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Salicylic acid mitigate the adverse effect of high temperature stress on yield and yield determining parameters of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted at Agronomy Farm, SKN College of agriculture, Jobner, Jaipur, Rajasthan to evaluate the effect of sowing time, varieties and salicylic acid (SA) application on the yield of Wheat. The experiment was carried out in split plot design and replicated thrice The experiment consisted of two date of sowing 20th November (timely sowing) and 20th December (late sowing) with two varieties Raj-4079 & Raj-4120 and four levels of salicylic acid (Control, SA 50 ppm, SA 100 ppm and SA 150 ppm). Salicylic acid was sprayed at two stages i.e. at first 50 DAS stage and at second 80 DAS. Under this experiment determine the effect of high temperature and SA on various yield parameters like Plant height(cm), number of effective tillers^{-1}, grain yield per plant, test weight, seed, straw, biological yield and harvest index (HI) and this parameters were recorded at harvesting and after harvesting. Results were revealed that yield parameters viz. Plant height (76.94 cm), effective tillers^{-1}(2.28), grain yield (16.37 g/plant), test weight (41.39 g), seed yield (30.22q/ha), straw yield(51.22q/ha), biological yield(81.44q/ha) and harvest index (39.55%) were higher in timely sowing compare to late sowing. In case of varieties all yield parameters found superior in Raj-4079 than Raj-4120. The study thus reveals that adverse effect of temperature on yield & yield attributes of wheat varieties may be improved by treatment with SA (150 ppm) under normal as well as late sown conditions. Salicylic acid (SA) 150 ppm concentration of spray treatment mitigates the effect of high temperature on yield and yield attributes traits in wheat genotypes with better result in yield.

Keywords: Salicylic acid, ppm, high temperature, varieties, yield, parameters

Introduction
Global warming is predicted to increase the frequency and severity of heat stress leading to drastic reduction in the food production (Talukder *et al*. 2014) [15]. Wheat is a major cereal crop, accounts for about 30% of the world's cereal area to provide food for 36% of the global population (Cossani & Reynolds, 2012 [2]; Prerna *et al*., 2013) [13]. Since 1980s, global wheat productivity is estimated to have been reduced by as much as 5% due to increasing temperature (Lobell *et al.*, 2011). It has been shown to lose 3–4% of yield per °C above the optimum day time temperature of 15- 20°C (Wardlaw *et al*., 1989) [16]. India has the largest area under wheat (30.0 million hectares) but ranks second in production (93.5 million tonnes) after China with the average productivity of 3117 kg/ha (Economic Survey, 2014-15). It is cultivated mainly in the states of Uttar Pradesh, Madhya Pradesh, Punjab, Rajasthan, Haryana, Bihar, Gujarat and Maharashtra. Among the different states of India, Uttar Pradesh ranks first in area and total production, while Punjab ranks first in productivity (GOI, 2013-14) [8]. In Rajasthan, the crop occupies an area of 2.82 million hectares and production of 8.95 million tonnes with an average productivity of 3174 kg/ha (GOI, 2013-14) [8].
Developing crop plants with improved thermo-tolerance can mitigate the adverse effects of heat stress. Wheat is an important cereal crop and late sowing encounters high temperature stress at grain development stage, which causes a great yield reduction. Salicylic acid has recently been recognized as plant hormone. Salicylic acid, a phenolic compound, has been found to be involved in inducing thermo-tolerance in the crop. Salicylic acid pretreatment induced thermo-tolerance and definitely play a role in initiating various mechanisms involved in overcoming high temperature limitations (Kaur *et al*., 2008) [10].

Materials and Methods
The present investigation was conducted at Agronomy Farm, SKN College of agriculture, Jobner (260 05´ N latitude, 750 28´ E longitude and at an altitude of 427 m above mean sea

level), Jaipur, Rajasthan, India during *rabi* season of 2013-14. The climate of this region is typically semi-arid which is characterized by the aridity and extremity of temperature fluctuations in summer and winter. During summer, maximum temperature ranges between 35-46^{0}C while in winter, it may falls down to as low as -1^{0}C. The average rainfall of this locality is approximately 400 mm, most of which is received during rainy season from July to September. The soil of the experimental field was loamy sand in texture and alkaline in reaction. The experiment consisted of two varieties Raj-4079 and Raj-4120, two dates of sowing 20th November (timely sowing) and 20th December (late sowing)] and four level salicylic acid (control, 50 ppm, 100 ppm and 150 ppm salicylic acid, thereby making sixteen treatment combinations. The treatments were randomly allotted to the plots using Fisher's random number table (Fisher, 1950). Following growth and yield attributing characters were measured and recorded at harvesting and after harvesting stages. At harvest the height and number of effective tillers were recorded in five randomly selected plants and their mean was computed. After harvest the test weight, grain, seed, straw yield, biological yield and harvest index were recorded.

Harvesting yield = Economical yield/ Biological yield*100 (Donald 1976)

Statistical analysis: The experimental data recorded for yield were statistically analysed by Panse and Sukhatme (1985). Appropriate standard error for each of the factor was worked out. Significance of differences among treatment effects was tested by "F" test. Critical difference (CD) was worked out wherever the difference was found to be significant at 5 or 1 per cent level of significance.

Results

Result of the plant height, number of effective tillers, grain yield, test weight, seed yield, biological yield and harvest index in two wheat varieties with different date of sowing.

1. **Plant height:** Data presented in table and fig. 1 showed that sowing times had significant effect on plant height of wheat. Wheat planted on 20th November recorded significantly taller plant than 20th December planted of crop. 20th December planted of crop was decreased the plant height by 4.21 per cent over 20th November planted of crop and further showed that the plant height was also differed significantly under varieties of wheat. The variety Raj-4079 produced the tallest plant (79.64 cm) followed by Raj-4120. Treatment with SA increased plant height in two different date of sowing and varieties Raj-4120 & Raj-4079. The plant height with SA treatment of 150 ppm varied from 6.36 per cent over control, SA 100 ppm varied from 13.52 per cent over control and SA 50 ppm varied from 21.58 per cent over control but lowest plant height (66.90 cm) was observed under control.
2. **Number of effective tillers per plant:** A perusal of data presented in table and fig. 1 showed that sowing times had significant effect on number of effective tillers per plant in wheat. Wheat planted on 20th November recorded significantly increased the number of effective tillers per plant than 20th December planted of crop. 20th December planted of crop was decreased the number of effective tillers per plant by 2.63 per cent over 20th November planted of crop and further showed that the number of effective tillers per plant was also differed significantly under varieties of wheat. The varietyRaj-4079 produced the highest number of effective tillers per plant (2.27) followed by Raj-4120. Treatment with SA increased number of effective tillers per plant in two different date of sowing and varieties Raj-4120 & Raj-4079. The number of effective tillers per plant with SA treatment of 150 ppm varied from 2.19 per cent over control, SA 100 ppm varied from 4.48 per cent over control and SA 50 ppm varied from 6.42 per cent over control but lowest number of effective tillers per plant (2.14) was observed under control.
3. **Grain yield per plant:** A critical examination of data (Table 1 and fig. 2) revealed that the sowing times had significant effect on grain yield per plant in wheat. Wheat planted on 20th November recorded significantly increased the grain yield per plant than 20th December planted of crop. 20th December planted of crop was decreased the grain yield per plant by 6.35 per cent over 20th November planted of crop and further indicated that the grain yield per plant was also differed significantly under varieties of wheat. The variety Raj-4079 produced the highest number of grain yield per plant (2.27) followed by Raj-4120. Treatment with SA increased grain yield per plant in two different date of sowing and varieties. The grain yield per plant with SA treatment of 150 ppm varied from 6.03 per cent over control, SA 100 ppm varied from 12.89 per cent over control and SA 50 ppm varied from 21.23 per cent over control but lowest grain yield per plant (14.17 g) was observed under control.
4. **Test weight:** A reference to data in (table 1 and fig. 2) revealed that the test weight of wheat was decreased gradually with delayed sowing. Wheat planted on 20th November recorded significantly increased the test weight than 20th December planted of crop. 20th December planted of crop was decreased the test weight by 7.51 per cent over 20th November planted of crop and further indicated that the test weight was also differed significantly under varieties of wheat. The variety Raj-4079 produced the highest test weight (42.29 g) followed by Raj-4120. Treatment with SA increased test weight in two different date of sowing and varieties. The test weight with SA treatment of 150 ppm varied from 4.78 per cent over control, SA 100 ppm varied from 14.79 per cent over control and SA 50 ppm varied from 21.88 per cent over control but lowest test weight (36.38 g) was observed under control.
5. **Seed yield:** Data (Table 2 and fig. 3) indicates that the sowing times brought out significant effect on seed yield of wheat. Wheat planted on 20th November recorded significantly increased the seed yield than 20th December planted of crop. 20th December planted of crop was decreased the seed yield by 4.83 per cent over 20th November planted of crop and further revealed that the seed yield was also differed significantly under varieties of wheat. The variety Raj-4079 produced the highest seed yield (30.77 q/ha) followed by Raj-4120. Treatment with SA increased seed yield in two different date of sowing and varieties. The seed yield with SA treatment of 150 ppm varied from 7.96 per cent over control, SA 100 ppm varied from 14.88 per cent over control and SA 50 ppm varied from 21.47 per cent over control but lowest seed yield (26.82 q/ha) was observed under control.
6. **Straw yield:** It is evident from the data (Table 2 and fig. 3) revealed that the straw yield of wheat was decreased

gradually with delayed sowing. Wheat planted on 20th November recorded significantly increased the straw yield than 20th December planted of crop. 20th December planted of crop was decreased the straw yield by 4.80 per cent over 20th November planted of crop and further revealed that the straw yield was also differed significantly under varieties of wheat. The variety Raj-4079 produced the highest straw yield (51.77 q/ha) followed by Raj-4120. Treatment with SA increased straw yield in two different date of sowing and varieties. The straw yield with SA treatment of 150 ppm varied from 4.86 per cent over control, SA 100 ppm varied from 12.69 per cent over control and SA 50 ppm varied from 18.14 per cent over control but lowest straw yield (45.32 q/ha) was observed under control.

7. **Biological yield:** A reference to data in (Table 2 and fig. 3) revealed that the biological yield of wheat was decreased gradually with delayed sowing. Wheat planted on 20th November recorded significantly increased the biological yield than 20th December planted of crop. 20th December planted of crop was decreased the biological yield by 4.81 per cent over 20th November planted of crop and further revealed that the biological yield was also differed significantly under varieties of wheat. The variety Raj-4079 produced the highest biological yield (82.54 q/ha) followed by Raj-4120. Treatment with SA increased biological yield in two different date of sowing and varieties. The biological yield with SA treatment of 150 ppm varied from 6.03 per cent over control, SA 100 ppm varied from 13.50 per cent over control and SA 50 ppm varied from 19.39 per cent control but lowest biological yield (72.14 q/ha) was observed under control.
8. **Harvest index:** Results data (Table 2) revealed that the harvest index did not differ significantly due to different date of sowing of wheat that the further indicated harvest index was not affected significantly due to different varieties and concentration of salicylic acid in wheat.
9. **Correlation analysis:** The correlation analysis indicates that most of the parameters have positive correlation with seed yield of wheat (Table 3). Plant height and number of effective tillers per plant were showed positive and significant correlations with seed yield. Correlation of grain yield, test weight, straw yield and biological yield were highly significant with seed yield. However, harvest index the response was non-significant.

Table 1: Effect of salicylic acid to mitigate the high temperature stress on plant height, number of effective tillers per plant, test weight (g) and grain yield/plant (g) in wheat

Treatments	Plant height at harvest(cm)	Number of effective tillers/plant	Test weight (g)	Grain yield/plant (g)	Test weight (g)	
Varieties						**Varieties**
Raj-4120	72.68	2.23	37.38	15.00	37.38	
Raj-4079	79.64	2.27	42.29	16.60	42.29	
S.Em.±	1.16	0.013	0.447	0.32	0.447	
C.D. (P=0.05)	3.25	0.03	1.41	0.93	1.41	
Date of sowing					Date of sowing	Date of sowing
20 November (timely sowing)	76.94	2.28	41.39	16.37	41.39	
20 December (Late sowing)	73.70	2.22	38.28	15.33	38.28	
S.Em.±	1.16	0.013	0.447	0.32	0.447	
C.D. (P=0.05)	3.25	0.03	1.41	0.93	1.41	
Salicylic acid				Salicylic acid	Salicylic acid	Salicylic acid
Control	66.90	36.38	36.38	14.17	36.38	2.14
Salicylic acid 50 ppm	72.00	38.49	38.49	15.31	38.49	2.18
Salicylic acid 100 ppm	77.20	42.66	42.66	16.37	42.66	2.23
Salicylic acid 150 ppm	82.44	44.80	44.80	17.42	44.80	2.28
S.Em.±	1.71	0.616	0.616	0.35	0.616	0.014
C.D. (P=0.05)	5.10	1.77	1.77	1.03	1.77	0.04

Table 2: Effect of salicylic acid to mitigate the high temperature stress on seed yield, straw yield, biological yield and harvest index in wheat

Treatments	Yield (q/ha)			Harvest index (%)
	Seed	**Straw**	**Biological**	
Varieties				
Raj-4120	28.21	48.21	76.42	36.91
Raj-4079	30.77	51.77	82.54	37.28
S.Em. ±	0.435	0.533	1.065	0.173
C.D. (P=0.05)	1.37	1.68	3.36	NS
Date of sowing				
20 November (timely sowing)	30.22	51.22	81.44	39.55
20 December (Late sowing)	28.76	48.76	77.52	34.84
S.Em. ±	0.435	0.533	1.065	0.173
C.D. (P=0.05)	1.37	1.68	3.36	NS
Salicylic acid				
Control	26.82	45.32	72.14	37.17
Salicylic acid 50 ppm	28.41	47.41	75.82	37.47
Salicylic acid 100 ppm	30.30	51.30	81.60	37.13

Salicylic acid 150 ppm	32.92	53.92	86.84	37.91
S.Em. ±	0.542	0.614	1.384	0.234
C.D. (P=0.05)	1.56	1.86	3.31	NS

Table 3: Simple correlation coefficients of yield attributes and yield with seed yield of wheat

Treatments	Correlation coefficient (r)
Yield v/s	
(i) Plant height	0.492**
(ii) Number of effective tillers/plant	0.622**
(iv) test weight	0.880**
(v) Straw yield	0.810**
(vi) Biological yield	0.961**
(vii) Harvest index	0.911**

Discussion

Plant yield or economic biomass production is very crucial for agriculture point of view to feed food for exponentially growing population. High temperature stress is considered as major factor for looming or yield penalty for all important major agricultural crops. The delayed sowing after 20th November high temperature caused hastening of flowering and maturity in wheat by 30 days in late sowing as compared to normal sowing conditions. Karim *et al*. (2011) [9] noted that the application of 100, 200 and 400 ppm salicylic acid increased in plant height, number of tillers/plant and shoot dry weight in wheat. Sanaa *et al.* (2006) [14] reported that salicylic acid had no significant effect on grain yield. The combination of kinetin 50 ppm and salicylic acid 20 ppm gave best result in change in growth parameter, number of effective tillers per plant, 1000-grain weight, grain weight/plant and grain yield. An experiment conducted at Egypt showed that foliar application of salicylic acid (100 mg/L) resulted in the highest increase in yield and its components (Amin *et al*., 2008) [1]. Garg *et al*. (2013) [7] reported reduction in thousand grain weight due to reduction in grain filling duration and grain growth rate with increase in temperature. In our experiment wheat variety Raj-4079 give better yield over the variety Raj-4120 with SA 150 ppm concentration under normal and late sown conditions compare to without SA with maintaining yield parameters viz. Plant height, number of effective tillers, grain yield, test weight, straw yield, biological yield and harvest index. Therefore, selection of variety Raj-4079 under treatment with SA 150 ppm are suitable for high temperature stress condition for better yield.

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