Indian Journal of Agronomy **66** (1): 19–24 (March 2021)

Research Paper

Effect of thermal environment and bioregulators on productivity, profitability and nutrient uptake of wheat (*Triticum aestivum*) under semi-arid conditions of Rajasthan

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Received: December 2019; Revised accepted: December 2020

ABSTRACT

A field study was carried out at Agronomy Farm, Jobner, Jaipur, Rajasthan during the rainy (*rabi*) seasons of 2016–17 and 2017–18, to evaluate the effect of sowing at different thermal environments and foliar spray of bio-regulators in wheat (*Triticum aestivum* L.). The experiment was laid out in split plot design with 4 replications, consisting of 24 treatments, namely, 3 sowing temperature (22°C, 20°C and 18°C) in main plot and eight bio-regulators (control, water spray, salicylic acid @ 100 ppm, salicylic acid @ 200 ppm, thio salicylic acid @ 100 ppm, thio salicylic acid @ 200 ppm, thioglycolic acid @ 100 ppm and thioglycolic acid @ 200 ppm) in subplots. The pooled results showed that crop sown at 20°C temperature exhibited the maximum dry-matter accumulation, grain yield (3.8 t/ha), harvest index (43.58 %), nitrogen uptake (65.1 kg/ha by grain and 30.4kg/ha by straw), phosphorus uptake (19.8 kg/ha by grain and 8.4 kg/ha by straw) and potassium uptake (18.5 kg/ha by grain and 82.6 kg/ha by straw) and net returns (₹69 × 10^3/ha) of wheat. Among the bio-regulators treatments an application of salicylic acid @ 200 ppm (B_4) resulted significantly higher grain yield (3.9 t/ha), harvest index (43.68%), nitrogen uptake (69.9 kg/ha by grain and 32.0 kg/ha by straw), phosphorus uptake (21.2 kg/ha by grain and 8.6 kg/ha by straw) and potassium uptake (19.9 kg/ha by grain and 88.7 kg/ha by straw) and net returns (₹72.1 × 10^3/ha) and proved superior to all the above parameters. The interactive effect of treatment combination, sowing at 20°C along with the application of SA @ 200 ppm) recorded the significantly higher grain yield (4.1 t/ha) and net returns (₹75.8 × 10^3/ha).

Key words: Bio-regulators, Net returns, Nutrient uptake, Sowing temperature, Wheat, Yield

Wheat is an important winter cereal, contributing about 32% of the total food grain production in India. In India, wheat occupies an area of about 33.61 million hectare (m ha) with annual production of 106.21 million tones (mt) having a productivity of 3160 kg/ha during 2019–20 (DWR, 2020a). In Rajasthan, the production reached the level of 12.19 m t with productivity of 3,676 kg/ha with an acreage of 3.31 m ha (ICAR, 2020b). Modeling results indicated that wheat production will be affected by climate change in the developing countries than the developed countries (Dixon *et al.*, 2009). However, it is evident that the potential of new cultivars have not been fully utilized in most of the developing countries (Kajla *et al.*, 2015) due to improper agronomic practices, poor management and unfavourable weather conditions such as high temperature, drought and salinity (Rajanna *et al.*, 2018; Rana *et al.*, 2018).

Climate change and its variability are emerging as the major challenges likely to impact the sustainability of the production system of Indian agriculture. It is severely affecting cereal production across the world, through increase in CO_2 concentration and temperature, resulting in heat stress (Rajanna *et al*., 2019). Among various factors responsible for low yield of wheat crop in the country, sowing temperature and foliar spray of bio-regulators are of primary importance. Time of planting is one of the most important non-monetary inputs for optimizing the growth according to prevailing agro-climatic conditions and genotypes whenever the temperature plays an important role in growth, development and yield of wheat crop. Timely sowing of wheat crop generally results in higher yield as compared to early-and late-sown crop (Rana *et al.,* 2018).

Another programmatic approach is the exogenous application of stress signaling molecules and stress alleviating compounds based on their specific properties and function

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to improve germination, photosynthesis and consequent growth in a number of various agronomic crops (Godara *et al.,* 2012; Shivran *et al*., 2019). Bio-regulators such as salicylic acid, thio-salicylic acid, thiourea, thioglycolic acid and abscisic acid, regulate the protective responses of plants to both biotic and abiotic stresses independently. Application of bio-regulator in low concentration is critical for plant metabolism by reducing environmental stresses in plants (Singh and Meena, 2020). Their application, therefore, holds a great potential as a stress management tool for providing tolerance to cereal crops against environmental pressures consequently aids to enhance potential crop yield. Hence, this research was carried out to determine the suitable sowing temperature and foliar spray of bio-regulator for wheat and to assess the mitigation of high temperature stress in wheat sown under different thermal environments.

MATERIALS AND METHODS

A field experiment was carried during the winter (*rabi*) seasons of 2016–17 and 2017–18 at the Agronomy farm of Sri Karan Narendra College of Agriculture, Jobner (26º 05' N, 75º 28' E, 427 m above mean sea-level), Rajasthan. The maximum temperature ranged from 20.4 to 34.8ºC during 2016–17 and 23.6 to 34.0ºC during 2017–18 and minimum temperature from 02.8 to 15.1ºC and 01.4 to 13.5ºC respectively. The annual rainfall of 24.8 mm and 5.6 mm was received during both the crop seasons respectively. The soil of the experimental field was loamy sand with 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). The experiment was laid out in split plot design, comprising different thermal environments for sowing (D_1, 22°C; D_2, 20°C and D_3, 18°C) in main plots and 8 foliar spray of bio-regulators (B_1, control; B_2, water spray; B_3, salicylic acid @ 100 ppm; B_4, salicylic acid @ 200 ppm; B_5, thiosalicylic acid @ 100 ppm; B_6, thiosalicylic acid @ 200 ppm; B_7, thioglycolic acid @ 100 ppm and B_8, thioglycolic acid @ 200 ppm) in subplots replicated 4 times. These bio-regulators were sprayed by using foot sprayer at tillering and ear-emergence stage of wheat. Seed rate of 100 kg ha of wheat variety 'Raj 3765' was used in this study. Sowing was done with 'pora' method in rows, keeping 22.5 cm spacing with approximate depth of 5 cm at different thermal environments. The seeds were treated with Fipronil @ 6 ml/kg seed at the time of sowing. Irrigation was applied at the critical stages of crop growth. Half dose of nitrogen @ 120 kg/ha through urea and uniform dose of phosphorus @ 40 kg/ha through diammonium phosphate were applied at the time of sowing. Remaining nitrogen was top-dressed at 20–25 days after sowing.

For dry-matter calculation, 5 plants were randomly selected from sampling rows of each plot at physiological maturity. Stem, leaves and ears were separated and kept in separate paper bags. These samples were sun-dried for few days and then transferred to hot-air oven for drying at 65 °C till constant weight was obtained. Dry weight of stem, leaves, ears and total dry-matter accumulation were recorded. The crop was harvested from a plot of 3.0 m × 2.25 m (6.75 m^2) separately, tied in bundles and tagged. These bundles were left on the threshing floor for sun drying. After drying, the harvested produce of each plot was weighed to obtain biological yield/plot. Threshing was done by beating with wooden sticks and winnowed traditionally. The produce thus obtained from each plot was weighed and verified as the grain yield per plot. The straw yield was obtained by deducting the weight of grain yield from biological yield. Harvest index was computed by dividing grain yield with biological yield and expressed in percentage. The grain and straw samples collected at threshing from each plot were air-dried and ground to a fine powder for estimation of nutrient uptake. The total cost of cultivation was deducted from the gross returns to work out the net income for each treatment combination and was recorded accordingly. The benefit: cost ratio was calculated for each treatment by dividing gross returns with cost. All observations for separate years and the pooled data were statistically analysed for their significance test by using the F-test.

RESULTS AND DISCUSSION

Effect of sowing at different thermal environments

Sowing at different thermal environments significantly influenced the dry-matter accumulation (DMA) at physiological maturity, yield, nutrient uptake and economics of wheat. Sowing at 20 °C (D_2) recorded the maximum dry-DMA by leaves, stem, ear and total DMA at physiological maturity, grain and straw yields and proved significantly superior to rest of the treatments but it was at par with D_1 (sowing at 22 °C) (Table 1). The increase in yield owing to the above treatment, i.e. D_2, was 5.28 and 9.72% grain yield and 4.79 and 7.65% straw yield, respectively, over D_1 and D_3 treatment. The significantly lowest yield parameters were noted with the treatment D_3 (sowing at 18 °C). The harvest index of wheat was not influenced significantly by thermal environment treatments. The higher yield in mid-November (sowing at 20°C temperature) sown crop may be attributed to favourable climatic conditions for longer duration, harnessing of more solar radiation as evident through higher dry-matter production and better partitioning of photosynthates, which in turn has increased the yield (Jat *et al*., 2013; Rajanna and Dhindwal, 2019).

Wheat sowing at 20 ºC (D_2) recorded significantly higher N, P and K uptake by grain and straw and net returns (₹69 × 10^3/ha) and benefit: cost ratio (2.93) and also proved superior to D_1 and D_3 treatments (Table 2). The treatment D_3 (sowing at 18ºC) noted lowest N, P and K uptake by grain and straw, net returns and benefit: cost ratio. The lower uptake and economics might be due to development of root-system and leaf canopy which probably affected adversely by prevailing temperature under untimely sown wheat. Consequently, the crop was not able to absorb nutrients optimally as compared to timely sown crop (Mukherjee, 2012). The significantly higher economics recorded under the treatment D_2 was possibly owing to proportionately larger increase in grain and straw yield as compared to the lower cost involved which contributed to higher net returns and benefit: cost ratio (Meena *et al*., 2015; Kumar *et al*., 2016).

Effect of foliar spray of bio-regulators

Dry-matter accumulation at physiological maturity, grain, straw yields, harvest index, nutrient uptake and economics of wheat were significantly influenced by foliar spray of bio-regulators. The treatment B_4 (salicylic acid @ 200 ppm) recorded the maximum dry-matter accumulation by leaves, stem, ear and total DMA at physiological maturity which superseded the remaining treatments while it was at par with B_8 in respect to leaves DMA (Table 1). The quantum increase in yield owing to B_4 treatment was 19.94 and 15.37% in grain yield and 17.49 and 13.64% in straw yield over B_1 (control) and B_2 (water spray) respectively. Similarly, the significantly higher grain, and straw yields were observed under the application of salicylic acid @ 200 ppm with the corresponding values of 3.9 and 5.0 t/ha, respectively, being at par with B_6 (thiosalicylic acid @ 200 ppm) and B_8 (thioglycolic acid @ 200 ppm) proved significantly superior to rest of the treatments. The treatment B_4 (SA @ 200 ppm) significantly increased the harvest index over the remaining treatments. The significantly lowest DMA and yield were noted with the treatment B_1. Thus, overall improvement in growth parameters under SA, TSA and TGA application appears to be on account of photosynthetic efficiency by virtue of improvement in total chlorophyll content, greater developed assimilating apparatus (flag-leaf area), ultimately resulted in increased dry-matter accumulation and yield (Nathawat *et al*., 2016; Shivran *et al*., 2019).

Significantly maximum N, P and K uptake by grain and straw, respectively, were recorded under treatment B_4 (SA @ 200 ppm) which superseeded rest of the treatments, while it remained at par with B_8 remained (TGA @ 200 ppm) except for N uptake by straw which at par with B_6 and B_8. The higher net returns (₹72.1 × 10^3/ha) and benefit: cost ratio (3.04) were obtained under the treatment B_4 which proved significantly superior over the other treat-

Table 1. Effect of sowing at different thermal environments and foliar spray of bio-regulators on dry-matter accumulation (DMA) at physiological maturity, yield and harvest index of wheat (pooled data of 2 years)

Treatments	DMA (g/plant) at physiological maturity				Yield (t/ha)		Harvest index (%)
	Leaves	Stem	Ear	Total	Grain	Straw	
Sowing at different thermal environments							
D_1, 22ºC	0.96	4.93	6.04	11.93	3.6	4.7	43.50
D_2, 20ºC	0.98	4.96	6.06	11.97	3.8	4.9	43.58
D_3, 18ºC	0.93	4.90	5.96	11.83	3.4	4.5	43.08
SEm±	0.01	0.02	0.01	0.02	0.03	0.03	0.12
CD (P=0.05)	0.02	0.05	0.02	0.06	0.12	0.11	NS
Foliar spray of bio-regulators							
B_1, Control	0.86	4.50	5.29	10.65	3.2	4.3	43.14
B_2, Water spray	0.90	4.63	5.46	10.99	3.4	4.4	43.23
B_3, SA @ 100 ppm	0.97	5.00	6.12	12.09	3.4	4.5	43.47
B_4, SA @ 200 ppm	1.05	5.36	6.81	13.22	3.9	5.0	43.68
B_5, TSA @ 100 ppm	0.91	4.75	5.73	11.39	3.6	4.7	43.28
B_6, TSA @ 200 ppm	0.99	5.11	6.32	12.42	3.8	4.9	43.50
B_7, TGA @ 100 ppm	0.93	4.88	5.91	11.71	3.6	4.8	43.15
B_8, TGA @ 200 ppm	1.03	5.25	6.53	12.81	3.9	5.0	43.63
SEm±	0.01	0.02	0.02	0.02	0.05	0.06	0.14
CD (P=0.05)	0.04	0.05	0.05	0.06	0.15	0.18	0.38
Interaction (D × B)							
SEm±	0.01	0.03	0.01	0.04	0.09	0.11	0.17
CD (P=0.05)	NS	NS	NS	NS	0.26	NS	NS

NS, Non-significant

Table 2. Effect of sowing at different thermal environments and foliar spray of bio-regulators on nutrient uptake and economics of wheat (pooled data of 2 years)

Treatments	Nutrient uptake (kg/ha)						Economics	
	Nitrogen		Phosphorus		Potassium		Net returns (₹×10³/ha)	Benefit: cost ratio
	Grain	Straw	Grain	Straw	Grain	Straw		
Sowing at different thermal environments								
D_1, 22°C	57.4	26.8	17.0	7.7	15.8	73.1	63.9	2.79
D_2, 20°C	65.1	30.4	19.8	8.4	18.5	82.6	69.0	2.93
D_3, 18°C	54.5	24.0	14.7	7.0	13.6	70.2	60.2	2.69
SEm±	1.6	0.7	0.5	0.2	0.5	1.7	1.0	0.03
CD (P=0.05)	4.8	2.0	1.6	0.6	1.7	5.4	3.0	0.08
Foliar spray of bio-regulators								
B_1, Control	50.3	21.3	12.9	6.4	11.8	64.7	55.8	2.63
B_2, Water spray	54.1	23.8	14.7	6.9	13.7	69.0	58.3	2.65
B_3, SA @ 100 ppm	54.7	26.6	16.9	7.4	15.6	69.9	60.1	2.70
B_4, SA @ 200 ppm	69.9	32.0	21.2	8.6	19.9	88.7	72.1	3.04
B_5, TSA @ 100 ppm	56.7	25.7	16.0	7.5	14.8	73.1	63.9	2.78
B_6, TSA @ 200 ppm	61.2	29.3	18.7	8.3	17.3	78.1	68.8	2.88
B_7, TGA @ 100 ppm	58.2	27.4	17.1	7.8	16.0	75.1	65.8	2.82
B_8, TGA @ 200 ppm	66.5	30.6	19.9	8.4	18.6	83.8	70.1	2.90
SEm±	2.0	1.1	0.7	0.3	0.8	2.4	1.3	0.04
CD (P=0.05)	5.6	3.0	2.1	0.8	2.2	6.7	3.7	0.10

ments and remained at par with B_6 and B_8 treatment in respect to net returns. The lowest nutrient uptake of N, P and K by grain and straw; net returns and benefit: cost ratio were recorded in the B_1 (control). Application of growth regulator might have helped in improvement of metabolic processes of plants, growth and development owing to greater absorption of nutrients from rhizosphere, might be due to metabolic role of SH-group in root physiology and biochemistry (Premaradhya *et al.,* 2018). The cost involved under this treatment was lower than its additional income, hence, higher yield coupled with less investment led to more net returns (Premaradhya *et al.,* 2018).

Interaction effect

Data revealed that effect between sowing at different thermal environments and foliar spray of bio-regulators was found to be non-significant with regard to dry-matter accumulation, straw yield, harvest index and nutrient uptake of wheat. While interaction effect of sowing at different thermal environments and foliar spray of bio-regulator treatments on grain yield and economics of wheat was found to be significant (Table 3; Figs 1, 2). The treatment combination, D_2B_4 (sowing at 20°C along with the application of SA @ 200 ppm) resulted in the significantly higher grain yield (4.1 t/ha), net returns (₹75.8 × 10³/ha) and benefit: cost ratio (3.14). The lowest grain yield (3.0 t/ha), net returns and benefit: cost ratio were recorded under D_3B_2. Sowing at optimum thermal regime in concurrence with foliar spray of bio-regulators played key role in more photosynthesis owing to metabolic activities in the plant and translocation of photosynthates to the new developing sinks might be the possible reasons for the above interactions as reported by Muhal and Solanki (2015).

Table 3. Interaction effect of sowing at different thermal environments and foliar spray of bio-regulators on grain yield of wheat (pooled data of 2 years)

Treatment (Foliar spray of bio-regulators)	Sowing at different thermal environments		
	D_1: 22 °C	D_2: 20 °C	D_3: 18 °C
B_1, Control	3.1	3.3	3.1
B_2, Water spray	3.4	3.9	3.1
B_3, SA @ 100 ppm	3.5	3.4	3.4
B_4, SA @ 200 ppm	3.8	4.1	3.8
B_5, TSA @ 100 ppm	3.5	3.8	3.4
B_6, TSA @ 200 ppm	3.9	3.9	3.6
B_7, TGA @ 100 ppm	3.6	3.7	3.7
B_8, TGA @ 200 ppm	3.9	4.0	3.6
SEm±	0.09		
CD (P=0.05)	0.26		

It can be concluded that the higher productivity and profitability of wheat (var. 'Raj 3765') can be obtained when the crop sown at 20°C with application of salicylic acid @ 200 ppm under semi-arid eastern plains zone of Rajasthan and this treatment proved viable option for farmers.

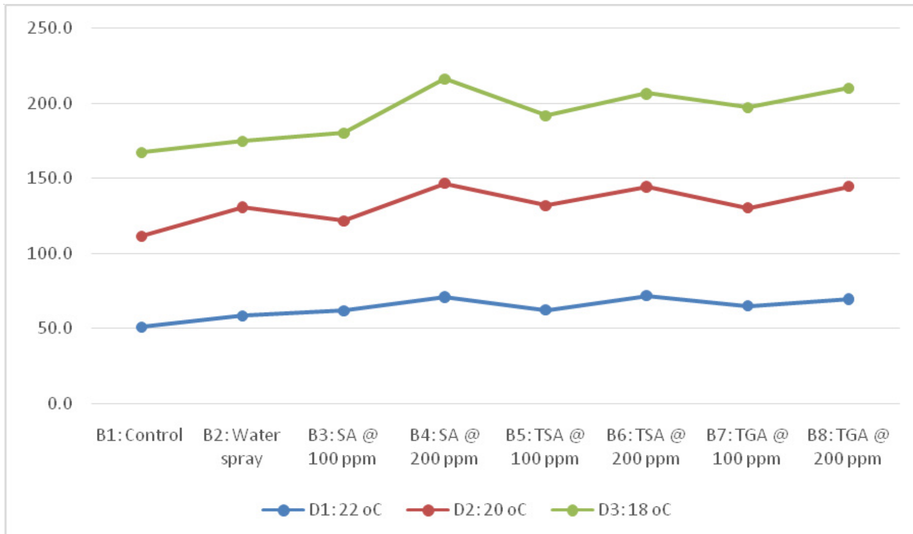

Fig. 1. Interaction effect of sowing at different thermal environments and foliar spray of bio-regulators on net returns (pooled over 2 years)

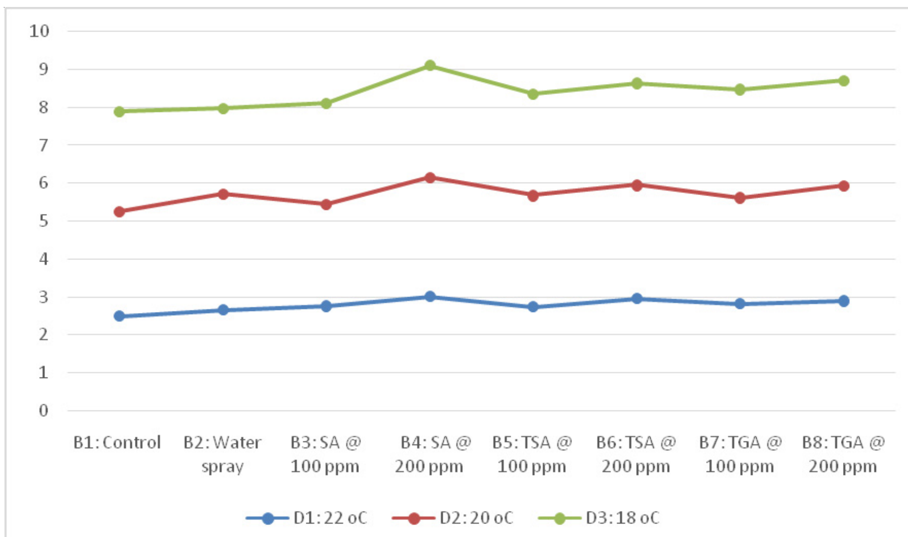

Fig. 2. Interaction effect of sowing at different thermal environments and foliar spray of bio-regulators on benefit: cost ratio (pooled over 2 years)

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