The Pharma Innovation

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Effect of foliar application of Thio-urea on morphological and physiological parameters in wheat (*Triticum aestivum* L.) cultivars under terminal heat conditions

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Abstract
The present investigation entitled "Effect of foliar application of Thio-urea on morphological and physiological parameters in wheat (*Triticum aestivum* L.) cultivars under terminal heat conditions" was conducted at Student Instructional Farm of CSUA&T Kanpur, during *Rabi* 2017-18 and 2018-19. It was designed in double-split plot design with three replications. The objective of investigation was to study the effect on foliar application of thio-urea with different doses on plant traits (morphological and physiological) of two wheat varieties under timely and late sown condition. The two conditions *i.e.,* timely (D_1) and late (D_2) conditions were allocated in the main plots and two wheat varieties *i.e.,* V_1 (K-402) and V_2 (K-607) in sub plot and for each five chemical treatments were applied as foliar spray at heading stages by 500ppm (T_1), 750ppm (T_2), 1000ppm (T_3) and 1500ppm (T_4) thio-urea, along with control (T_0) in sub-sub plots. Results revealed that growth in terms of morphological parameters and physiological and its components varied significantly among tested wheat genotypes during both years of study timely and under late sown conditions. The significantly higher morphological traits (Days to flowering, Days to anthesis, Days to maturity) and physiological traits (Canopy temperature depression (CTD), Chlorophyll Fluorescence and Relative water content can be obtained by foliar application of 750ppm thio-urea (T_2) with both conditions of *i.e.,* timely (D_1) and late (D_2) of wheat crop. In this parameter represents thio-urea doses 500ppm (T_1), *i.e.,* 5.4 & 5.2 g, 750ppm (T_2) *i.e.,* 5.6 & 5.4 g, 1000ppm (T_3) *i.e.,* 5.3 & 5.1 g and 1500ppm (T_4) *i.e.,* 5.2 & 5.7 g as compare to control (T_0) *i.e.,* 5.2 & 5.3 g. In cultivars, maximum responsive variety was K-402 (V_1). Further, these genotypes took significantly lesser days for their phonological stages *i.e.*, days to anthesis, flowering and maturity as compared to timely sown evaluated under late sowing stress.

Keywords: Days to flowering, days to maturity, RWC

Introduction

Wheat (*Triticum aestivum* L.) is an important staple cereal crop throughout the world. It is eaten in various forms by more than thousand million human beings in the world. Its straw is used as the feed for large population of cattle. In India, it is the second staple food crop following rice. It contains about 8-15% protein and its glutein is especially important for bakery and bread making. India is the largest wheat producing country in the world after China. The wheat production has increased manifold from 6.60 million tons at the time of independence to 97.44 million tons (Anonymous, 2017-18) [1]. Wheat is a long day crop and requires relatively low temperature and photoperiod play a key role in determining duration of different phenophases, which affect the vegetative and reproductive development and yield (Slefer and Rawson 1994) [8]. Further, photosynthesis and productivity are limited by physiological and environmental constraints (Parry *et al*., 2011) [6]. The major effects of high temperature on the vegetative stage of crop leading damage to components of leaf, photosynthesis, reducing carbon dioxide assimilation rates compared with environment having more optimal temperature. Higher temperature (>28 ^{0}C) during grain development is the single most important factor that limits productivity of wheat in India. Due to intensive cropping system farmers by and large delay wheat sowing, particularly, in wheat grown belt of northern India which ultimately results in exposure of plants to extreme high temperature. This increased temperature hastens the phonological development of crop, reduces total duration of crop growth, grain filling and finally lowering the grain yield and its quality (Wang *et al.,* 1992) [9]. Thio-urea has been reported to play avital role in the physiology of plants both as a sulphydryl compound and as an amino compound like urea. The stimulating action of thiourea in various

physiological functions of plants is well known (Mayer, 1956; Mayer and Poljakoff-Mayber, 1958 and Poljakoff-Mayer *et al.*1958) [4, 5, 5]. Thio-urea (TU) derivatives have a long history as a legend in coordination chemistry and coordinate to a metal via both sulphur and oxygen (Burrows *et al.,* 1999) [2]. Thio-urea an orange sulphur compound with the formula CS $(NH_2)_2$. It is structurally similar to urea, except that the oxygen atom is replaced by a sulphur atom, but the properties of urea and thio-urea differ significantly. Metal complex of thio-urea, organic and inorganic part of the complex. A number of thio-urea derivatives have been reported to form complexes with copper and cobalt (Dominguez *et al.*, 2002) [3]. Thio-urea, also called thiocarbamide, an organic compound that resembles urea but contains sulphur instead of oxygen; *i.e.,* the molecular formula is CS $(NH_2)_2$, while that of urea is CO $(NH_2)_2$. Like urea, it can be prepared by causing a compound with the same chemical composition to undergo rearrangement, as by heating ammonium thiocyanate (NH_4SCn). A method of preparation more commonly used consists of the addition of hydrogen sulphide to cyanamide. Thio-urea, a sulphydral compound is known to improve pulse productivity and its role as a drought ameliorant is well established under the arid and semi-arid regions (Sahu *et al.*, 1993) [7].

Materials and Methods
The present study was carried out at the Experimental Students Farm, Nawabganj of Chandra Shekhar Azad University of Agriculture and Technology Kanpur, (U.P.), India, during *Rabi* season 2017-18 and 2018-19. Geographically Kanpur is located of 26.30^0 N Longitude of 80.15^0 E and above 127 meters sea level. The experimental design was split- split plot design in which sowing conditions was in main plot (D_1- Timely sowing, D_2- Late sowing), two cultivars (V_1: K- 607, V_2: K- 402) in subplot while five treatments in these one doses thio-urea (T_1-500ppm, T_2-750ppm, T_3- 1000ppm, T_4-1500ppm) with control T_0- water spray in sub-sub plot with three replications. According to each plot size 4.0m×3.0m a total dose of A total dose of 150 kg/ha Nitrogen, 80 kg/ha Phosphorus and 60 kg/ha Potash, through urea, single super phosphate (SSP) and murate of potash (MOP), respectively were used in the experiment. Half does of nitrogen, total Phosphorus and Potash were given as basal dose before sowing of seed; remaining half dose of nitrogen was given in two equal split doses, one at tillering and other at the time of spike initiation.

Results & Discussion
Days to Flowering
The data regarding on days to flowering as presented in Table 1, revealed that days to flowering affected by condition, varieties, foliar spray of thio-urea and their interactions.

1. **Effect of condition:** Since, both experimental year timely sowing condition *i.e.,* D_1 (77.4 and 75.1 days) counted significantly maximum days to flowering as compared to late sowing *i.e.,* D_2 (68.5 and 66.4 days).

2. **Effect of varieties:** The wheat varieties V_1 *i.e.,* 71.1 days at par with V_2 *i.e.,*70.5 days followed by V_1 *i.e.,* 73.2 days took non-significantly higher days to flowering while, lowest days to flowering was counted in V_2 *i.e.,* 72.7 days with both years of experimentation.

3. **Effect of treatment:** Among the treatments, significantly more mean value of days to flowering found in treatment T_2 with 76.7 and 74.4 days at par with T_3 with 74.1 and 71.9 days followed by T_4 with 72.9 and 70.7, T_1 with 72.0 and 69.9 while, less in T_0 with 69.0 and 67.0 days for both corresponding years.

4. **Interaction effect between condition and varieties:** The interaction effect of conditions and varieties was recorded non-significant effect for days to flowering for both years. The statistically maximum number of days to flowering was in combination D_1V_1 (78.0 and 75.7 days) and combination D_1V_1 with 76.8 (year 2017-18) and 74.5 days at par in year 2018-19 followed by all other combinations as well as, minimum in combination D_2V_2 (68.6 and 66.5 days).

5. **Interaction effect of condition and treatments:** Though, non-significant effect of days to flowering indicated that interaction between condition and treatments while, numerically more data of days to flowering observed in combination D_1T_2 *i.e.,* 81.7 and 79.2 followed by D_1T_3 *i.e.,* 78.8 and 76.4 while minimum in D_2T_0 *i.e.,* 64.8 and 62.8 over D_1T_0 *i.e.,* 73.3 and 71.8 at flowering stage with both experimental seasons, respectively.

6. **Interaction effect of varieties with treatments:** The data of interaction effect of varieties and treatment was evolved non-significant on days to flowering for both years of experimentation in (Table 1) however, numerically highest days to flowering counted in combination V_2T_2 with 81.5 and V_2T_1 with 80.0 while lowest in combination V_1T_0, V_2T_0 with 69.8 and 68.2 days, respectively.

7. **Interaction effect of condition, varieties and treatments:** In the second year, non-significantly higher value of interaction effect among conditions, varieties and treatments was showed in combination $D_1V_1T_2$ (82.0 days) and lower in $D_1V_1T_0$ (73.0 days). However, the first year non-significantly maximum value of days to flowering elucidated in combination $D_1V_2T_2$, $D_1V_1T_2$ (80.0 days) at par with $D_1V_1T_4$, $D_1V_2T_2$ (78.0 days) followed by other combinations and minimum in combination $D_2V_2T_0$ 61.0 days).

Table 1: Effect on foliar application of thio-urea on days to flowering of wheat

Varieties/ Conditions	2017-18			2018-19		
	V_1	V_2	Mean	V_1	V_2	Mean
D_1	78.0	76.8	77.4	75.7	74.5	75.1
D_2	68.4	68.6	68.5	66.4	66.5	66.4
Mean	**73.2**	**72.7**		**71.1**	**70.5**	

Treatment/ Conditions	2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
D_1	73.3	75.5	81.7	78.8	77.8	77.4	71.8	73.2	79.2	76.4	75.5	75.1
D_2	64.8	68.6	71.7	69.4	68.1	68.5	62.8	66.5	69.6	67.3	65.9	66.4
Mean	69.0	72.0	76.7	74.1	72.9		67.0	69.9	74.4	71.9	70.7	

| **Treatment/ Varieties** | **2017-18** | | | | | | **2018-19** | | | | | |

	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
V_1	69.8	72.2	76.8	74.3	73.1	73.2	67.7	70.1	74.5	72.1	71.0	71.1
V_2	68.2	71.8	76.6	73.7	72.7	72.7	80.0	80.0	81.5	71.7	70.5	70.5
Mean	69.0	72.0	76.7	74.1	72.9		67.0	69.9	74.4	71.9	70.7	

Combinations		T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
D_1	V_1	73.0	75.0	82.0	79.0	78.0	71.0	73.0	80.0	77.0	76.0
D_1	V_2	73.0	75.0	80.0	77.0	76.0	70.0	72.0	78.0	75.0	74.0
D_2	V_1	66.0	68.0	71.0	68.0	67.0	64.0	66.0	69.0	66.0	65.0
D_2	V_2	63.0	68.0	72.0	69.0	68.0	61.0	66.0	70.0	67.0	66.0

Factor	D	V	T	DxV	DxT	VxT	DxVxT	D	V	T	DxV	DxT	VxT	DxVxT
SE (d)	0.6	0.5	0.6	0.8	0.9	0.9	1.3	0.7	0.6	0.7	0.9	1.0	1.0	1.5
C.D. at 5%	2.7	NS	1.3	NS	NS	NS	NS	3.0	NS	1.5	NS	NS	NS	NS

Days to anthesis

The data evolved (Table 2.) on the effect of foliar sprayed thio-urea with four varieties in two conditions and their interaction for days to anthesis:

1. **Effect of condition:** It is visualized that the mean value of both experimental years of the conditions statistically influenced the days to anthesis. The significantly higher mean value observed in D_1 *i.e.*, 86.2 and 84.0 days and lower in D_2 *i.e.*, 76.9 and 74.5 days to anthesis.
2. **Effect of varieties:** The effects of varieties on days to anthesis were found statistically non-significant. Among the varieties, V_1 was recorded significantly superior (81.8 and 79.5 days) and in V_2 (81.3 and 79.0 days) inferior during both years *i.e.,* 2017-18 and 2018-19, respectively.
3. **Effect of treatments:** The significantly both year maximum value on days to anthesis counted in the treatment T_2 with 85.2 and 82.9 days as compared to treatment T_3 with 82.9 and 80.6 days and treatment T_4 with 81.6 and 79.2 days and treatment T_1 with 80.6 and 78.3 days to anthesis for both yeas of experimentation as well as T_0 with 77.5 and 75.2 days was low in second year.
4. **Interaction effect of condition and varieties:** Statistically more value of conditions with varieties for days to anthesis stated in combination D_1V_1 *i.e.*, 86.8 and 84.6 days mean time combination. On the other hand, least in combination D_2V_2 *i.e.*, 76.9 and 74.6 days during both experimental years.
5. **Interaction effect between condition and treatments:** Although, effect of conditions and treatments value did not probe significant for days to anthesis during both years while numerically maximum value noted in the combination D_1T_2, D_1T_3 with 90.0 and 87.7, 87.9 and 85.6 days but minimum in the combination D_2T_4, D_2T_0 with 76.4 and 73.9, 72.7 and 70.5 days for both year of experimentation, respectively.
6. **Interaction effect of varieties with treatments:** Though, in the second year value between varieties and treatments was recorded non-significant but numerically maximum value was in the combination V_2T_2 (83.1 days) and minimum value in the combination V_2T_0 (74.2 days). On the other hands, statistically higher value for days to anthesis noted also in the combination V_1T_2 (85.2 days) followed by V_2T_2 (85.3) compared to other combinations and lower in the combination V_2T_0 (76.6 days) during first year of experimentation.
7. **Interaction effect among condition, varieties and treatments:** The data on the effect of sowing dates, varieties and treatments predicate statistically non-significant but numerically higher days to anthesis was in the combination $D_1V_1T_2$ *i.e.*, 90.0 and 88.0 days as well as least in the combination $D_2V_2T_0$ *i.e.*, 71.0 and 69.0 days with both experimental years.

Table 2: Effect on foliar application of thio-urea on days to anthesis of wheat cultivars under timely and late sown conditions

Varieties/Conditions	2017-18			2018-19		
	V_1	V_2	Mean	V_1	V_2	Mean
D_1	86.8	85.7	86.2	84.6	83.4	84.0
D_2	76.8	76.9	76.9	74.6	74.6	74.5
Mean	81.8	81.3		79.5	79.0	

Treatment/ Conditions	2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
D_1	82.3	84.2	90.0	87.9	86.8	86.2	79.9	82.2	87.7	85.6	84.6	84.0
D_2	72.7	76.9	80.5	77.8	76.4	76.9	70.5	74.5	78.0	75.6	73.9	74.5
Mean	77.5	80.6	85.2	82.9	81.6		75.2	78.3	82.9	80.6	79.2	

Treatment/Varieties	2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
V_1	78.4	81.0	85.2	82.8	81.6	81.8	76.2	78.9	82.8	80.6	79.2	79.5
V_2	76.6	80.8	85.3	82.9	81.6	81.3	74.2	77.8	83.2	80.7	79.3	79.0
Mean	77.5	80.6	85.2	82.9	81.6		75.2	78.3	82.9	80.6	79.2	

Combinations		T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
D_1	V_1	82.0	85.0	90.0	88.0	87.0	80.0	83.0	88.0	86.0	85.0
D_1	V_2	81.0	83.0	89.0	87.0	86.0	79.0	81.0	87.0	85.0	84.0
D_2	V_1	74.0	76.0	79.0	77.0	75.0	72.0	74.0	77.0	75.0	73.0
D_2	V_2	71.0	76.0	81.0	78.0	76.0	69.0	74.0	79.0	76.0	74.0

Factor	D	V	T	DxV	DxT	VxT	DxVxT	D	V	T	DxV	DxT	VxT	DxVxT
SE (d)	0.7	0.6	0.7	0.9	1.0	1.0	1.4	0.6	0.5	0.6	0.7	0.8	0.8	1.2
C.D. at 5%	3.2	NS	1.4	NS	NS	NS	NS	2.8	NS	1.2	NS	NS	NS	NS

Days to Maturity

The data overlooked on the effect of foliar spray of thio-urea on condition, varieties, treatments and their interaction for Days to maturity in Table 3.

1. **Effect of condition:** The mean value of days to maturity counted significantly maximum in timely sown condition *i.e.,* D_1 (123.5 and 122.2) and minimum in late sown condition *i.e.,* D_2 (118.6 and 117.6 days) during both experimental years.

2. **Effect of varieties:** The non-significantly higher mean value of days to maturity recorded in the variety V_1 with 121.4 and 120.1 days but least in V_2 with 120.7 and 119.6 for experimental years *i.e.,* 2017-18 and 2018-19, respectively. **Effect of treatments:** Among the treatments, statistically highest mean value of days to maturity probed in treatment T_2 *i.e.,* 122.9 and 121.5 days at par with T_3 *i.e.,* 121.7 and 120.4 days followed by T_4 *i.e.,* 121.7 days, T_1 *i.e.,* 121.5 days while lowest in the treatment T_0 *i.e.,* 118.5 days in the both year of experimentation, respectively.

3. **Interaction effect of condition and varieties:** It is visualized that the value of days to maturity was showed non-significantly more in combination D_1V_1 with 124.1 days at par in combination D_1V_2 with 122.9 and 121.7 combinations of condition and varieties while less in combination D_2V_1 with 118.8 and 117.6 days for both corresponding years, respectively.

4. **Interaction effect between condition and treatments:** Though, first year data on conditions with treatments was recorded non-significant on days to 75% maturity. But, numerically higher was in combination D_1T_2 *i.e.,* 125.8 days and lower in combination D_1T_0 *i.e.,* 120.2 days. Mean while second year, these value stated non-significantly maximum in combination D_1T_2 *i.e.,* 124.2 days at par with D_1T_3 *i.e.,* 123.1 days followed by other tested combination and minimum in combination D_1T_0 *i.e.,* 118.8 days.

5. **Interaction effect of varieties with treatments:** Although, data on varieties and treatments was recorded non-significant but numerically maximum days to maturity was in the combination V_1T_2 (123.2 and 121.7 days) and minimum in the combination V_2T_0 (117.7 and 116.8 days) during years *i.e.,* 2017-18 and 2018-19, respectively.

6. **Interaction effect of condition, varieties and treatments:** The value show statistically non-significant for both years of experimentation while, numerically higher and similar value of days to maturity in the combination $D_1V_1T_3$ and $D_1V_2T_2$ with 125.0 days in the year 2017-18. In year 2018-19, was only higher in combination $D_1V_1T_3$ and $D_1V_2T_2$ with 123.0 days followed by other tested combinations. On the other hands, combination $D_2V_2T_0$ with 115.0 days to maturity were lower for both concerning years.

Table 3: Effect on foliar application of thio-urea on days to maturity of wheat cultivars under timely and late sown conditions

Varieties/Conditions	2017-18			2018-19		
	V_1	V_2	Mean	V_1	V_2	Mean
D_1	124.1	122.9	123.5	122.7	121.7	122.2
D_2	118.8	118.5	118.6	117.6	117.6	117.6
Mean	121.4	120.7		120.1	119.6	

Treatment Conditions	2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
D_1	120.2	123.9	125.8	124.4	123.3	123.5	118.8	122.7	124.2	123.1	122.1	122.2
D_2	116.9	119.1	120.0	119.0	118.2	118.6	116.3	118.0	118.9	117.8	116.9	117.6
Mean	118.5	121.5	122.9	121.7	120.7		117.5	120.4	121.5	120.4	119.5	

Treatment/Varieties	2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
V_1	119.3	121.7	123.2	122.0	121.0	121.4	118.3	120.6	121.7	120.5	119.6	120.1
V_2	117.7	121.3	122.6	121.3	120.5	120.7	116.8	120.1	121.4	120.4	119.4	119.6
Mean	118.5	121.5	122.9	121.7	120.7		117.5	120.4	121.5	120.4	119.5	

Combinations		T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
D_1	V_1	120.0	124.0	126.0	125.0	124.0	119.0	122.0	124.0	123.0	122.0
	V_2	119.0	123.0	125.0	123.0	122.0	118.0	122.0	123.0	122.0	121.0
D_2	V_1	118.0	119.0	119.0	118.0	117.0	117.0	118.0	118.0	117.0	116.0
	V_2	115.0	118.0	120.0	119.0	118.0	115.0	117.0	119.0	118.0	117.0
Factor	D	V	T	DxV	DxT	VxT	DxVxT	D	V	T	DxV	DxT	VxT	DxVxT
SE (d)	0.6	0.5	0.6	0.7	0.8	0.8	1.2	0.5	0.5	0.5	0.7	0.7	0.7	1.0
C.D. at 5%	2.5	NS	1.2	NS	NS	NS	NS	2.4	NS	1.0	NS	NS	NS	NS

Canopy Temperature Depression (CTD) in ºC

The data on CTD at heading stage is revealed from Table 4. Which affected due to condition, varieties, foliar spray of thio-urea and their interaction.

1. **Effect of condition:** The significantly maximum mean value of conditions to CTD was recorded in late sown condition *i.e.,* D_2 (3.0 and 3.2 ºC) and minimum in timely sown condition *i.e.,* D_1 (2.6 and 2.8 ºC) during both years of experimentation.

2. **Effect of varieties:** For both experimental year, non-significantly higher mean value of varieties to CTD in ºC was measured in variety V_1 *i.e.,* 3.0 and 2.9 but lower in variety V_2 *i.e.,* 2.9 and 2.8, respectively.

3. **Effect of treatments:** Among the treatments, treatment T_2 gave better performance with 3.1 and 2.9 ºC in both years but in first year at par with treatment T_3 with 3.0 and 2.8 ºC. Next to this were, treatment T_4 with 2.8 and 2.7 similar then T_0 with 3.1 and 2.5 ºC, while T_1 gave lower performance with 2.9 and 2.8 ºC, respectively.

4. **Interaction effect of condition and varieties:** The value sowing dates and varieties recorded significantly superior for CTD in combination D_2V_1 (3.39 and 3.2 ºC) followed by combination D_2V_2 (3.0 and 2.91 ºC) gave inferior performance during both years of experimentation.

5. **Interaction effect between condition and treatments:** Although, the effect of condition with treatments did not show significant but numerically maximum value was in combination D_2T_2 *i.e.,* 3.2 and 3.4 ℃ followed by other combinations as well as minimum was in combination D_1T_0 *i.e.,* 2.6. and 2.7 ℃ for years 2017-18 and 2018-19, respectively.

6. **Interaction effect of varieties and treatments:** It is visualized that the value of both experimental year was significant maximum value of CTD recorded in combination V_2T_2 (3.1 and 3.2 ℃) at par with combination V_1T_0; V_1T_1 and V_2T_4 (3.33 and 3.1; 3.0 ℃ and 3.2; 3.01 and 2.84 ℃) and minimum in combination V_2T_4 (2.7 and 2.8 ℃), respectively.

7. **Interaction effect among condition, varieties and treatments:** Though, the value of conditions, varieties and treatments for CTD in ℃ noted non-significant but numerically maximum value of CTD measured in combination $D_2V_2T_1$ with 3.5 and 3.3 as compared to other combinations as minimum in combination $D_1V_1T_2$ with 2.4 and 2.3 for both concerning years, respectively.

Table 4: Effect on foliar application of thio-urea on days to maturity of wheat cultivars under timely and late sown conditions

Varieties/Conditions		2017-18						2018-19					
		V_1		V_2		Mean		V_1		V_2		Mean	
D_1		124.1		122.9		123.5		122.7		121.7		122.2	
D_2		118.8		118.5		118.6		117.6		117.6		117.6	
Mean		121.4		120.7				120.1		119.6			
Treatment/ Conditions		2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean	
D_1	120.2	123.9	125.8	124.4	123.3	123.5	118.8	122.7	124.2	123.1	122.1	122.2	
D_2	116.9	119.1	120.0	119.0	118.2	118.6	116.3	118.0	118.9	117.8	116.9	117.6	
Mean	118.5	121.5	122.9	121.7	120.7		117.5	120.4	121.5	120.4	119.5		
Treatment/ Varieties		2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean	
V_1	119.3	121.7	123.2	122.0	121.0	121.4	118.3	120.6	121.7	120.5	119.6	120.1	
V_2	117.7	121.3	122.6	121.3	120.5	120.7	116.8	120.1	121.4	120.4	119.4	119.6	
Mean	118.5	121.5	122.9	121.7	120.7		117.5	120.4	121.5	120.4	119.5		
Combinations		T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2		T_3	T_4	
D_1	V_1	120.0	124.0	126.0	125.0	124.0	119.0	122.0	124.0		123.0	122.0	
	V_2	119.0	123.0	125.0	123.0	122.0	118.0	122.0	123.0		122.0	121.0	
D_2	V_1	118.0	119.0	119.0	118.0	117.0	117.0	118.0	118.0		117.0	116.0	
	V_2	115.0	118.0	120.0	119.0	118.0	115.0	117.0	119.0		118.0	117.0	
Factor	D	V	T	DxV	DxT	VxT	DxVxT	D	V	T	DxV	DxT	VxT	DxVxT
SE (d)	0.6	0.5	0.6	0.7	0.8	0.8	1.2	0.5	0.5	0.5	0.7	0.7	0.7	1.0
C.D. at 5%	2.5	NS	1.2	NS	NS	NS	NS	2.4	NS	1.0	NS	NS	NS	NS

Chlorophyll Fluorescence (F_v/F_m ratio)
The data with respect to the effect of condition, varieties, foliar applied potassium nitrate, thio-urea and their interaction on chlorophyll fluorescence in F_v/F_m at heading stage have been presented in Table *5*.

1. **Effect of condition:** Although, data on the effect of sowing dates to chlorophyll fluorescence was significant but numerically maximum in the D_1 *i.e.,* 0.758 and 0.636 F_v/F_m over D_{12} *i.e.,* 0.737 and 0.647 during both years of experimentation.

2. **Effect of varieties:** It is revealed that non-significantly higher mean value of chlorophyll fluorescence measured in variety V_1 with 0.704 and 0.0.689 F_v/F_m, but least in V_2 with 0.701 and 0.684 F_v/F_m for years *i.e.,* 2017-18 and 2018-19, respectively.

3. **Effect of treatments:** For both experimental years, the significantly higher mean value recorded in treatment T_2 (0.704 and 0.688) and T_3 occupy IInd rank (0.707 and 0.686), T_4 IIIrd rank (0.701 and 0.680) and T_1 IVth rank (0.715 and 0.690) compared to T_0 (0.686 and 0.688) for chlorophyll fluorescence at flowering stage.

4. **Interaction effect of condition with varieties:** The value of interaction effect between conditions and varieties non-significantly more value of chlorophyll fluorescence (F_v/F_m) was in combination D_1V_1 with 0.758 and 0.625 and least in combination D_2V_1 with 0.743 and 0.646 Fv/Fm in both corresponding years of experimentation, respectively.

5. **Interaction effect between condition and treatments:** It is visualized that the interaction effect on conditions and treatments for chlorophyll fluorescence in F_v/F_m recorded non-significant while, numerically higher in combination D_2T_2 *i.e.,* 0.747 and 0.649 over other combinations but lower was in combination to D_1T_0 *i.e.,* 0.636 and 0.746 with both concerning experimental years.

6. **Interaction effect of varieties and treatments:** Though, interaction value of varieties and treatments was not found significant in chlorophyll fluorescence (F_v/F_m) but numerically maximum value was in combination V_1T_2 (0.701 and 0.690), second in combination V_2T_1 (0.695 and 0.716) and minimum in combination V_1T_0 (0.678 and 0.685) during both years of experimentation, respectively.

7. **Interaction effect of condition, varieties and treatments:** The interaction effect among conditions, varieties and treatments had showed non-significant for both years of experimentation. Numerically interaction value of chlorophyll fluorescence in F_v/F_m measured higher in combination $D_1V_1T_2$ *i.e.,* 0.755 and 0.625 and lower in combination $D_1V_2T_0$ *i.e.,* 0.656 and 0.749 Fv/Fm in year 2017-18 and also year 2018-19, respectively.

Table 5: Effect on foliar application of thio-urea on chlorophyll fluorescence (Fv / Fm ratio) at heading stage of wheat cultivars under timely and late sown conditions

Varieties/Conditions	2017-18						2018-19					
	V_1		V_2		Mean		V_1		V_2		Mean	
D_1	0.625		0.646		0.636		0.758		0.760		0.758	
D_2	0.743		0.732		0.737		0.646		0.648		0.647	
Mean	0.684		0.689				0.701		0.704			

Treatment/Conditions	2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
D_1	0.636	0.646	0.630	0.632	0.634	0.636	0.746	0.760	0.768	0.762	0.755	0.758
D_2	0.740	0.734	0.747	0.740	0.726	0.737	0.627	0.662	0.649	0.653	0.647	0.647
Mean	0.688	0.690	0.688	0.686	0.680		0.686	0.715	0.704	0.707	0.701	

Treatment/ Varieties	2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
V_1	0.678	0.685	0.690	0.684	0.683	0.684	0.685	0.714	0.701	0.706	0.699	0.701
V_2	0.698	0.695	0.687	0.688	0.677	0.689	0.687	0.716	0.707	0.708	0.703	0.704
Mean	0.688	0.690	0.688	0.686	0.680		0.686	0.715	0.704	0.707	0.701	

Combinations		T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
D_1	V_1	0.616	0.639	0.625	0.632	0.616	0.742	0.786	0.755	0.762	0.752
	V_2	0.656	0.654	0.635	0.632	0.653	0.749	0.767	0.764	0.761	0.757
D_2	V_1	0.739	0.732	0.754	0.737	0.751	0.628	0.660	0.647	0.650	0.645
	V_2	0.740	0.736	0.739	0.743	0.702	0.625	0.664	0.650	0.655	0.648
Factor	D	V	T	DxV	DxT	VxT	DxVxT	D	V	T	DxV	DxT	VxT	DxVxT
SE (d)	0.006	0.007	0.009	0.1	0.013	0.013	0.018	0.008	0.006	0.006	0.008	0.008	0.008	0.011
C.D. at 5%	0.025	NS	0.012	NS	NS	NS	NS	0.03	NS	0.02	NS	NS	NS	NS

Relative Water Content (RWC) at heading stage

The data stated for relative water content at heading stage as affected due to condition, varieties and treatments of foliar spray thio-urea and their interaction effect are predicated in Table 6.

1. **Effect of condition:** The statistically maximum value of conditions to RWC at heading stage *i.e.,* (D_1) 80.6 and 79.0, minimum *i.e.,* (D_2) 80.3 and 79.1 in significantly for both years, respectively.
2. **Effect of varieties:** The mean value of varieties recoded significantly higher to RWC for both conditions with variety V_2 with 81.1 and 80.1 but lowest in variety V_1 with 79.7 and 78.0 during both years of experimentation.
3. **Effect of treatment:** The significant effect of treatments was noted on RWC for both corresponding years. The statistically higher mean value of RWC observed in treatment T_1 *i.e.,* 82.8, 80.8 and followed by T_2 *i.e.,* 80.5, 79.0; occupy IIIrd and IVth rank to T_3 *i.e.,* 79.1, 78.0 and T_4 *i.e.,* 81.0, 77.6, to similar and lower in T_0 *i.e.,* 80.3, 78.3 after heading stage, respectively.
4. **Interaction effect of condition and varieties:** It is revealed that interaction effect of conditions with varieties that statistically significant of maximum value of RWC was in combination D_2V_2 (81.6, 81.5) over in D_1V_1 (80.5, 79.2) as compare to other combinations at heading stage for concerning years (2017-18 & 2018-19), respectively. On the other hands, significantly minimum interaction value was in combination D_1V_2 (80.6, 78.8) at

heading stage in combination D_2V_1 (78.9 and 76.7) during both experimental years.

5. **Interaction effect of condition and treatments:** Although, data on interaction effect of conditions with treatments to RWC significant at heading stage for both years. However, numerically maximum interaction value in combination D_1T_4 *i.e.,* 82.4 and 79.9 followed by D_1T_2 *i.e.,* 80.1 and 78.7 while minimum in D_1T_0 *i.e.,* 78.1 and 77.1 over D_2T_0 *i.e.,* 81.9 and 79.6 at heading stage with both experimental seasons, respectively.
6. **Interaction effect of verities and treatments:** Though, value of interaction effect on varieties and treatments for RWC was significant at heading stage during both years. Numerically highest interaction value was noted in combination V_2T_1 *i.e.,* 84.6 and 85.3 followed by V_2T_2 *i.e.,* 80.7 and 79.9. On the other hands, minimum was in combination V_1T_0 *i.e.,* 77.7 and 77.3 at over V_2T_0 *i.e.,* 82.8 and 79.4, respectively for both years of experimentation.
7. **Interaction effect of condition, verities and treatments:** The value of interaction effect among condition, verities and treatments on RWC was significant during both years on these interactions. The numerically more in $D_1V_2T_1$ followed by $D_1V_1T_3$ at heading *i.e.,* 83.3, 83.2 and 83.2, 81.6 and also but minimum in combination $D_1V_1T_0$ followed by $D_2V_1T_0$ with 78.3, 77.2 and 77.1, 77.3 respectively for both corresponding years.

Table 6: Effect on foliar application of thio-urea on relative water content (RWC) at heading stage of wheat cultivars under timely and late sown conditions

Varieties/Conditions	2017-18						2018-19					
	V_1		V_2		Mean		V_1		V_2		Mean	
D_1	80.5		80.6		80.6		79.2		78.8		79.0	
D_2	78.9		81.6		80.3		76.7		81.5		79.1	
Mean	79.7		81.1				78.0		80.1			

Treatment/ Conditions	2017-18						2018-19					
	T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
D_1	78.1	80.7	80.1	80.9	82.4	80.6	77.1	80.3	78.7	79.0	79.9	79.0
D_2	80.9	84.9	77.8	77.7	79.6	80.3	79.6	81.3	82.3	77.0	75.4	79.1
Mean	80.3	82.8	79.0	79.1	81.0		78.3	80.8	80.5	78.0	77.6	

Treatment/Varieties		2017-18						2018-19					
		T_0	T_1	T_2	T_3	T_4	Mean	T_0	T_1	T_2	T_3	T_4	Mean
V_1		77.7	80.9	78.0	79.8	82.2	79.7	77.3	76.2	80.3	78.5	77.5	78.0
V_2		82.8	84.6	79.9	78.4	79.8	81.1	79.4	85.3	80.7	77.5	77.8	80.1
Mean		80.3	82.8	79.0	79.1	81.0		78.3	80.8	80.5	78.0	77.6	
Combinations		T_0		T_1	T_2	T_3	T_4	T_0		T_1	T_2	T_3	T_4
D_1	V_1	78.3		78.1	80.5	83.2	82.5	77.2		77.4	78.6	81.6	80.8
	V_2	79.0		83.3	79.7	78.6	82.4	76.9		83.2	78.9	76.1	79.0
D_2	V_1	77.1		83.8	75.5	76.3	82.0	77.3		75.1	82.0	75.1	74.1
	V_2	76.6		85.9	80.2	78.2	77.2	81.8		87.4	82.6	78.8	76.7
Factor		D	V	T	DxV	DxT	VxT	DxVxT	D	V	T	DxV	DxT	VxT	DxVxT
SE (d)		0.2	0.4	1.0	0.6	1.4	1.4	2.1	0.1	0.5	0.8	0.7	1.2	1.2	1.7
C.D. at 5%		NS	1.3	2.1	1.8	3.0	3.0	4.2	NS	1.4	1.7	2.0	2.4	2.4	NS

Conclusion

Finally, it may be concluded that significantly higher best morphological and physiological traits can be obtained by foliar application of 750ppm thio-urea (T_2) with both conditions of sowing in both years *i.e.*, timely sown (D_1) and Late sown condition (D_2) of wheat crop.

Next to this were (T_3) *i.e.*, 5.3 and 5.1 g, 500ppm thio-urea (T_1) *i.e.*, 5.2 and 5.4 g, 1500ppm thio-urea (T_4) *i.e.,* 5.2 and 5.7 g, as compared to control (T_0) *i.e.*, 4.39 and 4.35 g. Among cultivars, maximum responsive was K-402 (V_2).

Acknowledgement

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