	0.6	0.3	2.2	2.0	3.4	3.5	0.3	0.7	0.68	0.8
C.D. at 5%	NS	NS	0.39	0.38	0.59	0.59	NS	NS	6.2	5.7	9.8	10.2	NS	NS	NS	NS

Table 5: Interaction between levels of irrigation and antitranspirants on plant height at harvest of Indian mustard-2018-19

Treatment	Antitranspirants (A)				
Irrigation levels (I)	**A_1**	**A_2**	**A_3**	**A_4**	**Mean**
I_1	204.8	206.0	206.6	207.5	206.2
I_2	211.9	217.9	216.7	228.8	218.8
I_3	221.5	224.7	232.1	229.7	227.0
Mean	212.7	216.2	218.4	222.0	
S.Em.±	3.38				
C.D. at 5%	6.84				

Table 6: The values of correlation coefficient 'r' between seed yield and growth attributes

Sr. No.	Characters	Correlation coefficient 'r'	
		2017-18	2018-19
1	Plant height	0.7864**	0.7047**
2	Number of primary branches per plant	0.8434**	0.8019**
3	Number of secondary branches per plant	0.7585**	0.6301**
4	Dry matter accumulation	0.8328**	0.6989**
5	Crop growth rate ($gm^{-2}day^{-1}$)	0.8024**	0.8296**

* = Significant at 5 percent level, ** = Significant at 1 percent level

6. Conclusions

The irrigation schedule of two at 40 and 75 days after sowing (I_3) to mustard was found significantly superior in terms of all the growth parameters. Genotype RH-0749 proved to be best as compared to RH-0725 in terms of all morpho-physiological traits. Whereas, application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS (A_4) recorded significantly higher growth parameters followed by kaolin 6% at 45 and 90 DAS (A_3) and PMA @ 250 ppm at 45 and 90 DAS (A_2) superior over control (A_1), respectively during both years of experimentation. Thus, maximum growth traits can be achieved by sowing the 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 under the agro-climatic condition of Bawal, Rewari, Haryana.

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