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Interactive effect of thermal environments and bio-regulators on wheat (*Triticum aestivum*)

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ABSTRACT

Wheat grain yield is affected by several biotic and abiotic factors. Among the abiotic factors heat stress is the most important factor that greatly affects the productivity of wheat. A study was carried out in loamy-sand soil to evaluate the effect of sowing at different thermal environments and its interaction with foliar spray of bio-regulators on growth indices and yield of wheat during *rabi* 2016–17 and 2017–18 at S K N Agriculture University, Jobner, Jaipur, Rajasthan. The experiment was laid out in a split plot design with four replications consisting of 24 treatments. Wheat sown at 20ºC temperature, reported maximum growth indices i.e. LAD, CGR, RGR and NAR at 30–60 DAS and 60–90 DAS which were significantly higher than D_1 (sowing at 18ºC) and D_3 (sowing at 22ºC). The significantly higher LAI was recorded under B_4 (SA @200 ppm) over all other treatments, while it remained at par with B_3, B_7 and B_8 at 60 DAS and B_6 and B_8 at 90 DAS. At 30–60 DAS and 60–90 DAS, significantly higher LAD, CGR and RGR were noticed under the treatment B_4 (SA @200 ppm) which superseded over rest of the treatments while it remained at par with B_8 except CGR at 60–90 DAS. It is concluded that salicylic acid @200 ppm may be sprayed on 20ºC temperature sown crop, plays a major role in mitigating the abiotic stress via creation of favourable micro-climate; thereby increasing the productivity.

Keywords: Bio-regulators, Growth indices, Heat stress, Sowing temperature, Wheat, Yield

The Asian countries including India are more vulnerable to climate change. The important components of climate change are decline in rainfall and rise in temperature. India is a country of tropical, sub-tropical and temperate region with annual mean temperature being 25°C, which is expected to rise about 0.21°C by 2050 (Singh and Dwivedi 2015). Wheat productivity is greatly influenced by various biotic and abiotic stresses like inter and intra-seasonal weather variability. In India, it occupied an area of about 33.61 m ha with the annual production of 106.21 million tons with an average yield of 3160 kg/ha during 2019–20 (IIWBR 2020), which is much lower than the wheat productivity (3522 kg/ha) at global level (FAO 2020). To feed the growing population of the world higher wheat productivity is need of the hour to avoid hunger and malnutrition. The scientific assessment report of the Intergovernmental Panel on Climate Change showed that between 1880–2012, globally average temperature increased by 0.85°C. The growth and development of wheat crop apart from being governed by genetic characteristics, largely depends on a number of environment factors which vary under sowing at different thermal environments (dates) (Yajam and Madani 2013). While, the delayed sowing shortens the span of crop growth and such crop suffers yield penalty due to sudden rise in temperature at the later stages of the crop growth. This penalty on grain yield can be minimized by changing the sowing time and foliar application of bio-regulators.

Bio-regulators plays an important role in the regulation of plant developmental processes and signalling networks as they are involved either directly or indirectly in a wide range of biotic and abiotic stress responses and tolerance in plants. Salicylic acid (SA) is a phenolic compound involved in the regulation of growth and development of plants and their responses to biotic and abiotic stress factors. SA is also involved in the regulation of important plant physiological processes such as photosynthesis, nitrogen metabolism, proline (Pro) metabolism, production of glycine betaine (GB), antioxidant defence system and plant water relations under stress conditions and, thereby provides protection in plants against abiotic stresses (Khan *et al*. 2013). The temperature rise would be mitigated through applying bio-regulators as per scientific evidence obtained so far. Keeping this in mind, the present investigation was conducted.

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MATERIALS AND METHODS

The experiment was conducted during *rabi* 2016–17 and 2017–18 at the Agronomy farm of S.K.N. College of Agriculture, Jobner, Rajasthan. The research farm is 26° 05' North latitude, 750° 28' east longitude and at an altitude of 427 meters amsl. The location is characterized by a semi-arid type of climate with hot summers and harsh cold winters. The average maximum and minimum temperatures showed significant fluctuations in summer and winter, respectively. The day temperatures may reach up to 48ºC during summer. May is the hottest month and January is the coolest month. During winter the night temperature sometimes go down even to 0ºC. The average annual rainfall is 350–450 mm and approximately 80% of which realized during the south-western monsoon season (June to September). The soil of the experimental field was loamy sand with alkaline reaction (8.15 *p*H), low in available nitrogen (130.3 kg N/ha), available phosphorus (15.2 kg P_2O_5/ha) and medium in potassium (149 kg K_2O/ha). Meteorological data have also been recorded during crop seasons of 2016–17 and 2017–18. The rainfall was negligible during both the years. The maximum temperature ranged from 34.8–20.4ºC during 2016–17 and 34.0–23.6ºC during 2017–18 and minimum temperature ranged from 02.8–15.1ºC during 2016–17 and 01.4–13.5ºC during 2017–18.

Experimental treatments and procedures: The experiment was laid out in split plot design with three sowing dates at different thermal environments (22°C, 20°C and 18°C) allotted to main plot and eight foliar spray of bio-regulators (control, water spray, salicylic acid @100 ppm, salicylic acid @200 ppm, thiosalicylic acid @100 ppm, thiosalicylic acid @200 ppm, thioglycolic acid @100 ppm and thioglycolic acid @200 ppm) in sub-plots replicated four time. The field was cultivated thoroughly with the help of tractor mounted cultivator. After that the main plots were divided into sub plots. The sowing was done at a depth of 4–6 cm keeping a row to row spacing of 22.5 cm in order to have recommended planting density. The seed rate of wheat variety Raj-3765 was 100 kg/ha. Seed treatment was also done before sowing with Fipronil @6 ml/kg seed. The recommended dose of nitrogen, phosphorus and potassium was 120, 40 and 0 kg/ha, respectively. Fifty percent N and 100% P were applied as basal dose and 50% N was applied with the first irrigation for all the sowing at different thermal environments.

Growth Parameters

Leaf Area Index (LAI): LAI is the ratio of leaf area to ground area and calculated as per the formula of Watson (1952).

Leaf Area Duration (LAD): LAD is a measure of a plant's ability to produce and maintain leaf area and is obtained by integrating the leaf area index over a crop growth period. This is usually expressed in days or weeks (Power *et al*. 1967).

Crop growth rate (CGR): CGR is the rate of dry matter production per unit ground area per unit time. It was calculated according to Watson (1952) and expressed in g/m/day.

Relative growth rate (RGR): It is the rate of increase in the dry weight per unit dry weight already present and was calculated using the formula of Blackman (1919) and expressed as g/g/day.

Net assimilation rate (NAR): It is the rate of dry weight increase per unit leaf area per unit time (g/m^2 leaf area/day) and was calculated as suggested by Gregory (1926).

Yield: Crop was harvested and weighed for biological yield after sun drying. The product was ground and after proper cleaning weighed to record grain yield. The straw yield was calculated by subtracting the grain yield from the biological yield. Crop was expressed in kg/ha with a moisture content of 14%.

Harvest index: Harvest index was measured as the ratio of economic yield to biological yield.

Statistical analysis: All the observation during individual years as well as in pooled analysis was statistically analysed for their test of significance using the F-test (Gomez and Gomez 1984). The significant of difference between treatment means were compared with t critical difference at 5% level of probability.

RESULTS AND DISCUSSION

Effect of sowing at different thermal environments: A critical examination of pooled data revealed that sowing at different thermal environments significantly influenced the growth indices and yield of wheat. Maximum leaf area index (0.256, 2.28 and 4.51 at 30, 60 and 90 DAS, respectively) was observed with sowing at 20ºC (D_2) which was at par with D_1 (sowing at 22ºC) at 60 DAS but significantly superior over D_3. The varying treatments of sowing at thermal environments also caused significant variation on growth indices i.e. LAD, CGR, RGR and NAR. At 30–60 DAS and 60–90 DAS, significantly higher LAD (38.0 and 101.7), CGR (1.26 and 3.31 g/m^2/day), RGR (37.8 and 33.1 mg/g/day) and NAR (7.22 and 4.54 g/m^2 leaf area/day) were noticed in D_2 (sowing at 20ºC) over D_1 and D_3. Regarding yield, the treatment D_2 (sowing at 20ºC) recorded the maximum grain (3771 kg/ha), straw (4880 kg/ha) and biological (8651 kg/ha) yield proved significantly superior over D_1 (sowing at 22ºC) and D_3 (sowing at 18ºC) (Table 1). Jat *et al*. (2013) and Thorat *et al*. (2016) also reported that mid-November (sowing at 20ºC temperature) sown crop recorded maximum growth indices (LAI, LAD, CGR, RGR and NAR) which may be attributed to favourable climatic conditions throughout the life cycle and thus the different phases of plant life were accomplished at appropriate timings, which ultimately improved the yield. The treatment D_3 (sowing at 18ºC) recorded significantly lower growth indices and yield of wheat. When the crop was sown late, there would have been low temperature in the beginning, but after February onward the temperature starts increasing very fast and the plants do not get favourable environment conditions to express their full potential. The comparable results of declining grain yield with late sowing of wheat were also noticed by Amrawat *et al*. (2013) and Lakhran *et al*. (2015).

Table 1 Effect of sowing at different thermal environments and foliar spray of bio-regulators on leaf area index and leaf area duration (pooled data of two years)

Treatment	Leaf area index (LAI)			Leaf area duration (LAD)	
	30 DAS	60 DAS	90 DAS	30–60 DAS	60–90 DAS
Sowing at different thermal environments					
D_1: 22°C	0.237	2.15	4.31	35.7	96.8
D_2: 20°C	0.256	2.28	4.51	38.0	101.7
D_3: 18°C	0.229	1.89	4.16	31.8	90.7
SEm±	0.006	0.04	0.04	0.61	1.14
CD (P=0.05)	NS	0.17	0.18	1.88	3.53
Foliar spray of bio-regulators					
B_1: Control	0.223	2.06	4.20	34.2	93.9
B_2: Water spray	0.228	2.03	4.23	33.9	93.9
B_3: SA @100 ppm	0.246	2.17	4.35	36.3	97.9
B_4: SA @200 ppm	0.268	2.29	4.54	38.4	102.5
B_5: TSA @100 ppm	0.233	1.82	4.02	30.8	87.6
B_6: TSA @200 ppm	0.247	1.98	4.44	33.4	96.3
B_7: TGA @100 ppm	0.229	2.20	4.32	36.4	97.8
B_8: TGA @200 ppm	0.250	2.28	4.47	37.9	101.3
SEm±	0.01	0.04	0.03	0.52	0.96
CD (P=0.05)	NS	0.13	0.12	1.46	2.70
Interaction (D × B)					
SEm±	0.02	0.08	0.07	0.90	1.67
CD (P=0.05)	NS	NS	NS	NS	NS

Effect of foliar spray of bio-regulators: Growth indices such as LAI, LAD, CGR, RGR and NAR as well as grain, straw, biological yield and harvest index of wheat were significantly influenced by foliar spray of bio-regulators. The significantly higher LAI (0.268, 2.29 and 4.54 at 30, 60 and 90 DAS, respectively) was recorded under B_4 (SA @200 ppm) over all other treatments, while it remained at par with B_3, B_7 and B_8 at 60 DAS and B_6 and B_8 at 90 DAS. Similarly, during 30–60 DAS and 60–90 DAS, significantly higher LAD and CGR were also noticed under the treatment B_4 (SA @200 ppm), which superseded over rest of the treatments, while it remained at par with B_8 except CGR during 60–90 DAS. Treatment B_4 observed the maximum RGR and proved significantly superior over rest of the treatments except B_6, B_7 and B_8 at 30–60 DAS and B_8 at 60–90 DAS. However, the significantly higher NAR at 30–60 DAS was recorded under the treatment B_8 (TGA @200 ppm) over rest of the treatments while it remained at par with B_5 and B_7. While at 60–90 DAS, the treatment B_4 (SA @200 ppm) noticed the maximum NAR and being at par with B_8, superseded over rest of the treatments (Table 2). Overall enhancement in above parameters seems due to dynamic vegetative growth of plants which eventually resulted in higher leaf area, growth indices and increased photosynthesis. These findings are in close conformity to those of Nathawat *et al*. (2016).

Though, the treatment B_4 produced significantly higher grain, straw and biological yield with the corresponding values of 3874, 4998 and 8873 kg/ha, respectively which was significantly superior over rest of the treatments except B_6 (thiosalicylic acid @200 ppm) and B_8 (thioglycolic acid @200 ppm). The maximum harvest index was also calculated under B_4 (salicylic acid @200 ppm). It might be due to foliar spray treatments which improved crop growth in terms of leaf area, duration and growth rate, ultimately greater the yield which was the collective result of enhanced growth. This subsequently resulted in the noted growth in crop yield (Azimi *et al.* 2013 and Lakhran *et al*. 2021). The significantly lowest growth indices and yield were observed with the treatment B_1. The increase in yield due to B_4 treatment was 19.94, 15.37% in grain yield, 17.49, 13.64% in straw yield and 18.54, 14.40% in biological yield over B_1 (control) and B_2 (water spray), respectively. These outcomes are in agreement with the results of Azimi *et al.* (2013).

From present study, it is concluded that growth and yield of wheat were significantly affected by sowing at different thermal environments and foliar spray of bio-regulators. For wheat, it is recommended that the crop be sown at a prevailing average temperature of 20ºC and a leaf spray of salicylic acid (200 ppm) at the tillering and seedling stages to obtain high yields in accordance with their environmental climatic conditions must be done.

Table 2 Effect of sowing at different thermal environments and foliar spray of bio-regulators on crop growth rate, relative growth rate and net assimilation rate (pooled data of two years)

Treatments	Crop growth rate ($g/m^2/day$)		Relative growth rate (mg/g/day)		Net assimilation rate (g/m^2 leaf area/day)	
	30–60 DAS	60–90 DAS	30–60 DAS	60–90 DAS	30–60 DAS	60–90 DAS
Sowing at different thermal environments						
D_1: 22°C	1.04	3.05	34.3	28.9	5.43	4.41
D_2: 20°C	1.26	3.31	37.8	33.1	7.22	4.54
D_3: 18°C	0.86	2.80	30.4	25.1	4.13	4.34
SEm±	0.01	0.01	0.23	0.14	0.13	0.03
CD (P=0.05)	0.02	0.03	0.70	0.44	0.40	0.09
Foliar spray of bio-regulators						
B_1: Control	0.91	2.69	32.2	28.4	4.92	4.00
B_2: Water spray	0.96	2.84	32.9	29.1	5.29	4.23
B_3: SA @100 ppm	1.03	3.21	34.0	29.4	5.38	4.57
B_4: SA @200 ppm	1.18	3.46	35.4	30.1	5.67	4.72
B_5: TSA @100 ppm	1.02	2.83	33.6	28.2	5.92	4.55
B_6: TSA @200 ppm	1.08	3.00	34.8	28.8	5.69	4.42
B_7: TGA @100 ppm	1.09	3.02	35.2	28.5	5.82	4.30
B_8: TGA @200 ppm	1.15	3.38	35.2	29.8	6.08	4.64
SEm±	0.01	0.01	0.26	0.21	0.10	0.05
CD (P=0.05)	0.03	0.04	0.73	0.58	0.28	0.14
Interaction (D × B)						
SEm±	0.01	0.02	0.42	0.36	4.00	0.08
CD (P=0.05)	NS	NS	NS	NS	4.23	NS

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