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Effect of salicylic acid and boron application on growth and yield of no-tilled rapeseed (*Brassica campestris*) under rainfed condition

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Abstract
In order to investigate the effect of Salicylic Acid (SA) and Boron (B) application on growth and yield of Rapeseed (*Brassica campestris*) var. M-27 under no-tilled and rainfed condition was conducted Agricultural Research Farm, Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Utlou, Bishnupur District, Manipur, India during the year 2018-2019. The experiment was conducted in Factorial Randomized Block Design with 4 replications. The results of the experiment revealed that foliar application of boron (0.25 %) twice at 30 days after sowing (DAS) and at flowering coupled with foliar spray of SA (200 ppm) at 25, 50 and 75 DAS gave the highest growth and yield of rapeseed.

Keywords: Rapeseed, salicylic acid, boron, no-tilled

Introduction
Rapeseed hold prominent position next to soybean, being one of the most important edible oilseed crops cultivated in India including Manipur under zero tillage condition. Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 28.6% in the total production. The production potentiality of rapeseed has not been fully exploited even though it is endowed with large potentialities due to the existing gap between domestic availability and actual consumption of edible oils. In order to bridge such gap, the country is forced to import edible oils. However, Rapeseed-mustard is the major source of income especially even to the marginal and small farmers in rainfed areas. One of the key factor underlying the success of no-till in combination with the other conservation agriculture principles is that it conserves soil resources by reducing soil erosion (Verhulst *et al.*, 2010) [19]. Being sown in winter, the crop often faces the problem of water stress since there is less rain and this lead to reduction in yield. Above that, if the soils are to be ploughed, nearly 15-20 days will be wasted for tillage operation, leading to late sowing and moisture loss. In Manipur, rabi crop cultivation is totally rainfed and dependent on the conserved moisture in the soil as there is no facility for irrigation (Singh *et al.*, 2013) [17]. Therefore, the best method for the cultivation of this crop is the adoption of no-till method with an improved and scientific approach.
Foliar application of substances during the moisture sensitive stages may also result in immediate supply of nutrients under low soil moisture status. Determination of appropriate substance and dose for foliar spraying is an important consideration for efficient absorption and assimilation of nutrients. Salicylic acid (SA) is an endogenous plant hormone that has been found to play a major role in the regulation of plant growth and development, such as seed germination, organ differentiation, stomatal movement, photoperiodic responses, and senescence mediation (Raskin, 1992; Khan *et al.*,2003; Hayat *et al.*,2008) [15, 10, 7]. Boron is one among the micronutrients required for normal growth and development of plants. It's neither an enzyme constituent nor there is convincing evidence that it directly affects enzyme activities (Abhilish *et al.*, 2016) [1]. Salicylic Acid and Boron are known to have the capacity to counteract the drought stress in plants. Keeping in view of these facts, an experiment was conducted to find out the effect of Salicylic acid and Boron application on growth and yield of no-tilled Rapeseed (*Brassica campestris*) under rainfed condition.

Materials and Methods

The field experiment was conducted during the *Rabi* season of 2018-19 at the experimental site of Pandit Deen Dayal Upadhyay Institute of Agricultural Sciences, Utlou, Bishnupur District, Manipur. The texture of the experimental field is clay loam with pH of 5.5, organic carbon of 1.41% and available N, P and K of 289 kg ha^{-1}, 47 kg ha^{-1} and 260 kg ha^{-1}, respectively. The experiment was laid in Factorial Randomized Block Design with 3 levels of SA *i.e,* no SA application (S_0), 150ppm (S_1) and 200ppm (S_2) at 25, 50 and 75 DAS through foliar sprays and three methods of boron application through Borax *i.e.*, no B application (B_0), 0.25% B spray at 30 DAS (B_1), 0.25% B spray at 30 DAS and at flowering (B_2) comprising nine treatments with four replications. The crop was supplied with recommended dose of fertilizers i.e., 40:20:20 kg/ha of N, P_2O_5 and K_2O respectively. Plant height and number of primary and secondary branches per plant were recorded at 50, 75 DAS and at harvest whereas fresh and dry weights were determined at 60 DAS and at harvest. Yield and its components namely number of siliquae per plant, seeds per siliqua, siliqua length, test weight, seed yield, stover yield and harvest index were determined at harvest. To compare the effect of Salicylic Acid and Boron levels on growth and yield of rapeseed, variables were statistically analyzed following Gomez and Gomez (1984). The statistical differences of the data generated for each character were tested with least significant difference (LSD) at 5% probability level using analysis of variance technique (ANOVA). The standard error of means (SEm±) and critical difference (CD) at 5% level of significance were calculated to compare the treatment means.

Results and Discussion

Effect on growth and growth parameters of rapeseed

Plant Height

Data presented in Table 1 clearly shows that the individual application of boron, B_2 (0.25% boron through borax at 30 DAS and at flowering) significantly increased the plant height when compared with control. The values of plant height were 44.39 cm, 65.08 cm and 75.67 cm respectively at 50 DAS, 75 DAS and at harvest. This result was supported by the findings of Hussain *et al.* (2008) [8] who reported that the highest plant height of mustard was obtained when the plant was treated with boron. Among the three levels of SA foliar application, the treatment S_2 (SA @ 200 ppm) gave maximum plant height in all the three stages as compared to control *i.e.* 45.16 cm, 65.08 cm and 76.58 cm respectively at 50 DAS, 75 DAS and at harvest. The result was in corroboration with the findings of Devi *et al.* (2011) [4]. Significant enhancement in plant height under foliar spray of SA seems to be due to their direct effect on dry matter accumulation (DMA) by virtue of increased nutrient uptake and photosynthetic efficiency. However, the interaction effect due to SA and boron on plant height was found statistically non -significant at all the observation stages. This was in line with the findings of Mijwel (2015) [12] who reported that interaction of B and SA has non-significant effect on the plant height of Okra.

Table 1: Effect of Salicylic acid and Boron on plant height of Rapeseed (cm)

Treatment	Plant height (cm)		
Boron levels	**50 DAS**	**75 DAS**	**Harvest**
B_0	38.03	59.52	67.58
B_1	43.74	63.80	73.92
B_2	44.39	65.08	75.67
SE (m)±	0.61	0.55	0.63
CD (P=0.05)	1.78	1.63	1.86
Salicylic acid levels			
S_0	37.75	59.51	67.92
S_1	43.25	63.80	72.67
S_2	45.16	65.08	76.58
SE (m)±	0.61	0.55	0.63
CD (P=0.05)	1.78	1.63	1.86
Boron×Salicylic acid			
B_0S_0	35.20	57.73	62.25
B_0S_1	37.53	58.09	67.75
B_0S_2	41.35	62.73	72.75
B_1S_0	38.94	59.63	70.00
B_1S_1	45.58	64.25	74.25
B_1S_2	46.70	67.53	77.50
B_2S_0	39.10	61.00	71.50
B_2S_1	46.65	66.00	76.00
B_2S_2	47.43	68.25	79.50
SE (m)±	1.05	0.95	1.09
CD (P=0.05)	NS	NS	NS

B_0 =0% Boron, B_1 = 0.25% Boron at 30 DAS, B_2 =0.25% Boron at 30 DAS and at flowering, S_0 =Salicylic acid 0 ppm, S_1 = Salicylic acid 150 ppm, S_2 = Salicylic acid 200 ppm

Number of branches

Number of primary and secondary branches per plant was observed and recorded in Table 2 and is in the range of 5.72 to 6.21 and 9.45 to 13.05 respectively at harvest under different levels of application of boron. The increasing level of boron increased the number of secondary branches per plant significantly as compared to control. Among the different SA levels, S_2 (SA @ 200 ppm) gave the maximum number of 1^0 and 2^0 branches *i.e.* 6.30 and 14.00 at harvest respectively and the lowest was from the control plot, S_0 (SA @ 0ppm) *i.e.* 5.75 and 8.88 respectively at harvest. The result was in corroboration with the findings of Rehman and Khalil

(2018) [16] who reported that application of SA (0.5mM) improved number of branches (6.34) of canola. The combined application of SA and B had a non-significant effect on the number of primary and secondary branches. The result was supported by the finding of Masum *et al.* (2019) [11] who opined that two times foliar spray of boron at 1% at vegetative and pod formation stages of mustard gave non-significant effect on number of branches per plant.

Table 2: Effect of Salicylic acid and Boron on number of primary and secondary branches of Rapeseed

Treatment	No. of 1^0 branches	No. of 2^0 branches
Boron levels	**Harvest**	**Harvest**
B_0	5.72	9.45
B_1	6.09	12.15
B_2	6.21	13.05
SE (m)±	0.32	0.65
CD (P=0.05)	NS	1.92
Salicylic acid levels		
S_0	5.75	8.88
S_1	5.98	11.77
S_2	6.30	14.00
SE (m)±	0.32	0.65
CD (P=0.05)	NS	1.92
Boron×Salicylic acid		
B_0S_0	5.48	7.90
B_0S_1	5.73	8.10
B_0S_2	5.97	12.40
B_1S_0	5.85	9.10
B_1S_1	6.07	13.10
B_1S_2	6.37	14.30
B_2S_0	5.92	9.70
B_2S_1	6.13	14.10
B_2S_2	6.57	15.40
SE (m)±	0.55	1.13
CD (P=0.05)	NS	NS

B_0 =0% Boron, B_1 = 0.25% Boron at 30 DAS, B_2 =0.25% Boron at 30 DAS and at flowering, S_0 =Salicylic acid 0 ppm, S_1 = Salicylic acid 150 ppm, S_2 = Salicylic acid 200 ppm

Fresh Weight

Table 3 shows the data of fresh weight collected at 60 DAS and at harvest. When the different levels of B and SA were sprayed individually, the highest fresh weight at 60 DAS was obtained from the treatment B_2 (0.25% boron through borax at 30 DAS and at flowering) in case of boron individual application and for SA individual application, the highest was from S_2 (SA @ 200 ppm). The individual effect of SA and B application on rapeseed was found to be significant for fresh weight at harvest. This result was supported by the findings of Hussein Said-Al Ahl (2016) [9]. The combined effect of SA and B application on fresh weight of rapeseed was found to be non-significant.

Table 3: Effect of Salicylic acid and Boron on fresh weight and dry weight of Rapeseed **(g)**

Treatment	Fresh weight (g)		Dry weight (g)	
Boron levels	**60 DAS**	**Harvest**	**60 DAS**	**Harvest**
B_0	10.93	8.32	4.09	5.25
B_1	11.99	10.72	4.92	6.63
B_2	12.26	11.29	5.15	6.93
SE (m)±	0.43	0.69	0.28	0.49
CD (P=0.05)	NS	2.05	0.82	NS
Salicylic acid levels				
S_0	10.89	8.56	4.13	5.42
S_1	11.76	10.27	4.77	6.34
S_2	12.52	11.49	5.26	7.04
SE (m)±	0.43	0.69	0.28	0.49
CD (P=0.05)	1.26	2.05	0.82	NS
Boron×Salicylic acid				
B_0S_0	10.25	6.83	3.59	4.52
B_0S_1	10.78	8.13	3.93	5.00
B_0S_2	11.78	10.00	4.75	6.23
B_1S_0	11.10	9.29	4.28	5.78
B_1S_1	12.10	10.88	5.05	6.73
B_1S_2	12.79	12.00	5.44	7.40
B_2S_0	11.34	9.56	4.53	5.98
B_2S_1	12.45	11.82	5.33	7.30
B_2S_2	13.00	12.48	5.60	7.50
SE (m)±	0.74	1.20	0.48	0.85
CD (P=0.05)	NS	NS	NS	NS

B_0 =0% Boron, B_1 = 0.25% Boron at 30 DAS, B_2 =0.25% Boron at 30 DAS and at flowering, S_0 =Salicylic acid 0 ppm, S_1 = Salicylic acid 150 ppm, S_2 = Salicylic acid 200 ppm

Dry Weight

The dry weight of rapeseed was taken at 60 DAS and at harvest as shown in Table 4. Among the three levels of boron application, B_2 (0.25% boron through borax at 30 DAS and at flowering) gave highest dry weight (51.5g) at 60 DAS as compared to control plot B_0 (0% boron) *i.e.* 4.09g. Similar finding was observed when the borax (were foliar sprayed at different stages in black gram (Pandey and Gupta, 2012) [14]. When the different levels of SA were sprayed, the highest dry weight *i.e.* 5.26 g at 60 DAS was obtained from the treatment S_2 (SA @ 200 ppm) as compared to control. There was significant effect of foliar boron application on the dry weight of rapeseed at 60 DAS, which is in line with the findings of Fariduddin *et al.* (2003) [5] who reported that the dry matter accumulation was significantly increased in *Brassica juncea*, when lower concentrations of salicylic acid were sprayed. The interaction of B and SA resulted in the non-significant effect in the dry weight of rapeseed.

Table 4: Effect of Salicylic acid and Boron on number of siliquae, seeds per siliqua, siliqua length (cm) and test weight (g) of Rapeseed

Treatment	No. of siliqua	No. of seed per siliqua	Length of siliqua	Test Weight
Boron levels				
B_0	125.87	9.98	4.44	3.11
B_1	135.25	13.63	5.05	3.38
B_2	141.10	14.39	5.22	3.48
SE (m)±	1.84	0.35	0.26	0.11
CD (P=0.05)	5.39	1.01	NS	NS
Salicylic acid levels				
S_0	125.74	9.51	4.47	3.16
S_1	133.56	13.25	4.89	3.34
S_2	142.92	15.26	5.35	3.46
SE (m)±	1.84	0.35	0.26	0.11

CD (P=0.05)	5.39	1.01	NS	NS
Boron×Salicylic acid				
B_0S_0	119.70	7.40	4.05	3.0
B_0S_1	121.70	9.40	4.46	3.1
B_0S_2	136.30	13.20	4.81	3.3
B_1S_0	124.50	10.50	4.66	3.1
B_1S_1	138.10	14.20	4.95	3.5
B_1S_2	143.10	16.30	5.54	3.5
B_2S_0	133.10	10.70	4.70	3.3
B_2S_1	140.90	16.20	5.25	3.5
B_2S_2	149.40	16.30	5.71	3.6
SE (m)±	3.18	0.59	0.45	0.18
CD (P=0.05)	NS	1.75	NS	NS

B_0 = 0% Boron, B_1 = 0.25% Boron at 30 DAS, B_2 =0.25% Boron at 30 DAS and at flowering, S_0 =Salicylic acid 0 ppm, S_1 = Salicylic acid 150 ppm, S_2 = Salicylic acid 200 ppm

Effect on yield and yield attributes of rapeseed

Test Weight

Test weight of seeds observed in the range of 3.11 to 3.48g under different level of boron at harvest stage and that of different level of SA ranged from 3.16 to 3.46g at harvest. The interaction effect due to boron and SA on test weight of seeds was found statistically non-significant. Test weight of seeds noted 3.0 to 3.6 g under different treatments combination of SA and boron. Maximum test weight of seeds (3.6 g) was observed with B_2S_2, where boron (0.25 %) has been sprayed twice *i.e.* at 30 DAS and at flowering coupled with foliar spray of SA (200 ppm) at 25, 50 and 75 DAS however they show non-significant difference from each other. The results corroborate the findings of Tabatabaei and Noori (2014) [18].

Number of siliquae

The number of siliquae per plant was significantly influenced by different levels of boron and SA is presented in Table 4. Number of siliquae per plant observed in the range of 125.87 to 141.10 under different level of boron at harvest stage. It is clear from the table that the increasing level of boron increased the number of siliquae per plant significantly over control. Maximum number of siliquae plant was observed with application of B_2 (0.25% boron through borax at 30 DAS and at flowering). Number of siliquae per plant observed in the range of 125.74 to 142.62 under different level of SA at harvest stage. The result collaborates the findings of Nehal *et al.* (2007) [13] who reported that treatment of SA registered maximum and significantly increase in number of siliquae per plant over control. The increased number of siliquae per plant could be due to better translocation of nutrients and assimilates to the reproductive regions. Number of siliquae per plant ranged from 119.70 to 149.40 under different treatments combination of B and SA. The interaction effect due to B and SA on number of siliquae per plant was found statistically non-significant.

Number of Seeds per Siliqua

Application of boron *i.e.* B_2 (0.25% boron through borax at 30 DAS and at flowering) recorded significant increase in number of seeds per siliqua. The number of seeds per siliqua noted in the range of 9.98 to 14.39 under the different levels of boron. Similar result was also found by Tabatabaei and Noori (2014) [18]. Maximum number of seeds per siliqua (15.26) was observed with application of SA *i.e.* S_2 (SA @ 200 ppm) when compared with the other SA levels. The result was supported by the findings of Ali and Mahmoud (2013) [2] who showed that foliar application of SA enhanced significantly number of seeds per pod of mungbean as compared with control. The combined application of SA and B were found to give significant effect on the number of seed per siliqua. Highest number of seeds per siliqua (16.95) in case of combined application was obtained with the treatment B_2S_2, where boron (0.25 %) had been sprayed twice *i.e.* at 30 DAS and at flowering coupled with foliar spray of SA (200 ppm) at 25, 50 and 75 DAS and it was supported to the findings of Mijwel (2015) [12], who reported that combined application of boron and SA increased significantly the number of fruits of Okra.

Length of Siliqua

Among the three levels of boron application, we obtained the longest siliqua from the treatment B_2 (0.25% boron through borax at 30 DAS and at flowering) and the shortest from the control *i.e.* B_0. When all the three SA levels were compared, we get the longest siliqua from the treatment S_2 and the shortest from the control S_0. The length of siliqua ranged from 4.05 cm to 5.71 cm in the case of combined application of salicylic acid and boron. The maximum length of siliqua of the rapeseed was obtained from the treatment B_2S_2, where boron (0.25 %) was sprayed twice *i.e.* at 30 DAS and at flowering coupled with foliar spray of Salicylic Acid (200 ppm) at 25, 50 and 75 DAS and minimum for control plot. Both the individual and combined application of B and SA resulted in non-significant effect on the length of siliqua and it is supported by the findings of Masum *et al.* (2019) and Masum *et al.* (2019) [11] who revealed that foliar spray of boron at vegetative stage and at siliqua formation stage of mustard gave no significant effect on length of siliqua.

Seed Yield

Seed yield indicated in Table 5, there was a significant response in seed yield due to different levels of boron and SA as compared to respective control. Seed yield varied from 624-833 kg/ha under different levels of boron and the magnitude of increase in yield due to various levels was 33.5% over control. These results are in close conformity to those of Choudhary and Bhogal (2017) [3]. The increase in yield might have been due to significant improvement in plant growth including yield attributes by virtue of adequate supply of metabolites from the leaves due to increased growth. Seed yield varied from 623-867 kg/ha under different levels of SA and the magnitude of increase in yield due to various levels was 39% over control. Yazdanpanah *et al.* (2015) [20] reported that salicylic acid has positive effect on rapeseed yield, yield components and dry matter. The interaction effect due to boron and SA on seed yield was found statistically significant

and seed yield ranged from 536 to 958 kg/ha under different treatments combination of boron and SA. Maximum seed yield (958 kg/ha) observed with the treatment combination B_2S_2 whereas minimum seed yield was noted with treatment combination B_0S_0. Mijwel (2015) [12] reported that interaction of B and SA has significant effect on yield of okra.

Table 5: Effect of SA and B application on Seed yield (kg/ha), Stover yield (kg/ha), Biomass yield (kg/ha) and Harvest Index of Rapeseed

Treatment	Seed Yield	Stover Yield	Biomass Yield	Harvest Index
Boron levels				
B_0	624	2192	2815	22.1
B_1	780	2355	3135	24.9
B_2	833	2395	3228	25.7
SE (m)±	9.3	56.3	54.7	0.6
CD (P=0.05)	27.3	165.2	160.7	1.6
Salicylic acid levels				
S_0	623	2218	2840	21.9
S_1	747	2315	3062	24.4
S_2	867	2409	3276	26.4
SE (m)±	9.3	56.3	54.7	0.6
CD (P=0.05)	27.3	NS	160.7	1.6
Boron×Salicylic acid				
B_0S_0	536	2063	2599	20.7
B_0S_1	606	2164	2769	21.9
B_0S_2	729	2349	3078	23.7
B_1S_0	643	2268	2911	22.1
B_1S_1	786	2376	3162	25.2
B_1S_2	912	2421	3333	27.4
B_2S_0	689	2323	3012	23.0
B_2S_1	850	2405	3256	26.1
B_2S_2	958	2458	3416	28.1
SE (m)±	16.1	97.4	94.7	0.9
CD (P=0.05)	47.2	NS	NS	NS

B_0 = 0% Boron, B_1 = 0.25% Boron at 30 DAS, B_2 =0.25% Boron at 30 DAS and at flowering, S_0 =Salicylic acid 0 ppm, S_1 = Salicylic acid 150 ppm, S_2 = Salicylic acid 200 ppm

Stover Yield

On the application of the different levels of boron, the highest stover yield was recorded by the application of B_2 (0.25% boron through borax at 30 DAS and at flowering) *i.e.* 2395 kg/ha. The result concluded that the individual foliar spray of boron had a significant effect on the stover yield of rapeseed. The result was in close conforming to those of Masum *et al.* (2019) [11] who reported that two times foliar spray of boron at 1% at vegetative and pod formation stages of mustard (BARI Sarisha-14) gave maximum stover yield (1946.0 kg/ha). Among the different SA levels, S_2 (SA @ 200 ppm) gave the highest stover yield *i.e.* 2409 kg/ha and the lowest was from the control plot, S_0 (SA @ 0ppm) *i.e.* 2218 kg/ha. However, the different levels of SA had a non-significant effect on the stover yield of rapeseed. The combined application of SA and B also gave non-significant effect in the stover yield of rapeseed.

Biomass Yield

Biomass yield produced significant variations among different levels of boron. The individual effect of B on yield ranged from 2815 kg/ha for control to 3228 kg/ha for the treatment B_2 (0.25% boron through borax at 30 DAS and at flowering). This was in line with the findings of Hussain *et al.* (2008) [8]. Similarly, the different levels of SA application resulted in significant increase in the biomass yield upto 3276 kg/ha as compared with control which is 2840 kg/ha. However, the combined application of SA and B gives non-significant effect in the biomass yield of rapeseed.

Harvest Index

Among the different levels of boron application, the harvest index was highest from the treatment B_2 (0.25% boron through borax at 30 DAS and at flowering) *i.e.* 25.7. Again, when the different levels of SA were applied, the maximum harvest index was obtained from the treatment S_2 (SA @ 200 ppm) *i.e.* 26.4 (Table 5). There was significant increase in the harvest index of rapeseed with these treatments as compared with control. But, the interaction effect of B and SA resulted in non-significant result on the harvest index of rapeseed.

Conclusion

We can conclude that foliar application of SA (200 ppm at 25, 50 and 75 DAS) and B (0.25% through Borax, at 30 DAS and at flowering) increased the growth and yield of rapeseed. So, SA and B can be considered as an important substance that can improve various growth and yield parameters under water scanty rainfall conditions resulting in higher yield and ultimately the higher return.

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