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Productivity and Nutrient Content of Wheat (*Triticum aestivum* L.) as Influenced by Sowing Temperatures and Bio-regulators

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A field experiment was carried out during *rabi* seasons of 2016-17 and 2017-18 at Agronomy Farm, S.K.N. Agriculture University, Jobner, Jaipur, Rajasthan, to obtain a suitable combination of sowing at different thermal regimes and foliar sprays of bio-regulators. The experiment was conducted in a split-plot design with four replications. The main plot treatments comprised three sowings, viz. 22 ºC, 20 ºC and 18 ºC and subplots consisted of eight treatments of bio-regulators, viz. control, water spray, SA @ 100 ppm, SA @ 200 ppm, TSA @ 100 ppm, TSA @ 200 ppm, TGA @ 100 ppm and TGA @ 200 ppm. Crop sown at 20 ºC resulted in significantly highest yield and nutrient content over 22 ºC and 18 ºC. Among bio-regulators, an application of salicylic acid @ 200 ppm registered significantly highest yield and nutrient content in grain and straw of wheat, thus, hold a great promise in wheat production under heat stress.

Introduction

Wheat (*Triticum aestivum* L.) is one of the chief sources of diet by providing half of the dietary protein and more than half of the calories to the rising population of India. As a consequence, scientists are always focusing to produce higher yields to feed the nation (Khan *et al.*, 2015). Wheat is grown in India on 33.61 Mha and produces of 106.21mt with national average yield of 3160 kg/ha during 2019-20 (Anonymous, 2020a). In Rajasthan, the production reached the level 12.19 m t with productivity of 3676 kg/ha and acreage 3.31 m ha (Anonymous, 2020b). In developing countries, climatic variability can change Climate (abiotic stresses) causing strong physiological, biochemical, morphological, and molecular changes that negatively influence plant growth, quality and productivity (Meena *et al.*, 2016). Among them, heat stress is a global anxiety that drastically reduces the yield and quality of wheat (Lal, 2013). In this situation, several factors have a significant role in improving wheat yield, such as early and on-time sowing, judicious use of inputs and stress alleviating chemicals (Meena *et al.*, 2017).

Under the late sowing of wheat, applied inputs are not efficiently utilized which resulted into the yield declined by one per cent every day (Khan *et al.,* 2010). Consequently, all the growth stages, such as seed emergence, tillering, flowering, and grain filling, are negatively affected by the shortened crop growth period. A rise in temperature leads to leaf senescence by reducing the optimum growth period resulting in a low photosynthetic rate (Sattar *et al.,* 2010).

Bio-regulators (salicylic acid, thio salicylic acid and thio glycolic acid) regulate physical and physiological activities of the plants under adverse conditions (Agarwal *et al.,* 2017). Salicylic acid is an important signaling molecule naturally occurs in plants as hormone and aids to tolerance against environmental stresses such as salinity, chilling, drought, heat heavy metal toxicity stress (Singh *et al.,* 2020). The plant photosynthetic effectiveness and canopy photosynthesis are increased by the spray of thio salicylic acid and TGA due to presence of S-H group as an integral constituent of these thiols (Shivran *et al.,* 2019). They improve photosynthetically leaf surface area during vegetative phase in cereals by delaying senescence. Application of bio-regulators also increases the uptake and content of nutrients (N, P and K) as compared to control under heat stress (Vazirmehar and Rigi, 2014). Therefore, the present research aims to assess the effect of sowing at different thermal environments and foliar spray of bio-regulators on productivity and nutritional composition of wheat under the era of climate change.

Materials and Methods

An experiment was carried out during *rabi* seasons of 2016-17 and 2017-18 at the Agronomy Farm of S.K.N. College of Agriculture, Jobner situated at latitude of 26^0 05' North, longitude of 75^0 28' East and at an altitude of 427 metres above mean sea level. The site of the experiment is cold winter, hot and dry summer which is semi-arid type climate with 400 mm mean annual normal rainfall, of which 80% is received during July-September through south-west monsoon. The soil texture of the field was loamy sand with 8.25 pH, 1.24 dS/m EC, 0.22 % O.C. 130.3 kg/ha available N (Subbiah and Asija, 1956), 15.2 kg/ha available P (Olsen *et al.,* 1954) and 149 kg/ha available K (Jackson, 1973). Field experiment was conducted in four times replicated split plot design with 24 treatments, which consisting of three sowing at different thermal environments, viz. D_1 (22 ^oC), D_2 (20 ^oC), D_3 (18 ^oC) and eight foliar spray of bio-regulators, viz. 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. Bio-regulators were sprayed by using foot sprayer at tillering and ear emergence stages of crop growth.

The wheat cultivar 'Raj 3765' was sown during the experimentation, by pora method using 100 kg/ha seed rate with the 22.5 cm row spacing. The recommended dose of N (120 kg/ha) was applied in two splits, half dose before sowing and remaining half dose with first irrigation. The entire dose of phosphorus (40 kg P_2O_5/ha) was incorporated into the soil as basal just before sowing of the crop. Urea and DAP were broadcasted for nitrogen and phosphorus application. Six irrigations were given during entire life cycle of crop. Harvesting was done manually and after threshing, cleaning and drying, the grain and straw yields of wheat was calculated and expressed in kg/ha. According to recommendations, all other cultural practices were carried out. At the time of threshing, grain and straw samples were carried from each plot after proper drying and then grounding for estimation of nutrient content by standard methods.

Results and Discussion

Effect of sowing at different thermal environments

Yield and nutrient content in grain and straw varied significantly due to sowing at different thermal environments during both the years and in pooled mean. The significantly highest grain and straw yields of wheat were recorded under D_2 with the respective values of 3771 and 4880 kg/ha. The minimum grain and straw yields were noted with D_3 (3437 and 4533 kg/ha). The quantum increase in yield due to D_2 (sowing at 20 ^oC) was 5.28 and 9.72 per cent in grain yield and 4.79 and 7.65 per cent in straw yield over D_1 (sowing at 22 ^oC) and D_3 (sowing at 18 ^oC), respectively. Changing the sowing time towards favourable environment created a significant effect on the crop yield, probably driven by the different thermal regimes prevailing throughout the grain filling period resulted into higher yield. The findings of Tripathi *et al.*, (2013), Kumar *et al.*, (2013) and Suleiman *et al.*, (2014) are closely related to above results.

Sowing of wheat at 20 $^{\circ}C$ (D_2) significantly increased the nutrient (N, P and K) content in grain and straw and being at par with sowing at 22 $^{\circ}C$ (D_1) in respect to P content in straw proved superior over D_1 and D_3 treatments. The N, P and K content in grain and straw have positive association with temperature prevailed during the crop growth period and on-time sowing. These findings were similar to those of Mukherjee (2012) and Mukherjee *et al.*, (2017) (Table 1).

Table.1 Effect of sowing at different thermal environments and foliar spray of bio-regulators on grain and straw yields

Treatments	Yield (kg/ha)					
	Grain			Straw		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Sowing at different thermal environments						
D_1	3667	3498	3582	4742	4572	4657
D_2	3860	3681	3771	4940	4820	4880
D_3	3503	3372	3437	4623	4443	4533
SEm±	55	55	39	62	47	39
CD (P=0.05)	189	191	120	213	163	119
Foliar spray of bio-regulators						
B_1	3258	3203	3230	4314	4195	4254
B_2	3398	3318	3358	4470	4326	4398
B_3	3538	3327	3432	4623	4312	4467
B_4	3991	3758	3874	5045	4952	4998
B_5	3701	3461	3581	4842	4564	4703
B_6	3879	3701	3790	4944	4916	4930
B_7	3724	3575	3649	4910	4697	4804
B_8	3925	3792	3858	5000	4932	4966
SEm±	87	67	55	94	87	64
CD (P=0.05)	245	189	153	265	247	180
Interaction (D x B)						
SEm±	150	116	95	163	151	111
CD (P=0.05)	NS	NS	265	NS	NS	NS

Table.2 Effect of sowing at different thermal environments and foliar spray of bio-regulators on nitrogen content in grain and straw

Treatments	Nitrogen content (%)					
	Grain			Straw		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Sowing at different thermal environments						
D_1	1.65	1.53	1.59	0.581	0.559	0.570
D_2	1.77	1.65	1.71	0.630	0.605	0.617
D_3	1.59	1.52	1.56	0.536	0.515	0.525
SEm±	0.04	0.03	0.02	0.02	0.02	0.011
CD (P=0.05)	0.13	0.11	0.07	0.06	0.06	0.035
Foliar spray of bio-regulators						
B_1	1.57	1.51	1.54	0.506	0.483	0.494
B_2	1.60	1.53	1.56	0.544	0.523	0.534
B_3	1.67	1.50	1.59	0.604	0.581	0.593
B_4	1.86	1.75	1.80	0.655	0.623	0.639
B_5	1.65	1.48	1.57	0.551	0.532	0.542
B_6	1.65	1.55	1.60	0.596	0.576	0.586
B_7	1.64	1.53	1.58	0.575	0.556	0.566
B_8	1.73	1.70	1.71	0.626	0.603	0.615
SEm±	0.05	0.05	0.03	0.03	0.03	0.019
CD (P=0.05)	0.13	0.14	0.09	0.07	0.07	0.052
Interaction (D x B)						
SEm±	0.08	0.09	0.06	0.05	0.05	0.03
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table.3 Effect of sowing at different thermal environments and foliar spray of bio-regulators on phosphorus content in grain and straw

Treatments	Phosphorus content (%)					
	Grain			Straw		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Sowing at different thermal environments						
D_1	0.479	0.455	0.467	0.165	0.161	0.163
D_2	0.528	0.510	0.519	0.170	0.171	0.171
D_3	0.437	0.413	0.425	0.154	0.153	0.153
SEm±	0.015	0.016	0.011	0.004	0.005	0.003
CD (P=0.05)	0.052	0.054	0.034	0.012	0.014	0.012
Foliar spray of bio-regulators						
B_1	0.404	0.382	0.393	0.152	0.146	0.149
B_2	0.442	0.417	0.430	0.154	0.155	0.155
B_3	0.502	0.477	0.489	0.165	0.164	0.165
B_4	0.553	0.534	0.543	0.174	0.171	0.173
B_5	0.449	0.431	0.440	0.158	0.159	0.158
B_6	0.503	0.475	0.489	0.169	0.168	0.168
B_7	0.473	0.453	0.463	0.163	0.160	0.162
B_8	0.524	0.505	0.515	0.169	0.170	0.170
SEm±	0.022	0.024	0.016	0.005	0.006	0.005
CD (P=0.05)	0.062	0.068	0.045	0.015	0.017	0.015
Interaction (D x B)						
SEm±	0.04	0.04	0.03	0.009	0.014	0.008
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table.4 Effect of sowing at different thermal environments and foliar spray of bio-regulators on potassium content in grain and straw

Treatments	Potassium content (%)					
	Grain			Straw		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Sowing at different thermal environments						
D_1	0.446	0.427	0.437	1.621	1.502	1.562
D_2	0.495	0.477	0.486	1.736	1.621	1.678
D_3	0.401	0.381	0.391	1.565	1.492	1.529
SEm±	0.017	0.016	0.012	0.036	0.031	0.024
CD (P=0.05)	0.057	0.056	0.036	0.125	0.109	0.074
Foliar spray of bio-regulators						
B_1	0.371	0.349	0.360	1.538	1.485	1.511
B_2	0.409	0.389	0.399	1.565	1.495	1.530
B_3	0.461	0.449	0.455	1.644	1.473	1.558
B_4	0.520	0.501	0.510	1.832	1.717	1.775
B_5	0.416	0.399	0.408	1.622	1.450	1.536
B_6	0.469	0.448	0.458	1.617	1.523	1.570
B_7	0.440	0.422	0.431	1.608	1.497	1.553
B_8	0.491	0.467	0.479	1.698	1.668	1.683
SEm±	0.026	0.027	0.019	0.046	0.050	0.034
CD (P=0.05)	0.074	0.075	0.052	0.129	0.140	0.094
Interaction (D x B)						
SEm±	0.05	0.05	0.03	0.079	0.086	0.058
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Effect of foliar spray of bio-regulators

Data further indicated that different foliar spray of bio-regulator treatments were significantly influence the yield and nutrient content in grain and straw during both the years and in pooled analysis. The significantly higher values of grain and straw yields (3874 and 4998 kg/ha) of wheat were observed under the application of salicylic acid @ 200 ppm over remaining treatments while it was at par with thiosalicylic acid and thioglycolic acid @ 200 ppm. The significantly minimum grain and straw yields were obtained under control with the corresponding values of 3230 and 4254 kg/ha. Foliar spray of salicylic acid @ 200 ppm (B_4) represented an increase in yield to the tune of 19.94 and 15.37 per cent in grain yield and 17.49 and 13.64 per cent in straw yield, respectively over B_1 (control) and B_2 (water spray). The period of photo synthetically active sites in crop plants are extended in response to exogenous application of bio-regulators towards higher biomass accumulation increase in the crop yield, consequently delayed senescence of plant organs (particularly leaves and flowers). These findings are in agreement with Kumawat *et al.,* (2013) Sharma *et al.,* (2013) and Nathawat *et al.,* (2016).

Among foliar spray of bio-regulator treatments, SA @ 200 ppm (B_4) recorded the significantly higher nitrogen and phosphorus content in grain and straw which was at par with B_8 in respect of grain and with B_3 and B_8 in respect of straw. While with regard to P content in straw, the above treatment also remained at par with B_5, B_6 and B_7. Application of SA @ 200 ppm (B_4) significantly increased K content in grain and straw over other treatments but remained at par with B_6 and B_8. Since, content of nutrients is the function of grain and straw yield hence, a clear involvement of bio-regulators in the control of nutrient assimilation might be expected. These results are in line with those of Muhal *et al.,* (2014) and Premaradhya *et al.,* (2018) (Table 2–4).

Interaction effect

Data represented that collective effect between sowing at different thermal environments and foliar spray of bio-regulators was found to be non-significant with regard to straw yield and nutrient content of wheat. While, interaction effect of sowing at different thermal environments and foliar spray of bio-regulator treatments on grain yield of wheat was found to be significant.

Based on the study, it was concluded that highest productivity and nutrient content in grain and straw were obtained with the application of salicylic acid @ 200 ppm at tillering and ear emergence stages of wheat along with sowing at 20 ^{o}C mean temperature.

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