The Pharma Innovation Journal 2022; 11(5): 151-156

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(5): 151-156

www.thepharmajournal.com
Received: 03-02-2022
Accepted: 06-03-2022

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Effect of exogenous application of salicylic acid and sodium nitroprusside in wheat (*Triticum aestivum* L.) cultivars subjected to heat stress under early and late sown conditions

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Abstract
Late sowing of wheat in the rice-wheat cropping system is due to the late harvesting of rice and it is one of the major causes for low yield of wheat crop. Late sowing subjected plants to heat stress resulting in the reduction in yield due to the sub-optimal temperature during germination and supra-optimal during the reproductive growth, leading to significant yield reduction in wheat. Adaptation strategies to combat this could be either growing heat-tolerant cultivars or adjustments in sowing dates. Our results revealed that timely sown crop (N) showed significantly higher plant height, root length, total number of leaves, NAR, RGR and CGR compared with late sown condition (L). Among the varieties used, V_2 (HUW-234) had lesser decline in growth parameters than V_1 (HUW-468) due to late sowing, implying that 'HUW-234' has thermo-tolerant characteristics. Exogenous application of salicylic acid (SA) and sodium nitroprusside (SNP) played an important role in mitigating the adverse effects of heat stress. Combination of both was more effective than single treatment.

Keywords: Heat stress, late sown, salicylic acid, sodium nitroprusside, wheat

Introduction
Wheat (*Triticum aestivum* L.) is one of the oldest and most important cereal crops, and second to rice as the main food crop of many countries of the world including India, being used for human food and livestock feed. Its diverse uses, nutritive importance and storage qualities had made it a staple food for the world population. World had 20% diet calories in the wheat and it constitutes approximately 65% carbohydrates, 12% protein, 2.2% crude fibers, 1.5% fat, 12% water and 1.8% minerals. According to the Directorate of Economics and Statistics (2017), [13] worldwide approximately 218.543-million-hectare area produced 771.719 million tons with an average yield of 3531 kg/ha. Of these, India covers 29.14 million hectares of area for the production of 102.19 million tons with an average yield of 3507 kg/ha. India occupies the 3rd position in total cereal production after China and the USA while it holds the 2nd rank in wheat production next to China with a 12.77% share of the world's wheat production (Directorate of Economics and Statistics, 2017) [13]. Meanwhile, the crop is at risk from new and more destructive pests and diseases, shrinking water resources, limited availability of land and various abiotic stresses, especially heat.
Heat stress is defined as the rise in temperature beyond a threshold level for sufficient time to cause irreversible damage to growth and development of the plants (Wahid *et al*., 2007) [41]. High day or high night temperatures, as well as high air or soil temperatures can damage the plants in different ways. Increasing temperature is a key element of global climate change, affecting crop growth and productivity worldwide (Lal *et al*., 2021) [21]. Wheat is a major cereal crop grown in various parts of the world, which is severely affected by heat stress. The proximity of the equator and late sowing of wheat (due to late harvesting of rice) exposes the wheat to high-temperature stress during the grain filling stage (reproductive stage) leading to terminal heat stress in the crop and reduced yield (Dubey *et al*., 2020) [14]. Apart from this, an increase in population, colonization and industrialization by humans have severely affected the environmental conditions as well as crop production due to drastic increases in temperature resulting in global warming. The global air temperature is predicted to rise by 0.2 °C per decade, which will lead to temperatures 1.8–4.0 °C higher than the current level by 2100 (IPCC, 2007) [19]. Intergovernmental panel on climatic change (IPCC) reported an expected global mean temperature increase of 0.3 °C per decade and may reach approximately 1 and 3

°C above the present value by 2025 and 2100, respectively (Khan *et al.*, 2013) [24]. Major effects of high temperature on plants are inhibition of seed germination, reduction of plant growth, oxidative stress, reduction in leaf development, reduction in tiller formation, alternation in dry matter partitioning, yield reduction, pollen sterility (Akter and Islam, 2017) [3], rate and duration of endosperm cell division (Iqbal *et al*., 2019) [21], alteration in photosynthesis, reduction in crop quality, alteration in phenology (Chovancek *et al*., 2021) [10]. Wheat yields have been predicted to decrease by approximately 10% for every one-degree increase in temperature. According to various findings, it is suggested that the optimal temperature for grain set and grain filling ranges between 19°C and 22°C in wheat (Mukherjee *et al*., 2019) [30]. The threshold temperature i.e., the value of daily mean temperature at which a detectable reduction in growth begins, is 26 °C for wheat at the post-anthesis stage (Stone and Nicolas, 1995; Rao *et al*., 2015) [39, 34]. Heat stress adversely affects wheat during the grain-filling period by accelerating leaf senescence and affects final grain weight by shortening the grain filling duration (Dias and Lidon, 2009) [12].

Terminal heat stress in wheat can be mitigated by applying organic or inorganic bioregulators. These osmoprotectants are non-toxic, highly soluble, compactable solutes present in all organisms from archaebacteria to higher plants. Exogenous application of protectants such as osmoprotectants, phytohormones, signaling molecules have played an important role in the adaption of cells against adverse effects of heat stress due to growth promoting and antioxidant activities of these compounds. (Hemantaranjan *et al*., 2014) [17]. They also stimulated photosynthesis machinery and hence improved the yield and quality of crops (Rasheed *et al*., 2011) [35]. The overall growth and developmental metabolism of plants are well-coordinated and controlled by low molecular weight compounds that act as chemical messengers to perform a specific role in plants known as phytohormones (Voß *et al.*, 2014; Yadav *et al*., 2021) [40, 42]. The growth regulators primarily involved in dormant and stress conditions, for example, salicylic acid (SA), abscisic acid (ABA), ethylene (ET), jasmonates (JA), brassinosteroids (BRs), and nitric oxide (NO) donor (SNP), achieve much attention to improve plant growth through stress tolerance (Khan and Khan, 2013; Dempsey and Klessig, 2017) [23, 11]. Among them, SA and SNP (NO donor) occupy an important place to protect the plants against different biotic and abiotic stresses (Prakash *et al*., 2021) [31] including high temperature or heat stress (Rai *et al*., 2018, 2020) [32, 33] in many crops including wheat.

Materials and Methods

The experiments were conducted during the *rabi* season with two wheat genotypes, HUW-468 (heat-susceptible) and HUW-234 (heat-tolerant) for the field experiment. Experiments were conducted at the Agricultural Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi with two dates of sowing of both cultivars during both experimental years. Both varieties were subjected to early (last week of November) and late (last week of December) sown condi to study the impact of heat stress. The experimental site was located in the south-eastern part of the Varanasi, between 25.15ºN latitude and 82.59ºE longitude, 80 m above mean sea level having Gangetic alluvial clay loam soil characterized by a pH of 7.4. The experiment was laid out in split- split-plot design with three replications. Varanasi region is characterized by a sub-tropical climate, subjected to extremes of seasonal weather conditions. During peak summers of May and June, temperature was around 40 to 45 ºC. The temperature dropped from early November touching a minimum of <5 ºC during December and January. The total rainfall during the crop growth period in 2017-18 was 9.4 mm while during 2018-19, it was 32.4 mm. The maximum temperature during the crop growth period ranged from 16.1 ºC to 39.0 ºC during 2017-18 and from 19.8 ºC to 39.5 ºC during 2018-19. The minimum temperature during 2017-18 ranged from 5.9 ºC to 21.9 ºC, while during 2018-19, it was 3.9 ºC to 20.5 ºC. Varanasi exists almost in the middle of the Indo-Gangetic plain. In general, the soil is alluvial with sandy loam texture, deep, well-drained and moderately fertile, being low in available phosphorous and potassium. The pH range is neutral to slightly alkaline.

There were total 16 treatments with two genotypes (V_1: HUW-468; heat susceptible and V_2: HUW-234; heat tolerant) and two sown conditions (N: normal and L: late) having three replications. Treatments were applied at 40 and 80 DAS. Treatments were T_1: Control (water spray), T_2: SA @1.5 mM, T_3: SNP @0.2 mM, and T_4: SA @1.5 mM + SNP @0.2 mM. Healthy, bold, clean and free from pathogen, seeds were used for sowing at a row spacing of 25 cm. Sowing was done in *rabi* season on 22nd November and 23rd December during 2017-18, and in the next year, on 20th November and 24th December under normal fertility of the soil. Morpho-physiological parameters were taken after 50 and 90 DAS (days after sowing). Plant growth characteristics such as plant height (cm), root length (cm), total number of leaves, leaf area index (LAI), Net assimilation rate (NAR), Relative growth rate (RGR) and Crop growth rate (CGR) were measured. Plant height was measured from the base of the plant to the top of the main stem with a meter scale at 50 and 90 DAS and expressed in the centimeter. The average height of five plants was considered for the final reading. The maximum root length from the base of the shoot to the longest root tip was measured with the help of a scale at 50 and 90 DAS. Five readings per replication were recorded then the average value was finally taken. The total number of leaves per 20 cm row length was counted. LAI is the ratio of leaf area to ground area and was calculated as per the formula of Watson (1952). LAR is the ratio of leaf area to the weight of the plant and represents the ratio of photosynthesizing to respiratory material within the plant. It was calculated by the formula described by Watson (1952). It is expressed in $cm^2\ g^{-1}$. NAR indirectly indicates the rate of net photosynthesis. It is expressed as g of dry matter production per day per cm^2 leaf area. It was calculated as suggested by Gregory (1926). The relative growth rate (RGR) of crops at time instant (t) is defined as the increase of plant material per unit weight per unit time. It was calculated by using the formula of Blackman (1919) and expressed as $g\ g^{-1}\ day^{-1}$. CGR represents dry weight gained by a unit area of crop in a given time. It was calculated by using the following formula according to Watson (1952) and expressed in $g\ cm^{-2}\ day^{-1}$.

Table 1: Effect of SA, SNP and SA+SNP on growth characters of two wheat (*Triticum aestivum* L.) genotypes under normal and terminal heat stress (induced by late sowing) at 50 and 90 days after sowing during 2017-18 and 2018-19

Treatments	Plant height (cm)				Root length (cm)				Number of leaves/plant					Shoot fresh weight/plant		
	50 DAS		90 DAS		50 DAS		90 DAS		50 DAS		90 DAS			50 DAS		90 DAS
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
N	47.41	47.41	87.12	85.86	14.03	13.88	16.14	16.46	25.99	26.24	23.55	24.23	19.25	19.00	33.22	33.76
L	43.65	43.55	65.58	65.60	11.61	11.86	14.88	15.04	20.72	20.51	18.50	18.79	16.13	16.33	26.45	26.70
S.Em±	0.50	0.36	0.83	2.12	0.15	0.07	0.25	0.14	0.37	0.52	0.31	0.33	0.53	0.15	0.32	0.19
LSD (P=0.05)	2.15	1.57	3.58	9.15	0.67	0.33	1.10	0.63	1.59	2.23	1.36	1.43	2.29	0.67	1.41	0.83
V_1	49.91	49.60	78.17	78.05	14.54	14.61	17.27	17.43	26.65	26.67	24.08	24.78	20.24	20.32	32.48	32.85
V_2	41.16	41.36	74.53	73.42	11.10	11.13	13.75	14.07	20.05	20.08	17.97	18.24	15.15	15.02	27.19	27.61
S.Em±	0.71	0.58	0.43	1.19	0.34	0.29	0.44	0.34	0.80	0.58	0.91	0.52	0.36	0.28	0.87	0.42
LSD (P=0.05)	1.98	1.62	1.21	3.32	0.95	0.82	1.24	0.96	2.24	1.63	2.54	1.45	1.00	0.79	2.44	1.18
T_1	40.66	40.33	66.18	65.89	10.42	10.34	13.10	13.06	18.23	18.13	15.91	16.28	13.73	13.57	23.92	24.28
T_2	44.18	44.40	77.19	75.79	12.26	12.32	14.94	15.00	22.75	23.00	20.56	21.01	16.52	16.63	28.36	29.05
T_3	45.24	45.36	77.83	77.62	13.05	13.05	15.13	15.38	23.31	23.88	21.05	21.46	16.88	17.02	30.10	30.10
T_4	52.03	51.83	84.20	83.67	15.55	15.77	18.88	19.56	29.13	28.50	26.58	27.28	23.63	23.45	36.97	37.49
S.Em±	0.60	0.73	0.81	1.97	0.31	0.28	0.52	0.47	0.63	0.55	0.65	0.63	0.36	0.35	1.02	0.56
LSD (P=0.05)	1.24	1.50	1.67	4.06	0.65	0.59	1.09	0.05	1.30	1.15	1.34	1.31	0.76	0.73	2.10	1.17

Where, DAS= Days after sowing, N= Normal sown, L= Late sown, V_1= HUW-468 (heat susceptible), V_2= HUW-234 (heat tolerant), T_1= Control (water spray), T_2= Salicylic acid (1.5 mM), T_3= Sodium nitroprusside (0.2 mM), T_4= Salicylic acid (1.5 mM) + Sodium nitroprusside (0.2 mM)

Table 2: Effect of SA, SNP and SA+SNP on growth characters of two wheat (*Triticum aestivum* L.) genotypes under normal and terminal heat stress (induced by late sowing) at 50 and 90 days after sowing during 2017-18 and 2018-19

Treatments	Dry matter accumulation/plant				Number of tillers/plant				LAI				LAR			
	50 DAS		90 DAS		50 DAS		90 DAS		50 DAS		90 DAS		50 DAS		90 DAS	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
N	3.51	3.64	6.81	7.02	6.68	6.73	9.00	9.01	3.29	3.34	5.20	5.23	116.09	115.19	91.45	87.52
L	2.90	3.12	5.69	5.72	5.61	5.60	7.46	7.59	2.79	2.84	4.51	4.50	119.37	113.06	97.00	96.24
S.Em±	0.06	0.07	0.18	0.12	0.05	0.18	0.07	0.06	0.05	0.05	0.06	0.02	5.95	6.21	3.05	2.07
LSD (P=0.05)	0.28	0.34	0.79	0.52	0.21	0.79	0.34	0.28	0.22	0.24	0.29	0.11	25.61	26.72	13.16	8.94
V_1	3.78	3.96	7.36	7.42	6.52	6.40	8.66	8.75	3.24	3.28	5.06	5.13	102.17	98.81	81.92	81.67
V_2	2.63	2.80	5.14	5.32	5.77	5.93	7.97	7.85	2.84	2.89	4.64	4.61	133.29	129.44	106.53	102.10
S.Em±	0.12	0.10	0.14	0.07	0.21	0.09	0.07	0.08	0.03	0.08	0.05	0.05	6.12	6.69	3.11	2.41
LSD (P=0.05)	0.35	0.29	0.40	0.21	0.59	0.27	0.22	0.23	0.10	0.24	0.14	0.14	16.99	18.57	8.64	6.71
T_1	2.03	2.11	4.55	4.70	4.18	4.16	6.38	6.33	2.39	2.44	4.21	4.22	142.35	142.94	109.69	105.01
T_2	2.92	3.10	6.23	6.39	6.00	6.05	7.56	7.65	2.97	2.99	4.77	4.73	123.91	119.15	93.21	89.43
T_3	3.32	3.50	6.58	6.63	6.46	6.46	8.81	8.85	3.02	3.04	4.82	4.87	106.79	100.89	87.14	87.72
T_4	4.56	4.81	7.65	7.77	7.95	7.98	10.51	10.38	3.79	3.87	5.62	5.65	97.87	93.51	86.88	85.38
S.Em±	0.15	0.14	0.24	0.18	0.08	0.12	0.10	0.10	7.91	8.43	4.55	3.77	0.001	0.0008	4.55	3.77
LSD (P=0.05)	0.31	0.29	0.50	0.37	0.18	0.25	0.21	0.21	16.32	17.41	9.39	7.80	0.002	0.001	9.39	7.80

Where, DAS= Days after sowing, N= Normal sown, L= Late sown, V_1= HUW-468 (heat susceptible), V_2= HUW-234 (heat tolerant), T_1= Control (water spray), T_2= Salicylic acid (1.5 mM), T_3= Sodium nitroprusside (0.2 mM), T_4= Salicylic acid (1.5 mM) + Sodium nitroprusside (0.2 mM)

Table 3: Effect of SA, SNP and SA+SNP on growth characters of two wheat (*Triticum aestivum* L.) genotypes under normal and terminal heat stress (induced by late sowing) at 50 and 90 days after sowing during 2017-18 and 2018-19

Treatments	RGR				CGR				NAR			
	50 DAS		90 DAS		50 DAS		90 DAS		50 DAS		90 DAS	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
N	0.0238	0.0245	0.0174	0.0176	6.11	6.32	14.81	15.28	171.91	180.87	9.14	8.99
L	0.0201	0.0215	0.0172	0.0157	5.05	5.42	12.38	12.43	114.31	123.84	6.96	6.02
S.Em±	0.0007	0.0004	0.0009	0.0002	0.11	0.13	0.39	0.26	3.77	2.49	1.53	0.76
LSD (P=0.05)	0.003	0.002	0.004	0.001	0.49	0.59	1.71	1.15	16.25	10.73	6.60	3.30
V_1	0.0257	0.0267	0.0170	0.0160	6.58	6.88	16.01	16.13	179.65	188.26	9.40	9.04
V_2	0.0182	0.0192	0.0176	0.0172	4.58	4.87	11.18	11.58	106.57	116.44	6.70	5.97
S.Em±	0.0008	0.0007	0.003	0.001	0.22	0.18	0.32	0.16	7.16	5.51	0.97	0.70
LSD (P=0.05)	0.002	0.002	0.003	0.003	0.61	0.50	0.88	0.46	19.90	15.32	2.71	3.30
T_1	0.0136	0.0141	0.0202	0.0205	3.54	3.67	9.90	10.23	64.10	69.76	8.13	8.24
T_2	0.0207	0.0220	0.0190	0.0181	5.07	5.39	13.54	13.89	119.24	129.18	8.57	7.22
T_3	0.0237	0.0247	0.0169	0.0158	5.78	6.08	14.30	14.41	138.78	143.86	8.88	8.69
T_4	0.0299	0.0311	0.0132	0.0120	7.93	8.37	16.64	16.89	250.31	268.61	6.61	5.87
S.Em±	0.001	0.0008	0.001	0.001	0.26	0.24	0.53	0.39	8.29	5.97	1.65	1.31
LSD (P=0.05)	0.002	0.001	0.003	0.002	0.54	0.50	1.09	0.82	17.12	12.32	3.42	2.71

Where, DAS= Days after sowing, N= Normal sown, L= Late sown, V_1= HUW-468 (heat susceptible), V_2= HUW-234 (heat tolerant), T_1= Control (water spray), T_2= Salicylic acid (1.5 mM), T_3= Sodium nitroprusside (0.2 mM), T_4= Salicylic acid (1.5 mM) + Sodium nitroprusside (0.2 mM)

Results and Discussion

The result of the effect of foliar spray of SA, SNP and their combination on growth characters *viz.* plant height, number of leaves, shoot fresh weight, number of tillers per plant, and dry matter accumulation per plant means of two wheat genotypes (HUW-468 and HUW-234) under normal and late sown condition was found significant and presented in Tables 1 and 2. It was observed that the normal or timely sown condition recorded significantly maximum growth characters than the late sown condition. In normal and late sown conditions, V_1 (HUW-468) showed significantly maximum growth characters at both stages of the observation i.e., 50 and 90 days after sowing (DAS). Singh and Dwivedi (2015) [37] also examined the same in two wheat genotypes (HUW-510: high temperature tolerant and HUW-468: high temperature susceptible) and concluded that varieties sown in late conditions have low count of number of leaves as compared to timely sown. This result is in agreement with some previous reports on many crops such as wheat (Sadak *et al*., 2020) [36] and tomato (Agamy *et al*., 2013) [1]. Among the chemical treatments, at both stages of observation, the combination of SA and SNP (T_4) was more effective for growth characters increment compared to the other treatments. The minimum growth characters were reported in T_1 (Control) at both stages (50 and 90 DAS) of observation. Overall, maximum growth characters were observed in normal, V_1 and T_4 treatment at 90 days after sowing of the crop. Almost similar trends were found in the next year of trial. The decrease in growth characters at high temperature was associated with an increase in stress injury reflected as rise in electrolyte leakage, which is an indicator of damage to membranes. Electrolyte leakage has been reported as a useful indicator of heat stress injury in some previous studies (Liu and Huang, 2000; Gulen and Eris, 2004) [28, 15]. Increase in electrolyte leakage by heat stress matches with the ones reported in wheat (Almeselmani *et al*., 2009) [4] and rice (Sohn and Back, 2007) [38].

The maximum root length, LAI, and leaf area ratio (LAR) were found in normal sown condition compared to the late sown condition at all stages of observation. With respect to the varieties, V_1 showed significantly maximum root length, LAI, and LAR at both stages (50 and 90 DAS) of observation as well as in both the sowing conditions (normal and late). Among the treatments, T4 (SA+SNP) was more suitable for increasing root length, LAI, and LAR, whereas T_1 (Control) showed minimum root length at all the stages of observation. Overall, maximum root length, LAI, and LAR were found in early, V_1 and T_4 at the second observation which was 90 days after sowing. Root length recorded during 2018-19 under different sowing dates and genotypes followed a similar trend as observed during 2017-18 and values were comparable. Plant roots are the first part of plant which faces environmental conditions including various stresses. Barraclough and Leigh (1984) [6] conducted a field experiment on growth and activity of winter wheat roots and pointed out that the early-sown crops had greater root length than that of the late-sown crops, implying greater production of lateral roots. The present study is in accordance with the similar findings on wheat obtained by Yan *et al.* (2016) [43] and Kausar *et al*. (2013) [22]. There are also similar findings in other crops such as maize (Zanganeh *et al*., 2020) [44], finger millet (Kotapati *et al*., 2017) [25] and safflower (Chavoushi *et al*., 2019) [8]. Chen *et al.* (2018) [9] found the acceleration of leaf senescence under warmer environments, as well as considerable damage to leaf area by extremely high temperatures according to LAI values from remote-sensing data.

NAR, RGR and CGR were studied between 0-50 and 50-90 days after sowing or 10 days after chemical treatments during 2017-18 and 2018-19 in two wheat genotypes (heat susceptible and tolerant). During 2017-18, mean NAR, RGR and CGR were significantly higher in normal sown condition than late sown condition. In respect to varieties, V_1 showed the greatest NAR, RGR and CGR between 0-50 and 50-90 DAS in both normal and late sown conditions. Among the treatments, T_4 showed maximum NAR, RGR and CGR between 0-50 days after sowing compared to the other treatments, while T_3 showed maximum NAR between 50-90 days after sowing. On other hand, the minimum NAR, RGR and CGR were observed in T_1 (control) at the first interval of observation (0-50 DAS) and in T_4 at the second gap (50-90 DAS) of observation. Conclusion of the experiment for NAR, RGR and CGR showed that normal sown condition of V_1 with the foliar treatment of plants with T_4 between 0-50 days after sowing had maximum NAR, RGR and CGR. During 2018-19, NAR, RGR and CGR values obtained were comparable with those recorded during 2017-18. NAR represents dry weight addition per unit leaf photosynthetic area per unit time. Moreover, the NAR of a crop represents the net photosynthetic rate per unit leaf area duration. If we follow the crop response in terms of NAR, it decreased in later stages of the crop and this may be due to a periodic increase in leaf area duration, which resulted in less assimilation per unit time. Higher NAR in normal sown condition may be attributed to higher dry matter accumulation as compared with late sown. Ahmed and Farooq (2013) [2] and Bangar *et al*. (2020) [5] also reported a similar result in wheat. RGR can be attributed in terms of the juvenility of plants at earlier growth periods and shading effects of upper leaves on older ones at later growth stages. Additionally, the decline in RGR with the advancement in crop growth could be due to decline in the rate of dry matter production. The increase in RGR as a result of date of sowing would be due to the effectiveness of temperature increasing not only the total dry matter but also the rate of increment in total dry matter. This could also be attributed to increased photosynthetic efficiency by increasing leaf thickness and retaining more chlorophyll content and efficient translocation. Similar results were reported by Lopez-Carrion *et al.* (2008) [29] on Chinese cabbage (*Brassica rapa* L.) and Liu *et al*. (2014) [27] in cotton. The CGR is controlled by canopy, photosynthesis and respiration, so, it is considered more meaningful function of crop growth. Higher CGR in the early sown plants was due to higher production of dry matter owing to higher leaf area index (LAI). Maximum growth rate was confirmed at the beginning of reproductive growth, which decreases with the plant's higher maturity due to growth ending and leaves losses and withering. Ahmed and Farooq (2013) [2], Haider (2007) [16] and Ihsan *et al*. (2016) [18] also experimented on wheat and documented same. CGR increased under the foliar spray of SA and SNP in stressed and non-stressed condition. Combined application was more effective than single treatment. These results are confirmed by the findings of Iqbal *et al*. (2020) [20] and Bayat and Sepehri (2012) [7], in maize.

Fig 1: Plates: Experimental Field

Conclusion

Climate change has increased the intensity of heat stress that could adversely affect crop production worldwide, resulting in significant economic losses. The constant rise in ambient temperature is considered one of the most detrimental stresses. On the basis of present results, it is concluded that heat stress has negative effects on the growth and development of wheat. Genotypic and treatment differences were evident in relation to heat stress. Exogenous application of SA and SNP treatment, specially their combination, enhanced the tolerance of wheat plants to heat stress (imposed by late sowing) by improving different growth parameters. Therefore, the ameliorating effect of SA, SNP and their combination on plant growth and development under heat stress may be associated with increasing plant resistance.

Acknowledgements

The first author thanks UGC-BHU for fellowship during Ph.D. Programme.

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