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Effect of Synthetic Compounds on Performance of Wheat under High Temperature Stress Condition

Asheesh Chaurasiya[1], Durgesh Singh[1*], Swaraj Kumar Dutta[1], Shiv Bahadur[2] and Santosh Kumar Dubey[1]

[1]*Department of Agronomy, BAU, Bhagalpur-813210, India*
[2]*Department of Agronomy, NDUA&T, Faizabad-224229, India*

**Corresponding author*

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ABSTRACT

A field experiment was carried out in experimental farm of Bihar Agricultural University, Bhagalpur during the *rabi* season of 2014-15 to test the effect of synthetic compounds on performance of wheat under high temperature stress condition. Treatments were laid out in split plot design with three replications. Two contrasting varieties of wheat, i.e. DBW-14 (timely sown) and K 307 (late sown) were kept in main plots. Each main plot was further sub-divided into fourteen subplots which received foliar spray of different synthetic compounds either at a fixed dose at booting or at anthesis stage or half the fixed dose at both booting and anthesis stage. The foliar spray were as follows: M_1- no spray, M_2- KNO_3 (1.0 %) at booting stage, M_3- KNO_3 (1.0 %) at anthesis stage, M_4- KNO_3 (0.5 %) both at booting and anthesis stage, M_5- $CaCl_2$ (0.2%) at booting stage, M_6- $CaCl_2$ (0.2%) at anthesis stage, M_7- $CaCl_2$ (0.1%) both at booting and anthesis stage, M_8- Glycinebetaine (100 mM) at booting stage, M_9- Glycinebetaine (100 mM) at anthesis stage, M_{10}- Glycinebetaine (50mM) both at booting and anthesis stage, M_{11}- Arginine (2.5mM) at booting stage, M_{12}- Arginine (2.5mM) at anthesis stage, M_{13}- Arginine (1.25mM) both at booting and anthesis stage and M_{14}-spray of water both at heading and anthesis stage. Result shows that grain yield was increased significantly and maximized (36.96 and 31.23 qha^{-1} for V_1 and V_2 respectively) when the crop received foliar spray of KNO_3 at the rate of 0.5% both during booting and anthesis stage over no foliar spray. The corresponding values with the foliar spray of $CaCl_2$ showed same trend like KNO_3 and were found to be statistically at par. Economic analysis revealed that the foliar spray of KNO_3 at the rate of 0.5% both during booting and anthesis in DBW-14 significantly increased and maximized B: C ratio (1.9) over control but did not respond significantly in K 307. Thus, the study suggests that foliar spray of KNO_3 at the rate of 0.5% both during booting and anthesis in a short duration variety like DBW-14 is beneficial to mitigate the ill effects of high temperature stress and enhance the yield to a profitable limit.

Introduction

Wheat (*Triticum aestivum* L.) 2n=42 belongs to family Poaceae, mostly cultivated in temperate region as well as in tropical and subtropical climate with moderate success. In India, wheat plays an important role towards food security of the nation. Cultivation of wheat has been the symbol of green revolution and self-sufficiency in food grain production of the nation. According to FAO estimate, world would require around 840 million tonnes of wheat and India require about 140 million tonnes by the year 2050.

Environment is continuously changing over the past years due to human-induced activity and extreme climate events. Heat waves, droughts and floods are become a common phenomenon as a result of climate change (IPCC, 2012). Global climate models predict an increase in mean ambient temperatures between 1.8 and 5.8°C by the end of this century (IPCC, 2007). Agricultural production and global food security is directly affected by global warming (Ainsworth and Ort, 2010). Sowing of wheat often gets delayed under rice-wheat cropping system due to late harvesting of paddy (Prasad *et al.*, 2005). Due to late sowing of wheat, anthesis and grain filling period faces increased temperature (more than 20°C) (Tewolde *et al.*, 2006). High temperature stress is a major environmental stress that limits crop growth, metabolism and productivity, because temperature controls the rate of plant metabolic processes that ultimately influence the production of biomass, spikelets and grains (Hay and Walker, 1989). Previous global food assessments have shown that these negative effects are particularly exacerbated in tropical regions (Fischer *et al.*, 2005). Presently, Indian lowlands are the source of approximately 15% of global wheat production but it is anticipated that climate change will transform these into a heat stressed, short season production environment (Bita and Gerats, 2013).Wheat cultivation faces numerous challenges of terminal heat stress, which is a major constraint that limiting the wheat production. High temperature stress during reproductive phase of crop is termed as terminal heat stress. Wheat crop requires 19°C to 22°C temperature during setting and filling of grain (Porter and Gawith, 1999). 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 post anthesis stage (Stone and Nicolas, 1994). During the grain filling period, heat stress can accelerate leaf senescence and affect final grain weight by shortening the duration of grain filling (Dias and Lidon, 2009).

Lobell *et al.*, (2005) reported that wheat yield in Mexico decreased by 10% for every 1°C increase in night temperature and grain yield showed a strong negative correlation with increasing minimum temperature (Corbellini *et al.*, 1997 and Stone and Nicolas, 1995). stated that two typical heat stresses are common during wheat grain filling i.e. “Heat shock” which is characterized by sudden extreme high temperatures (>32^0C) for a short duration (3-5 days) while, “chronic heat stress” consists of moderately high maximum temperatures (20-30^0C) for a longer duration. High temperature during reproductive phase of wheat resulted, decline in photosynthesis, leaf area, water-use efficiency and decrease shoot and grain mass, kernels weight and sugar content (Shah and Paulsen, 2003). Wheat is much affected by relatively short periods (3-5 days) of heat stress in terms of yields and quality, especially when occurring during grain filling stage (Wardlaw *et al.*, 2002).

The North Indian states such as Uttar Pradesh, Punjab, Haryana, Uttarakhand and Himachal Pradesh are some of the major wheat producing states where the crop is more vulnerable at a 1°C rise in temperature resulting in reduction of wheat yield (Singh *et al.*, 2011) and according to a report of Ministry of Agriculture, GOI, 1^0C rise temperature during the growing season can result in 3-7% decrease in grain yield. Loss in yield of wheat due to elevated temperature is estimated in the vicinity of 50 percent by 2050

(IFPRI 2011). This yield loss will threaten the food security of at least 1.6 billion people in South Asia.

The yield loss of late sown wheat facing high temperature stress can be improved by exogenous application of many synthetic compounds. These synthetic compounds are inorganic salts like potassium nitrate, calcium chloride, glycine betaine and arginine. Several studied says that these compounds mitigate the ill effects of high temperature stress in plants through various mechanisms like preventing the degradation of chlorophyll, reducing electrolytic leakage and help to maintain or sometime increase the grain yield of crop. The main function of these compounds is as follow;

KNO_3 - Potassium (K+) has substantial effect on enzyme activation, protein synthesis, photosynthesis, stomatal movement and water-relation (turgor regulation and osmotic adjustment) in plants (Marschner, 1995). Increased application of K+ has been shown to enhance photosynthetic rate, growth, yield and drought resistance in different crops under abiotic stress conditions (Egilla *et al.*, 2001). $CaCl_2$ - Under heat stress, Ca^{2+} can maintenance of antioxidant activity in some cool season grasses (Jiang and Haung, 2001). Calcium application in the form of $CaCl_2$increased the malondialdehyde (MDA) content (lipid per oxidation product) and stimulated the activities of SOD and catalase, which could be the reason for the induction of heat tolerance (kolupaev *et al.*, 2005). Glycinebetaine - Glycinebetaine is the low molecular weight organic compounds have been successfully applied to induce high temperature tolerance in plants.Numerus reports are also available to show beneficial effects of some compounds like potassium nitrate (Sarkar and Bandopadhyay, 1991; Sarkar and Tripathy, 1994), calcium chloride (Tan *et al.*, 2011), glyceinebetaine (Rhodes and Hanson, 1993, Ashraf *et al.*, 2007) and arginine (Hassanein *et al.*, 2013) in many crops including wheat when applied exogenously under abiotic stresses like high temperature and drought. The main functions of these sprayed compounds are protection of chlorophyll, detoxification of reactive oxygen species, maintenance of favorable balance of water and photosynthesis in plants under stressful condition.

So, this experiment was conducted to test the efficacy of these synthetic compounds for improving grain yield by enhancing tolerance capacity of the crop against high temperature stress. Our mainfocus is reducing the impact of heat stress during reproductive and grain filling stages of wheat and develop a strategy to improve tolerance in late sown wheat.

Materials and Methods

Experimental site

A field experiment was conducted during *rabi* season 2014-15 at Crop Research Farm, Department of Agronomy, Bihar Agricultural University, Bhagalpur, Bihar. The geographical location of Bhagalpur comes under the Middle Gangetic plain region of Agro-climatic Zone III (A) in Bihar. It located between 25^{o} 50' N latitude and 87^{o}19' longitude at an altitude of 52.73 meter above mean sea-level. The soil at the experimental site was sandy loam with pH 6.92, bulk density 1.49 g cm^{-3}, organic carbon 0.49% and having 125.44, 18.05 and 118.95 kg ha^{-1} N: P: K respectively.

Climatic conditions of site

Climate of Sabour, Bhagalpur is sub-tropical, hot desiccating summer, cold winter and moderate rainfall. December and January are usually the coldest month where the mean temperature normally fall as low as $8.8^{0}C$

whereas; May and June are the hottest months, having the maximum average temperature of 36.1°C. The average annual rainfall is about 1207 mm (10 years' average) precipitating mostly between middle of June to middle of October.

Weather parameters during the experimental period

During experiment the maximum temperature varied from 18.1-32.2^{o}C, minimum temperature ranged from 5.8-20.5^{o}C and mean temperature period varied from 11.95-25.95^{o}C. So, meteorological data reveals that the wheat crop faced high temperature stress (beyond 20^{o}C) from February 2nd week onwards, which coincides with its grain filling stage. The crop received a total rainfall of 9.48 mm from December, 2014 to March 2015.

Experimental details

The experiment was laid out in the split plot design with three replications and size of experimental plot was 10 m^2. Sowing date was December 29, 2014 which considered as late sown irrigated condition for the region, with spacing 20 cm (row to row) and fertilizer dose was 80: 40: 40: (N: P_2O_5: K_2O Kg/ha). In this experiment two contrasting wheat varieties had been taken namely, DBW-14 (V1) and K-307 (V2). Variety DBW-14 is recommended for late sown irrigated conditions. The optimum sowing time of this variety is between 10th December to last week of December with 110-115 days' maturity period, having average yielding potential is about 30-40 q ha^{-1}. Second variety K-307 is recommended for timely sown irrigated condition. The optimum sowing time of this variety is 15 to 30th November with 125-130 days' maturity period, having average yielding ability is about 40-50 qha^{-1}**.** Different chemical compounds are sprayed in different quantity and on different growth stage of wheat for reducing the stress of high temperature. The treatments were; M_1- control plot, M_2- KNO_3 at booting stage (1.0%), M_3- KNO_3at anthesis stage (1.0%) and M_4- KNO_3 (0.5%) both at booting and anthesis stage, M_5- $CaCl_2$ at booting stage (0.2%), M_6- $CaCl_2$ at anthesis stage (0.2%) and M_7- $CaCl_2$ (0.1%) both at booting and anthesis stage, M_8- Gycinebetain at booting stage (100 mM), M_9- Glycine betain at anthesis stage (100 mM) and M_{10}- Glycinebetain (50 mM) both at booting and anthesis stage, M_{11}- arginine (2.5 mM) at booting stage, M_{12} - arginine atanthesis stage,M_{13}- arginine (1.25 mM) both at booting and anthesis stage and M_{14}- spray of water at both heading and anthesis stage.

Results and Discussion

Effect of the synthetic compounds on nutrient content and uptake

Application of synthetic compounds at different doses and stage does not affected significantly nitrogen and phosphorus (%) content in wheat grain and straw while, potassium content (%) in wheat grain and straw was found to be affected significantly (Table 2). Maximum potassium content (%) was recorded with the application of (M_4) KNO_3 @0.5% at booting and anthesis stage in wheat grain (0.29%) and straw (1.28%), followed by KNO_3 @ 1% at anthesis stage in wheat grain (0.28%) and straw (1.26%). Same pattern was observed in nutrient uptake (Table 3) because uptake is totally based on nutrient content and yield of crop. Between varieties there is no significant difference was observed while among treatments K uptake was affected significantly by the application of synthetic compounds. Maximum N uptake (68.66 kg ha^{-1}) and P uptake (17.80 kg ha^{-1}) was found in variety DBW-14 but maximum K content was recorded variety K-307 (72.67 kg ha^{-1}). In case sub plot maximum N uptake (73.48 kg ha^{-1}), P uptake (19.28 kg ha^{-1}) and K uptake

(75.46 kg ha^{-1}) was recorded with application of (M_4) KNO_3 @ 0.5% at booting and anthesis stage. Application of synthetic compounds provides protection against high temperature stress by several action in plant body. Literature says that these compounds mitigate the ill effects of high temperature stress in plants through various mechanisms like preventing the degradation of chlorophyll, reducing electrolytic leakage from cells etc.

Foliar spray of KNO_3 helps in protecting the photosynthetic apparatus of flag leaf throughout the anthesis and post anthesis period, which is considered to be the principal contributory organ for the supply of photosynthates to the developing grain (Borrill *et al.*, 2015). According to Wahid *et al.*, (2007) photosynthesis is the most sensitive process to elevated temperature and it affects grain yield of wheat (Al-Khatib and Paulsen, 1999). The effect of high temperature during anthesis and grain filling period may disrupt the structure and function of chloroplast and reduces chlorophyll content (Xu *et al.*, 1995), nutrient content and uptake by plants. It has also has been shows that exogenous Ca^{++} increased heat tolerance in several plants, which might be associative with high errant oxidative enzyme activities and reduced lipid peroxidation of cell membranes (Wang *et al.*, 2009). The reason behind inclusion of the subplot treatments with glycinebetaine (Agboma *et al.*, 1997) and arginine (Hassanein *et al.*, 2008) is their protective rolesin plants against high temperature stress.

Effect of the synthetic compounds on yields of wheat crop

Grain yield (Table 4) of late sown wheat, facing high temperature stress from anthesis onwards, increased significantly and maximized (34.10 qha^{-1}) over control (30.72 q ha^{-1}) when the crop was sprayed with 0.5% KNO_3 both at booting and anthesis stage (M_4) and was found to be at par with those obtained with M_3, M_7 and M_6 receiving single foliar spray of 1% KNO_3 at anthesis (33.58 q ha^{-1}), two foliar sprays of 0.1% $Cacl_2$ both at booting and anthesis (33.97q ha^{-1}) and a single foliar spray of 0.2% $CaCl_2$ at anthesis (33.58 q ha^{-1}), respectively. Across the two varieties, an increment of 10.99%, 10.59%, 9.45% and 9.31% in grain yield was observed in M_4, M_7, M_3 and M_6, respectively over control.

However, a varietal difference was observed between DBW-14 and K-307 with respect to grain yield when sprayed with different synthetic compounds. The quantum response in grain yield was found to be more pronounced in DBW-14 than in K307.In DBW 14, M_4 treatment produced the highest yield (36.96qha^{-1}) which was at par with M_3 (36.52q ha^{-1}), M_7 (36.22 q ha^{-1}) and M_6 (36.20 qha^{-1}) and were 17.28%, 15.88%, 14.93% and 14.88% higher over the yield of M_1 /control (31.51 q ha^{-1}), respectively. But in K-307, highest yield was obtained in M_7 (31.73 q ha^{-1}) which was followed by M_4 (31.23 q ha^{-1}) and were 6.03% and 4.36% higher over the yield ofM_1 /control (29.92 q ha^{-1}) respectively.

The maximum straw yield was recorded in variety K-307 (52.75 q ha^{-1}) followed by DBW-14 (47.69 qha^{-1}) while, by the application of synthetic compounds maximum straw yield was recorded in M_6 (51.61qha^{-1}) treatment which was statistically at par with M_4 followed by M_7 and M_3 treatment. The straw yield in M_6 treatment recorded 6.89% increase over M_1 (control) treatment. As the grain and straw yields responded similarly to the foliar spray of synthetic compounds, the harvest index was highest in variety DBW 14 (41.81%). Among the sub plot treatments, M_4 recorded highest harvest index (44.34%) which was 10.95% higher over M_1 (control) treatment followed by M_3, M_7 and M_6 treatments. On an average, M_4 treatments had the highest HI which was 40.06% higher over M_1 treatment.

Table.1 Temperature variability at different phonological stage of wheat during *rabi* season of 2014-15

Phenological stages of Wheat	DBW 14		K 307	
	T_{max} range	T_{min} range	T_{max} range	T_{min} range
Sowing - Booting	13.5 - 30.6	4.0 - 16.2	13.5 - 31.1	4.0 - 16.4
Booting - Anthesis	26.0 - 32.9	16.4 - 18.2	26.0 - 32.9	13.8 - 18.2
Anthesis - Physiological maturity	26.6 - 32.0	11.3 - 17.0	26.6 - 32.4	11.3 - 17.0

T_{max} – Maximum temperature, T_{min} – Minimum temperature

Table.2 Effect of foliar spray of synthetic compounds on N, P and K content of wheat (grain and straw)

Treatments	% N		%P		%K	
	Grain	Straw	Grain	Straw	Grain	Straw
Cultivars						
V1- DBW 14	1.35	0.47	0.45	0.05	0.25	1.20
V2-K 307	1.37	0.45	0.48	0.04	0.26	1.23
SEm(±)	0.02	0.007	0.01	0.01	0.01	0.06
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Sprayed compound						
M_1- No spray (control)	1.36	0.48	0.44	0.04	0.26	1.21
M_2-KNO_3(1%) B	1.32	0.45	0.44	0.05	0.28	1.22
M_3-KNO_3 (1%) A	1.35	0.44	0.46	0.04	0.28	1.26
M_4-KNO_3(0.5%) B+A	1.43	0.48	0.49	0.05	0.29	1.28
M_5-$CaCl_2$(0.2%) B	1.33	0.44	0.48	0.04	0.26	1.22
M_6-$CaCl_2$(0.2%) A	1.36	0.42	0.47	0.04	0.23	1.17
M_7-$CaCl_2$(0.1%) B+A	1.35	0.41	0.49	0.05	0.26	1.20
M_{8-} GB (100mM) B	1.37	0.49	0.47	0.05	0.27	1.24
M_9-GB (100mM) A	1.38	0.44	0.46	0.04	0.22	1.18
M_{10}-GB (50mM) B+A	1.39	0.49	0.48	0.04	0.23	1.21
M_{11}- Arginine (2.50mM)B	1.41	0.44	0.45	0.04	0.28	1.22
M_{12}- Arginine (2.50mM) A	1.34	0.48	0.46	0.05	0.27	1.17
M_{13}- Arginine (1.25mM) B+A	1.38	0.47	0.45	0.05	0.23	1.23
M_{14}-Water spray(H+A)	1.33	0.50	0.47	0.05	0.25	1.21
SEm(±)	-	-	-	-	0.04	0.06
CD (P=0.05)	NS	NS	NS	NS	0.01	0.02

Table.3 Effect of foliar spray of synthetic compounds on N, P and K uptake of wheat crop

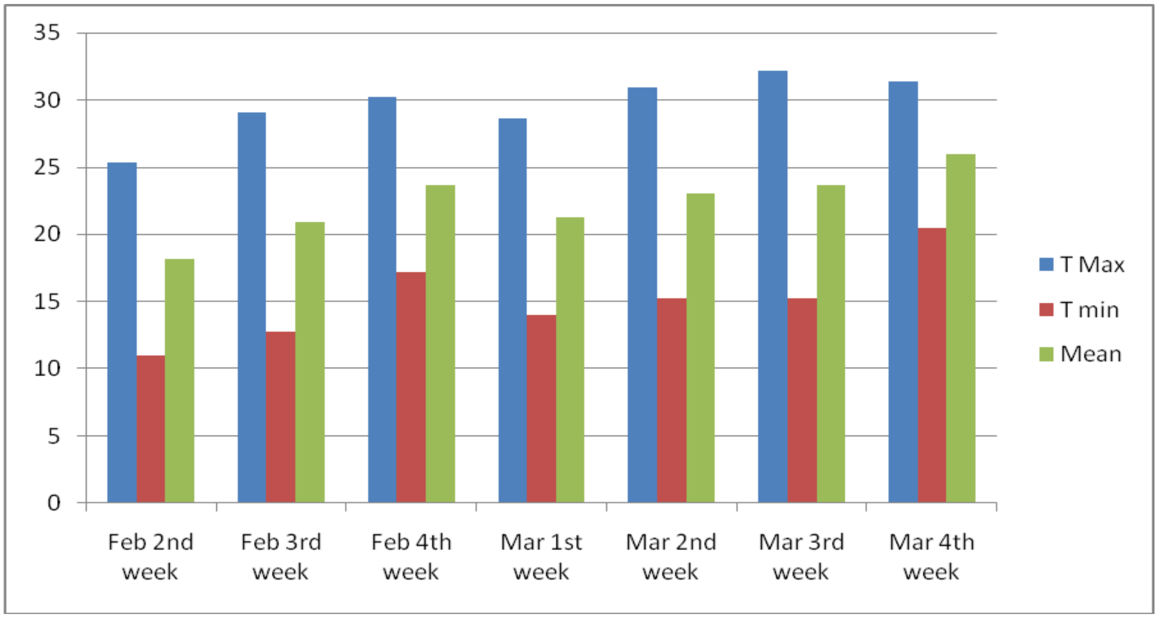
Treatments	N uptake		Total N uptake (Kg ha^{-1})	P uptake		Total P uptake (Kg ha^{-1})	K uptake		Total K uptake (Kg ha^{-1})
	Grain	Straw		Grain	Straw		Grain	Straw	
Cultivars									
DBW 14	46.25	22.41	68.66	15.42	2.38	17.8	8.57	57.23	65.8
K 307	41.07	23.74	64.80	14.39	2.11	16.5	7.79	64.88	72.67
SEm(±)	0.02	0.007	-	0.01	0.01	-	0.01	0.06	-
CD (P=0.05)	NS	NS	-	NS	NS	-	NS	NS	-
Sprayed compounds									
M_1- No spray (control)	41.78	23.17	64.95	13.52	1.93	15.45	7.99	58.41	66.39
M_2-KNO_3(1%) B	42.31	22.73	65.04	14.10	2.53	16.63	8.97	61.63	70.61
M_3-KNO_3 (1%) A	45.33	22.57	67.90	15.45	2.05	17.50	9.74	64.63	74.36
M_4-KNO_3(0.5%) B+A	48.76	24.72	73.48	16.71	2.57	19.28	9.55	65.91	75.46
M_5-$CaCl_2$(0.2%) B	41.93	21.42	63.36	15.13	1.95	17.08	8.20	59.40	67.60
M_6-$CaCl_2$(0.2%) A	45.72	21.68	67.40	15.80	2.06	17.87	7.73	60.38	68.12
M_7-$CaCl_2$(0.1%) B+A	45.86	21.05	66.90	16.65	2.57	19.21	8.83	61.60	70.43
M_{8}- GB (100mM) B	42.13	24.61	66.74	14.45	2.51	16.96	8.30	62.29	70.59
M_9-GB (100mM) A	43.35	22.18	65.52	14.45	2.02	16.46	6.91	59.47	66.38
M_{10}-GB (50mM) B+A	43.98	24.85	68.83	15.19	2.03	17.22	7.28	61.36	68.64
M_{11}- Arginine (2.50mM)B	43.70	22.24	65.93	13.95	2.02	15.97	8.68	61.66	70.34
M_{12}- Arginine (2.50mM) A	42.56	24.23	66.78	14.61	2.52	17.13	8.58	59.05	67.63
M_{13}- Arginine (1.25mM) B+A	44.55	23.25	67.79	14.53	2.47	17.00	7.42	60.84	68.26
M_{14}-Water spray(H+A)	41.56	24.04	65.60	14.69	2.40	17.09	7.81	58.18	65.99
SEm(±)	-	-	-	-	-	-	0.04	0.06	-
CD (P=0.05)	NS	NS	-	NS	NS	-	0.01	0.02	-

Table.4 Effect of foliar spray of synthetic compounds on yields of wheat and economics of different treatments

Treatment	Grain Yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest Index (%)	Cost of cultivation (□ ha^{-1})	Gross return (□ ha^{-1})	Net return (□ ha^{-1})	B:C Ratio
Cultivars							
V_1- DBW 14	34.26	47.69	41.81	27659	47960.34	20301.7	1.75
V_2-K 307	29.98	52.75	36.26	27658	41966.64	14308	1.54
SEm(±)	1.56	0.48	0.38	-	-	-	-
CD (P=0.05)	0.26	2.89	2.36	-	-	-	-
Sprayed compounds							
M_1- No spray (control)	30.72	48.27	38.94	25705	43005	17301	1.67
M_2-KNO_3(1%) B	32.05	50.52	38.82	26905	44867	17962	1.67
M_3-KNO_3 (1%) A	33.58	51.29	39.63	26905	47010	20105	1.75
M_4-KNO_3(0.5%) B+A	34.10	51.49	40.06	27305	47733	20428	1.75
M_5-$CaCl_2$(0.2%) B	31.53	48.69	39.31	29113	44135	15022	1.60
M_6-$CaCl_2$(0.2%) A	33.62	51.61	39.50	29113	47071	17958	1.71
M_7-$CaCl_2$(0.1%) B+A	33.97	51.33	39.93	29513	47564	18051	1.70
M_{8-} GB (100mM) B	30.75	50.23	37.93	27705	43048	15343	1.55
M_9-GB (100mM) A	31.41	50.40	38.41	27705	43974	16269	1.59
M_{10}-GB (50mM) B+A	31.64	50.71	38.41	28105	44292	16187	1.58
M_{11}- Arginine (2.50mM)B	30.99	50.54	37.97	27414	43384	15970	1.58
M_{12}- Arginine (2.50mM) A	31.76	50.47	38.63	27414	44462	17048	1.62
M_{13}- Arginine (1.25mM) B+A	32.28	49.46	39.55	27814	45190	17376	1.62
M_{14}-Water spray(H+A)	31.25	48.08	39.40	26505	43755	17250	1.65
SEm(±)	1.80	-	-	-	-	-	
CD (P=0.05)	0.63	NS	NS	-	-	-	-
Interaction VxM	2.54	NS	2.79	-	-	-	-

B= Booting, A= Anthesis, H= Heading stage, SEm(±)= Standard error of mean, CD= Critical difference, NS= Non-significant, GB= Glycinebetain, $KNO_{3=}$ Potassium nitrate, $CaCl_2$= Calcium chloride, B:C ratio= Benefit: Cost ratio

Fig.1 Temperature variation during crop period (anthesis to grain filling stage)



This suggests that anthesis stage of the late sown wheat facing high temperature stress is the most responsive stage for the foliar spray of the KNO_3 with higher dose if we want to improve yield (Das and Sarkar, 1981; Sakar and Bandopadhyay, 1991). The maximum responsiveness of anthesis stage of wheat towards foliar spray of KNO_3 may be attributed to high sensitivity of this stage against elevated temperature (30/20^{0}C, day/night) for 3 days (Saini and Aspinall, 1982). However, if we want to maximize the yield repeated spray at lower concentration is desirable both at booting and anthesis (Fig. 1 and Table 1).

The simple reason is that repeated spray ensures high insurance against yield loss if staggered spells of high temperature stress occurs during pre-anthesis stage (microsporogenesis) of a crop season which causes poor pollen viability, fewer pollen grains and ultimately leads to lower seed set in cereals like wheat and rice (Prasad *et al.*, 2008). Sakar and Tripathy (1994) also found more or less same trend in case of $CaCl_2$ whereby repeated spray of low dose $CaCl_2$ at booting and anthesis gives higher yield however, maximum responsiveness of yield was found when spraying was done at higher concentration during anthesis stage.

Economics of different treatments

The highest gross return was recorded from variety DBW-14 (Rs. 47,960 ha^{-1}) which was 14.28% higher over variety K-307(Rs. 41967 ha^{-1}). Among subplots, M_4 treatment with the foliar spray of KNO_3@ 1% at booting stage obtain the highest gross return (Rs. 51,744 ha^{-1}) which was 17.28% higher over M_1 (Rs. 43005 ha^{-1}) treatment and it was 16.48% higher over M_7 treatment in variety DBW-14. In variety K-307, highest gross return obtained in M_7 treatment (Rs. 44420 ha^{-1}) with the foliar spray of $CaCl_2$ (0.1%) @ both at booting and anthesis stage which is 6.03% higher over M_1 treatment followed by M_4 and M_{13} treatments. Over all highest gross return obtained in M_4 treatment (Rs.47733 ha^{-1}) which was about 11% higher over M_1 (no spray) treatments followed by M_7 and M_6 treatments.

The net return was highest in variety DBW-14 (Rs. 20328 ha^{-1}) which was about 42% higher over the variety K-307 (Rs. 14308 ha^{-1}). In sub plot, M_4 treatment obtained the highest net return (Rs. 24439 ha^{-1}) which was 33% higher over M_1 treatment followed by M_3 and M_6 respectively. In variety K-307, highest net return obtained in M_{14} treatment (Rs.16638 ha^{-1}) which was about 3% higher overM_1 treatment.

Overall average net return was obtained in M_4 treatment (Rs.20428 ha^{-1}) which was about 18% higher compare to M_1 (no spray) treatment followed by M_3 and M_6 treatments. The B: C ratio was highest in variety DBW-14 (1.75) which was about 14% higher compare to the variety K-307 (1.57). In subplot treatment, M_4 and M_3 obtain the highest B: C ratio (1.90) which was about 11% higher compared to M_1 (no spray).

Overall the highest B: C ratio was recorded in M_4 and M_3 treatment which was about 5% higher compare to M_1 (no spray) treatment. High temperature can affect metabolic process and ultimately reduce the quantity and quality of output. Spray of above compounds provides more yield even in high temperature stress condition and by more yield we get increased returns, which goes loss due to high temperature.

Rice-wheat system is predominant system of cropping in Indo-Gangetic regions of Bihar and Uttar Pradesh. Long duration rice varieties take more time to mature and delayed sowing of wheat after rice in this region. Due to late sowing of wheat, reproductive stage of the crop which is considered to be the most sensitive to elevated temperature, coincides with the period of high temperature spells, when mean atmospheric temperature rises beyond 20°C. This imposes stress to the crop during its anthesis to grain filling period. As a result, current photosynthesis gets hampered; resulting in poor translocation of assimilates to the developing grains resulting, lower the yield of wheat.

Based over one-year experimentation, it may be concluded that foliar spray of KNO_3 @ 0.5 per cent followed by $CaCl_2$ @ 0.1 per cent both at booting and anthesis stage should be applied on short duration wheat variety like-DBW 14for achieving maximum grain yield and economic return under irrigated late sown condition.

These compounds play beneficial role by increasing stomatal movement, protein synthesis, enzyme activation, water balance as well as maintain chlorophyll (photosynthetic ability) in leaves against high temperature loss.

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