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Effect of seeding dates and salicylic acid foliar spray on growth, yield, phenology and agrometeorological indices of *Brassica* species

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Abstract

A field experiment was conducted at Udaipur during the 2011-12 *Rabi* season to evaluate the effect of seeding dates and salicylic acid (SA) application on growth attributes, phenology and agrometeorological indices of *Brassica* species. The results revealed that crop sown during SMW (Standard Meteorological Week) 41 recorded significantly higher dry matter accumulation, number of branches plant^{-1}, number of siliquae plant^{-1}, length of siliqua, seed yield plant^{-1},1000-seeds weight, intercepted PAR, and IPAR. Amongst the *Brassica* species, B. *juncea* var. Bio-902 proved superior over *B. juncea* var. RGN-73 and *B. rapa* var. BSH-1 in terms of dry matter accumulation, number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, length of siliqua, seed yield plant^{-1}, and 1000-seeds weight. *Brassica juncea* var. RGN-73 and *B. rapa* var. BSH-1 required maximum number of days to attain physiological maturity. *Brassica rapa* var. BSH-1 required maximum GDD for opening first flower, and physiological maturity. *Brassica juncea* var. Bio-902 recorded higher value of HUE and intercepted more PAR compared to other species. Number of days taken to attain physiological maturity was significantly higher under 100 ppm SA foliar spray compared to water spray; 100 ppm SA foliar spray registered significantly higher GDD, higher HUE on seed yield basis, higher per cent PAR, and IPAR over water spray.

Introduction

Production potentiality of mustard can be fully exploited with suitable agronomic practices and genotypes. Among the different agronomic practices, optimum sowing time and suitable row spacing play an important role in fully exploiting the genetic potentiality of a variety as it provides optimum growth conditions including temperature, light, humidity and rainfall. The growth phase of the crop should synchronize with optimum environmental conditions for better expression of growth and yield. It is a fact that specified genotype does not exhibit the same phenotypic characteristics in all environmental conditions. Growth response of different genotypes, varies under different environment and their relative ranking usually differs and ultimately decides the selection of a genotype for a particular sowing date for stabilized higher yields (Finalay and Wilkinson, 1963, Eberhart and Russel, 1966 and Perkins and Jinks, 1968).

Plant productivity is severely affected by several abiotic stresses including, salinity, drought, high and low temperature, and heavy metals. Rapid and effective measures of plant treatments are necessary so that deterioration of crop due to high temperature can be controlled successfully. Out of the various abiotic stresses, high temperature is the second most important stress, which can strike crop at any time and impose many limitations on growth and development. Thermo-tolerance using various genetic approaches can mitigate the adverse effects of heat stress. For this purpose, a thorough understanding of physiological responses of plants to high temperature, and possible strategies for improving crop thermo-tolerance is imperative. The application of plant growth regulators is known to play an important role in plant response to stress. Salicylic acid plays diverse physiological roles in plants which include thermogenesis, flower induction, nutrient uptake, ethylene biosynthesis, stomatal opening, photosynthesis, and anti-oxidative enzymes (Hayat *et al.* 2007). Heat tolerance can be induced in a plant by prior exposure to moderately high temperatures which enables the plant to cope with subsequent potentially lethal, heat exposure (Howarth and Ougham, 1993). Salicylic acid has been found to be involved in both basal and acquired-thermo-tolerance in plants (Dat *et al.* 1998a, b, 2000, Lopez-Delgado *et al*., 1998).Taking cognizance of the facts mentioned above, present investigation was conducted.

Materials and Methods

Plant materials and growth conditions

The field experiment was conducted during *Rabi* season of 2011- 2012 at Instructional Farm, Rajasthan College of Agriculture, Udaipur situated at Southern part of Rajasthan at an altitude of 582.0 m above mean sea level, at $24^0 34'$ N latitude and $73^0 42'$ E longitude. The soils of experimental field was clay loam in texture and slightly alkaline. The experiment consisted of 18 treatment combinations, including three planting standard meteorological weeks (SMW) (SMW 41, SMW 43 and SMW 45) and three varieties of *Brassica* species (*B. juncea* var. Bio-902, *B. juncea* var. RGN-73 and *B. rapa* var. BSH-1), and two salicylic acid (SA) foliar spray, including water control, at 45 DAS, 60 DAS and 75 DAS. The experiment was laid out in split plot design with three replications. The crop was sown during SMW 41 (12^{th} October), SMW 43 (27^{th} October) and SMW 45 (11^{th} November) with a seed rate of 5 kg ha^{-1}, and with 30 cm row to row, and 10 cm plant to plant spacing. The crop was fertilized with 60 kg N and 40 kg P_2O_5 ha^{-1}. One half of nitrogen and full dose of phosphorus were given as basal application. The remaining dose of nitrogen was top dressed at first irrigation 30 days after sowing (DAS). The foliar spray of SA 100 ppm SA was applied at 45 DAS, 60 DAS and 75 DAS. The spray solution of 100 ppm SA was prepared by dissolving 100 mg of SA in one litre of water. The Growing Degree Days (GDD) was calculated as the difference between the daily mean temperature and threshold temperature as follows (Nuttonson, 1955).

$$\text{GDD} = \frac{(\text{Maximum temperature} + \text{Minimum temperature})}{2} - \text{Threshold temperature}$$

Threshold temperature of 5^0C was considered for mustard crop. Heat unit efficiency (HUE) for grain and biological yields was calculated as following the procedure of Pandey *et al*. (2010) :

$$\text{HUE (kg ha}^{-1}/\ ^0\text{C day)} = \frac{\text{Seed or stover yield (kg ha}^{-1})}{\text{GDD (}^0\text{C day)}}$$

Decagon ceptometer, (Decagon Devices, Inc.; model LP 80, Pullman, WA) was used to measure incoming, transmitted and reflected photosynthetically active radiation (PAR). Measurement of the photosynthetically active radiation was recorded at 45, 60 and 75 days after sowing at hourly interval from 11.00 to 14.00 hours. The intercepted photosynthetically active radiation (IPAR) was measured by facing the ceptometer (0.9 m) towards the sky above the plant canopy. The transmitted photosynthetically active radiation (IPAR) was measured by placing the ceptometer on the ground across the rows. The intercepted photosynthetically active radiation (IPAR %) was calculated by using the following formula :

IPAR (µ mole $m^{-2}s^{-1}$) = PAR above canopy - PAR below canopy

$$\text{IPAR (\%)} = \frac{\text{IPAR}}{\text{PAR above canopy}} \times 100$$

Results and Discussion

Effect of planting dates

Growth attributes

Significant effect of different weather conditions was observed on growth parameters viz., plant height and dry matter accumulation of mustard (Table 1).

Table 1: Effect of planting dates and salicylic acid (SA) foliar spray on dry matter accumulation of *Brassica* species

Treatments	Plant height (cm)	Dry matter accumulation (g plant^{-1})					
	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
Planting duration							
*SMW 41	151.2	1.3	22.3	29.5	34.3	42.6	45.7
SMW 43	153.6	1.4	20.2	25.1	29.5	39.9	44.1
SMW 45	149.0	1.3	18.5	23.8	29.4	36.6	38.4
SEm±	2.84	0.0	0.5	0.6	0.7	0.9	0.7
CD (P=0.05)	NS	NS	1.4	1.7	2.2	2.8	2.0
***Brassica* spp.**							
B. juncea var. Bio-902	142.8	1.6	24.4	29.4	34.5	43.7	48.8
B. juncea var.RGN-73	165.5	1.3	19.7	26.0	30.1	39.0	42.1
B. rapa var.BSH-1	145.4	1.2	17.0	23.1	28.5	36.5	38.3
SEm±	2.84	0.0	0.5	0.6	0.7	0.9	0.7
CD (P=0.05)	8.51	0.0	1.4	1.7	2.2	2.8	2.0
Foliar spray							
Water spray	149.8	1.3	20.6	26.3	29.5	38.7	42.4
**100 ppm SA	152.7	1.3	20.2	26.0	32.6	41.0	43.8
SEm±	0.99	0.0	0.3	0.3	0.4	0.4	0.5
CD (P=0.05)	NS	NS	NS	NS	1.1	1.2	1.4

*Standard Meteorological Week; **Salicylic acid

Table 2: Effect of planting dates and salicylic acid (SA) foliar spray on yield attributes of *Brassica* species

Treatments	Number of branches plant^{-1}	Length of siliqua (cm)	Number of siliquae plant^{-1}	Number of seeds siliqua^{-1}	1000-seeds weight (g)	Seed yield (g)
Planting duration						
SMW41	28.9	5.1	350.1	14.1	4.54	17.32
SMW 43	24.1	4.9	334.7	14.6	4.21	14.20
SMW 45	21.6	4.0	283.5	14.1	3.95	12.58
SEm±	0.46	0.09	5.92	0.38	0.05	0.30
CD (P=0.05)	1.37	0.26	17.74	NS	0.16	0.89
***Brassica* spp.**						
B. juncea var. Bio-902	29.2	4.9	351.5	16.7	4.51	17.06
B. juncea var.RGN-73	23.6	4.5	317.3	13.8	4.29	16.96
B. rapa var. BSH-1	21.8	4.6	299.6	12.2	3.90	10.08
SEm±	0.46	0.09	5.92	0.38	0.05	0.30
CD (P=0.05)	1.37	0.26	17.74	1.14	0.16	0.89
Foliar spray						
Water spray	24.1	4.5	318.3	13.6	4.14	14.15
100 ppm SA	25.6	4.8	327.2	14.9	4.32	15.25
SEm±	0.20	0.04	2.53	0.29	0.04	0.17
CD (P=0.05)	0.59	0.13	7.50	0.87	0.12	0.51

SMW: Standard Meteorological Week

SMW 43 sown crop achieved the highest plant height but difference was statistically non-significant. The crop sown on SMW 41 accumulated significantly higher dry matter compared to SMW 43 and SMW 45 sown crops. This was mainly because of production of more number of branches plant^{-1} (28.9; Table 2) and favorable weather available for the period. These results are in close conformity with the observation of Khushu and Singh (2005). A beneficial effect of early planting on dry matter accumulation in all the stages as compared to later plantings might be due to more favorable environment prevailed during the entire growing season. The early planting accumulated more growing days. A positive correlation was observed between dry matter accumulation (DMA) at harvest and GDD (r=0.510). The significant higher dry matter at successive growth stages seems to be on account of larger canopy development and more plant height under SMW 41 sown and 43 sown crops. The crop might have higher interception of PAR for growth and development. This is evident from higher intercepted PAR during 45, 60 and 75 DAS in early planting (Table. 5). The significant reduction in dry matter in late planting could also be ascribed to that late planting taken less number of days to physiological maturity.

Yield attributes

A significant effect in different yield attributes was observed due to various planting durations. The crop sown during SMW 41 recorded significantly higher yield attributes viz. number of branches plant^{-1}, length of silliqua, number of siliquae plant^{-1}, 1000-seeds weight, and seed yield plant^{-1} over late planting durations (Table 2).

The significant improvement in various yield attributes of the crop seems to be on account of fully exploiting environmental resources (above and below ground) for synthesis of photosynthates under early planting. Besides adequate supply of growth inputs (nutrients and water), the favourable weather conditions seem to have helped plants to use their full potential for reproductive growth. The production of higher amount of photosynthates in early planting helped the plant to develop larger nutrient sink in order to accumulate synthesized photosynthates. This resulted improvement in each component in early planting. The significant and positive correlation existed between dry matter at harvest and test weight (r=0.684), length of siliqua (r=0.667), number of siliquae plant^{-1} (r=0.918), and seed yield plant^{-1} (r=0.630).In early planting (SMW 41), yield attributes were quite high and seeds of higher weight, which positively contributed to higher yield. High temperature during grain development in late planting SMW 45 caused forced maturity of the crop resulting in development of seeds with lower weight which is evident from the low test weight.

On account of favourable weather conditions, improvement in growth and yield attributes, the crop sown during SMW 41 produced significantly higher seed yield over subsequent sowings. This could be attributed to overall improvement in DMA (Table 1), and yield attributes (Table 2) under early planting. Higher temperature during later phases of growth shortened the crop period (Table 3), and forced maturity resulted in reduced unit weight of seed and ultimately the lower seed yield under subsequent sowings. The correlation studies revealed that seed yield was negatively correlated with maximum, minimum and mean temperatures during 90 to 105 DAS (r= -0.654, -0.612, -0.639). In present investigation, it was observed that an increase in mean temperature by 1^0C during 90-105 DAS caused reduction in seed yield of about 250 kg ha^{-1}.

The significant increase in stover under SMW 41 sown crop seems to be due to higher dry matter production at successive growth stages. Increased seed and stover yields under SMW 41 resulted in production of higher biological yield; positive and significant correlation also existed between stover and dry matter at harvest (r=0.645). Similar results have also been reported by Singh and Singh (2002), and others (Annual Progress Report, 2000).

Phenology and agrometeorological indices

SMW 41 sown crop received maximum number of days to attain physiological maturity which consistently decreased with subsequent planting duration (Table 3). With delay in sowing, the crop duration was drastically reduced on account of shorter vegetative and reproductive phase. In late

Table 3: Effect of planting dates and salicylic acid (SA) foliar spray on days required to attain different phenological stages of *Brassica* species

Treatment	Emergence	Fifth leaf stage	Bud initiation	First flower opened	50 % flowering	Lower pod >2 cm long	Physiological maturity
Planting duration							
SMW 41	3.1	20.2	31.1	33.4	37.4	44.4	128.6
SMW 43	4.6	20.1	33.1	35.1	39.1	46.1	122.2
SMW 45	4.2	19.4	39.7	41.7	50.6	57.6	108.7
SEm±	0.12	0.21	0.35	0.32	0.34	0.34	0.13
CD (P=0.05)	0.36	0.64	1.04	0.97	1.03	1.03	0.38
***Brassica* spp.**							
B. juncea var. Bio-902	3.9	19.8	33.7	35.7	41.1	48.1	119.0
B. juncea var.RGN-73	3.9	20.1	33.7	35.7	42.1	49.1	120.2
B. rapa var.BSH-1	4.0	19.8	36.4	38.7	43.9	50.9	120.2
SEm±	0.12	0.21	0.35	0.32	0.34	0.34	0.13
CD (P=0.05)	NS	NS	1.04	0.97	1.03	1.03	0.38
Spray							
Water spray	4.0	20.0	34.6	36.7	42.3	49.3	119.4
100 ppm SA	3.9	19.8	34.6	36.7	42.4	49.4	120.2
SEm±	0.07	0.11	0.27	0.25	0.25	0.25	0.08
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.23

Table 4: Effect of planting dates and salicylic acid (SA) foliar spray on growing degree days (GDD) and heat unit efficiency (HUE) of *Brassica* species

Treatment	GDD (^{0}C days)				HUE (kg/ha/^{0}C day)	
	Emergence	Fifth leaf stage	First flower opened	Physiological maturity	On seed yield basis	On biological yield basis
Planting duration						
SMW 41	66.31	395.47	641.52	1769.4	1.11	3.87
SMW 43	76.70	369.64	610.14	1592.5	1.15	3.94
SMW 45	73.13	328.16	626.24	1340.0	1.10	4.27
SEm±	4.04	3.41	5.95	1.79	0.03	0.10
CD (P=0.05)	NS	10.22	17.85	5.37	NS	0.30
***Brassica* spp.**						
B. juncea var. Bio-902	66.45	363.06	611.64	1555.2	1.25	4.45
B. juncea var. RGN-73	74.84	367.07	611.83	1571.2	1.20	4.35
B. rapa var. BSH-1	74.84	363.23	654.44	1575.5	0.92	3.26
SEm±	4.04	3.41	5.95	1.79	0.03	0.10
CD (P=0.05)	NS	NS	17.85	5.37	0.08	0.30
Foliar spray						
Water spray	72.53	366.44	625.00	1561.7	1.09	3.94
100 ppm SA	71.56	362.43	626.94	1573.0	1.15	4.10
SEm±	2.36	1.90	3.91	1.15	0.01	0.05
CD (P=0.05)	NS	NS	NS	3.41	0.15	NS

sown crop the duration of crop growth decreased because of forced maturity due to higher mean temperature coupled with low relative humidity during the seed development stage. It is an established fact that crop phenology is largely dependent on genetic and environmental factors including, temperature, relative humidity, sun shine hours, rainfall (Venkataraman and Krishnan, 1992). The crop sown on SMW 41 required maximum GDD for physiological maturity (1769.4^{0}C day) which was significantly superior over SMW 43 and SMW 45 sown crops at maturity stage. The crop sown on SMW 45 required lowest growing degree days to attain physiological maturity stage (Table 4).

The growing degree days (GDD) concept was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature (Nuttonson, 1955). Early planting required more number of days to reach physiological maturity thus absorbed more GDD. While the late planting experienced higher temperature during later stage of the crop in less time. The crop sown during SMW 45 registered maximum heat use efficiency of 4.27 kg/ha/^{0}C days which was significantly superior over SMW 41 and SMW 43 (Table 4). The higher heat use efficiency (HUE) in SMW 45 sown crop could be ascribed by proportionate increased in dry matter per each unit absorbed.

Effect of *Brassica* species

Growth attributes

Brassica juncea var. RGN-73 registered maximum plant height of 165.5 cm at harvest which was significantly superior over *B. juncea* var. Bio-902 and *B. rapa* var. BSH-1 by 15.9 and 13.8 per cent.Variation of plant height was also reported by Singh *et al.* (2001). The *B. juncea* var. Bio-902 produced highest dry matter plant^{-1} followed by *B. juncea* var. RGN-73 and *B. rapa* var. BSH-1 (Table 1). This was mainly due to better plant height and more number of branches plant^{-1} in *B. juncea* var. Bio-902 compared to other *Brassica* species. The results obtained here are in close conformity with the finding of Patidar *et al.* (2004), and Begum *et al.* (2005).

Yield attributes

Significant improvement of various yield attributes viz. number of branches plant^{-1} (29.2), length of siliquae (4.9 cm), number of siliquae plant^{-1} (351.5), number of seeds silliqua^{-1} (16.7) and 1000 seed weight (4.51 g) was exhibited in *B. juncea* var. Bio-902 as compared to *B. juncea* var. RGN-73 and *B. rapa* var. BSH-1 (Table 2).These results are in agreement with those of Rana and Pachauri (2001). In the present investigation the maximum test weight was observed in *B. juncea* var. Bio-902 (4.51 g) followed by *B. juncea* var. RGN-73 (4.29 g) and *B. rapa* var. BSH-1 (3.90 g), and all are significantly different from each other. The superiority of *B. juncea* var. Bio-902 seems to be on account of efficient translocation of metabolism toward sink. These results are in agreement to that of Chaplot *et al.* (2012).

Phenology and agrometeorological indices

Brassica juncea var. RGN-73 and *B. rapa* var. BSH-1 took maximum number of days (120.2 each) to attain maturity stage which were significantly higher (1.2 days) than *B. juncea* var. Bio-902. *Brassica rapa* var. BSH-1 required maximum GDD (1575.53^{0}C day) followed by *B. juncea* var. RGN-73 (1571.24^{0}C day), and *B. juncea* var. Bio-902 (1555.17^{0}C day) (Table 4). *Brassica juncea* var. Bio-902 recorded higher value of HUE on seed and biological yield basis (1.25 and 4.45 kg ha^{-1}/ ^{0}C day) as compared to *B. rapa* var. BSH-1. Further, *B. juncea* var. Bio-902 and *B. juncea* var. RGN-73 found at par in respect to HUE on seed and biological yield basis. The differential behavior to heat unit requirements and days reported to reach the various phenological phase could be ascribed totally to their genetic makeup. The similar contentions were also given by Kaur and Hundal (2006), and Srivastava *et al*. (2011).

Salicylic acid

Growth attributes

The result revealed that foliar spray of SA significantly improved dry matter accumulation at 75, 90 and harvest over water spray (Table 1).In general, the favourable effect of foliar applied SA on overall growth of *Brassica* species might be due to increased photosynthetic efficiency by increased chlorophyll content, and greater development of assimilating apparatus (number of leaves and LAI), which ultimately resulted in increased DMA. In the present investigation, faster growth rate in terms of DMA due to foliar spray of SA could be ascribed to enhanced plant height and number of branches plant^{-1} over water spray. Hassanein *et al*. (2012) have also reported improvement in morphological characters (shoot height and shoot weight) of wheat under the influence of SA foliar spray.

Yield attributes

Foliar spray of 100 ppm SA significantly increased yield attributes including length of siliqua, number of siliquae plant^{-1}, 1000-seeds weight, and seed yield plant^{-1} over water spray (Table 2). It has been well documented that foliar spray of SA effectively improves overall growth of mustard crop in term of DMA by virtue of its influence on photosynthetic parameters, as well as maintaining better nutritional environment (higher N and P content in seed and stover) in plant system. Significant improvement in yield components of wheat crop under the influence of SA was also reported by Hassanian *et al.* (2012). Seed yield was significantly increased under foliar spray of SA by 5.0 per cent over water spray (Table 2). Since seed yield is a product of various yield components, the improvement in siliquae plant^{-1}, length of siliqua, 1000-seeds weight under foliar spray of SA could be ascribed for higher seed yield over water spray. Greater accumulation of biomass after foliar spray of SA (75, 90 DAS and harvest) might have resulted in significant improvement in yield attributes by virtue of adequate supply of metabolites. Significant enhancement in stover yield under foliar spray of SA seems to be due to their direct effect on DMA by virtue of increased nutrient uptake and photosynthetic efficiency, and plant height.

Photosynthetically active radiation (PAR)

Data in Table 5 show that the crop sown during SMW 41 intercepted higher PAR at 45, 60 and 75 DAS. As compared to SMW 43 and SMW 45 sown crop, the % IPAR was also more under SMW 41 at 45 and 60 DAS.With respect to Brassica species, B. *juncea* var. Bio-902 intercepted more PAR as compare to other species at 45, 60 and 75 DAS. The % IPAR ranged from 81-82 at 45 DAS, 96-97% at 60 DAS in *Brassica* species. However, at 75 DAS, all *Brassica* species experienced 97% IPAR. Similarly, foliar spray of 100 ppm SA also recorded higher % IPAR over water spray.

Table 5: Effect of planting dates and salicylic acid (SA) foliar spray on intercepted photosynthetic active radiation (IPAR) of *Brassica* species

Treatments	PAR (μ mole $m^{-2}s^{-1}$)			IPAR (%)		
	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS
Planting duration						
SMW 41	1013	1295	1279	82	98	97
SMW 43	1016	1257	1298	82	97	97
SMW 45	954	1258	1297	80	95	97
***Brassica* spp.**						
B. juncea var. Bio-902	999	1275	1260	82	97	97
B. juncea var. RGN-73	995	1273	1257	81	97	97
B. rapa var. BSH-1	988	1262	1257	81	96	97
Foliar spray						
Water spray	995	1270	1249	81	97	96
100 ppm SA	993	1268	1266	81	97	98

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