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Foliar spray of salicylic acid and oxalic acid ameolirates temperature (Heat) stress on wheat at anthesis stage

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Abstract
This study endeavors to quantitatively cognize the impact of changes in physiological mechanism due to climate change on wheat at vegetative stage and reproductive stage of crop. This experiment was conducted and evaluated for wheat crop using two chemicals salicylic acid and oxalic acid and meteorological data from a field site at Students Instructional Farm of the Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) during Rabiseasons of 2015-16 and 2016-17. This experiment was planned under FRBD (Factorial Randomized Block Design) with three replications and two date of sowing *viz*; 25th November and 25th December with two varieties NW-5054 and NW-2036.Results indicated that physiological traits were adversely affected by time of sowing due to onset of high temperature during crop growth and particularly grain filling. All the treatments reduced the detrimental effect of heat stress on both the varieties by improving physiological traits which ultimately helped in obtaining higher yield.

Keywords: Wheat, climate change, heat stress, salicylic acid, oxalic acid

Introduction
Wheat (*Triticum aestivum* L.) is the second most important staple food crop of the world. It accounts nearly 30% of global cereal production covering an area of 220 million hectare with an average productivity of 3.2 tonnes ha^{-1} (FAO, 2015) [6]. Wheat production in the year 2017-18 was recorded as 92.08 million tonnes covering an area of 26 million hectare in India (DES, 2014) [2]. The country further required 100 million tonnes of wheat by the year 2030 to fulfill the demands of the growing population which poses a major challenge in the background of prevailing changed climatic scenario. Crop performance and yield is the ultimate result of interaction of a crop genotype and its environment. Among various stresses, abiotic stresses such as heat, drought and salinity are considered as major threats to sustainable wheat production in India. According to world estimates, average yield losses in agricultural crops up to 50% is mainly due to different abiotic stresses as a result of these changing climatic conditions (Theilert *et al.*, 2006) [18]. The growth and yield of wheat crop is adversely affected by different environmental stresses like high temperature, soil moisture deficit, low light intensity etc. The cultivation of wheat is limited by temperature at both ends of the cropping season and high temperature stress has an adverse effect on wheat productivity. The terminal heat stress was at anthesis and grain filling stages accelerate maturity and significantly reduce grain size, weight and yield (Kamal *et al.*, 2013) [6]. High temperature is considered to be most important factor to reduce the wheat yield among the various stresses (Modarresi *et al.*, 2010) [13]. Heat stress reduces the leaf area, the duration of vegetative growth and leaf number in wheat. Heat stress is injurious to the photosynthetic apparatus during reproductive growth of wheat, diminish source activity and sink capacity, which results in reduced productivity and enhance leaf senescence causing reduction in green leaf area during reproductive stages. The rapid leaf senescence ultimately resulted in less productive tillers/plant, which is one of the major causes of yield loss of wheat. High temperature above 32 ^{0}C has been reported reducing grain yield and grain weight during grain filling, it's considered as a major determinant of wheat development and growth, decreasing yields by 3-5 % per 1 ^{0}C increase above 15 ^{0}C (Wollenweber *et al.*, 2003) [19].

Antioxidants play an important role in stress tolerance of crop plants which helps plants to ameliorate the bad effect of stress. Organic acids as antioxidants (such as citric acid and oxalic acid) play an important role in plant metabolism (Chaturvedi *et al.*, 2010) [1]. Organic acids (citric acid or oxalic) are non-enzymatic antioxidant and helps in chelating these free radicals and protecting plant from injury could result in prolonging the shelf life of plant cells and improving growth characters (Rao *et al.*, 2000) [14]. Oxalic acid (OA) is a common constituent of plants, and several species accumulate high levels of the simplest dicarboxylic acid. The most striking chemical property of oxalic acid is its strong chelating ability with multivalent cations. Recently, oxalic acid application has received much attention in relation to induced disease systemic resistance and its antioxidant capability (Malencic *et al.*, 2004) [10].

Salicylic acid (SA) is a phenolic compound involved in the regulation of growth and development of plants, and their responses to biotic and abiotic stress factors (Miura and Tada 2014) [12]. Exogenously sourced SA to stressed plants, either through seed soaking, adding to the nutrient solution, irrigating, or spraying was reported to induce major abiotic stress tolerance-mechanisms (Khan *et al*., 2014) [8]. Salicylic acid mediated improved plant tolerance to heat stress has also been reported (Khan *et al*., 2013) [9].

Materials and Methods

The experiment was conducted at Students Instructional Farm of the Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) during Rabi seasons of 2015-16 and 2016-17.Experimental site has sub-humid climate and falls in the Indogangetic plains having an alluvial soil and lies between latitude 26.47^0 North and at a longitude 82.12^0 East with an elevation of about 113 meters from sea level and is subjected to extremes of weather conditions. Two varieties (V_1) NW-5054 (Timely sown) and (V_2) NW-2036 (Late sown) were used for the study. A replicated field experiment consisting of seven treatments with two different agents was conducted in factorial randomized complete block design. Solution of different concentrations of oxalic acid and salicylic acid was prepared in desired volume of water dissolving required amount to prepare 100 mg, 150 mg, 200 mg, 25 ppm, 50 ppm and 75 ppm solution respectively for foliar spraying. In order to improve the spray retention, a sticky agent, teepol was mixed into the spray solution @ 0.5ml/litre. A spray volume of 500 liters per hectare was used to spray the crop. The spraying was done with the help of knapsack sprayer at 30 DAS.

The seeds were sown @ 100 kg ha^{-1} in row space 20 cm at average depth of 5 cm with the help of kudali. Nitrogen, phosphorus and potash were added at the rate of 120, 80 and 60 kg ha^{-1} through urea, DAP and murate of potash, respectively. Half of the nitrogen, total phosphorus and potash were added as basal dose before sowing of seeds. Remaining nitrogen was added in two equal split doses, one at tillering stage and other at the time of spike initiation. Recommended cultural practices and plant protection measures were adopted to grow the crop. Five plants were tagged in each treatment and used for assessing physiological traits. Plant height was measured from the base of the stem to the tip of the longest ear at maturity and plants were oven dried at 80^0C for 24 hours and their dry weights were recorded. The average dry weight (gm) was calculated on per plant basis. Superoxide dismutase (SOD) activity in plant tissue was measured, method described by Asada (1974) and expressed as unit g^{-1} fresh weight. Catalase activity was assayed according to the method of Sinha (1972) [17], by measuring the decomposition rate of H_2O_2 and expressed as (g^{-1} fresh weight min^{-1}). Peroxidase activity was determined by the method of Galston (1959) [4] and expressed as rate of dehydrogenation of guaiacol (g^{-1} fresh weight min^{-1}).

Results and Discussion

Effect of climate and date of sowing on wheat varieties

Each crop requires an optimum temperature, rainfall, humidity and other related weather conditions, which are necessary for higher yield. Wheat crop is more influenced with temperature. Wheat crop requires an optimum temperature ranges from (12-25 ºC) for their potential yield. Such ideal conditions seldom prevail and plant grows satisfactory within a definite range around their optimum point. If, temperature increased with 1-3 ºC the crop cannot show their full potential which results in yield loss. In this study the season during both the date of sowing was normal. Temperature ranges from (T_{max} 30.1-40 ºC) and (T_{min}14.3-24.6 ºC), average rainfall (8.9-37 mm) and average sunshine (5-8.2 hours). Detailed weekly metrological data was discussed in table 1. However, natural heat (temperature) stress condition was created through change in date of sowing of both the varieties with their recommended date of sowing. Temperature manipulates the vegetative as well as reproductive phases of crop which in due course results in poor plant vitality. The temperature for vegetative and reproductive phase of NW 5054 (timely sown) and NW 2036 (late sown) ranges from (T_{max} 19.2-14.3 ºC) and (T_{min} 8-6.8 ºC), (T_{max} 16.6-28.1 ºC) and (T_{min}5.1-14 ºC) on 1st date of sowing (25th November) and 2nd date of sowing (25th December) respectively. Although, the growth and development of a plant are thus result of coordinated interplay of the hereditary and environmental conditions.

The crop therefore, cannot show their potentialities unless the interdependent conditions are available in optimum proportion. Timeliness of sowing has always been considered an important incident in the life of crop plants. The relationship between the crop yield and weather clearly brought out the fact that for maximum growth and highest yield, the plant should have optimum environmental conditions.

Effect of date of sowing and chemicals on growth attributes of wheat varieties

Plant height is mainly controlled by the genetic makeup of genotype, but is also affected by the environmental conditions. Thus, the growth attributes (plant height and dry weight $plant^{-1}$) appears to be modified by the adverse weather and it took the normal course of happening. The findings of this investigation fall in line with those observed by (Shahzad *et al*. 2007) [16]. However, to overcome with this adverse condition or suppressed the effect of heat stress/ climate change to minimize the yield loss, some strong signaling molecules/chemicals was sprayed over crop at 30 DAS. Salicylic acid and oxalic acid known as an important signaling molecule or modulating plant response to environmental stress particularly heat stress (Senaratana *et al.*, 2000) [15]. Application of salicylic acid and oxalic acid (foliar spray) significantly increased the various growth parameters of wheat *viz*., plant height (Fig 1) and dry matter (Fig 2) accumulation almost at all the growth stages as compared to control during both the years of study. Similar results were also reported by (Karim *et al*., 2011) [7] that the application of

100, 200 and 400 ppm salicylic acid increased plant height, number of tillers/plant and shoot dry weight in wheat. Mehanna (2013) [11] reviewed that the beneficial effect of oxalic acid on growth might be attributed to its auxinic action that was reflected on enhancing cell division as well as its effect on stimulating the biosynthesis of carbohydrates.

Effect of date of sowing and chemicals on antioxidant enzyme activities of wheat varieties

Application of OA and SA showed a marked increase in superoxide dismutase, catalase and peroxidase. The results (Fig 3, Fig 4, Fig 5) show that application of oxalic acid and salicylic acid as foliar spray significantly increased antioxidant enzyme activities at 60 and 90 DAS of observations in both timely and late sown varieties (NW5054 and NW2036). (Raifa *et al.*, 2015) also reported that application of salicylic acid as seed soaking and foliar spray treatments effectively improved the performance of wheat varieties by enhancing antioxidant enzymes (SOD and CAT).

Table 1: Meteorological average mean data (weekly) during crop season *rabi*, 2015-16 and 2016-17

Standard week	Rainfall (mm)	Temp (ºC)		RH (%)	Sunshine (hrs.)
		Min.	Max.		
44	0.00	14.9	29.9	68.3	5.4
45	0.00	10.0	28.0	67.5	5.5
46	0.00	13.7	30.0	70.0	5.2
47	0.00	8.2	27.2	66.8	6.0
48	0.00	8.6	27.5	66.5	5.0
49	0.00	7.9	23.2	73.6	1.9
50	0.00	8.0	19.2	77.8	1.7
51	0.00	5.9	17.0	83.0	3.1
52	0.00	5.1	16.6	83.7	3.1
1	0.00	11.3	18.6	83.1	1.2
2	0.00	6.4	14.8	83.3	0.3
3	0.00	6.8	14.3	86.6	0.9
4	08.9	10.3	20.0	77.4	3.0
5	03.2	8.9	20.8	73.1	5.6
6	0.00	8.0	21.5	73.5	4.1
7	0.00	10.5	25.0	66.9	3.3
8	0.00	14.0	28.1	64.3	4.7
9	049.5	14.6	24.9	72.2	2.5
10	0.00	11.6	27.0	65.5	7.0
11	04.2	13.1	29.1	67.0	4.4
12	0.00	15.0	30.5	63.0	8.2
13	02.5	17.2	33.0	62.5	4.2
14	0.000	16.7	32.2	61.3	4.6
15	09.6	18.5	33.7	59.7	5.2
16	0.000	21.8	36.5	53.6	8.1
17	37.0	21.7	35.4	51.8	4.0
18	0.0	22.0	37.1	56.5	8.4

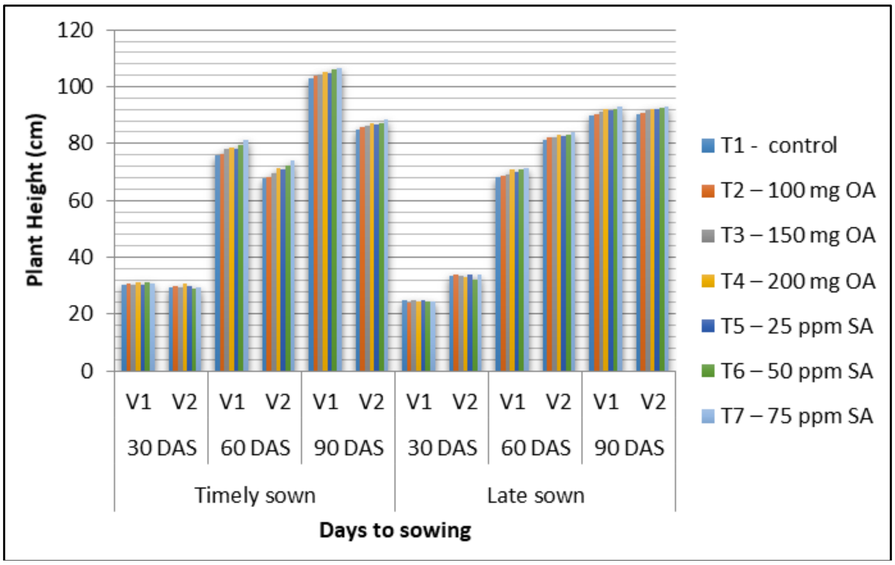

Fig 1: Effect of date of sowing and chemicals on plant height (cm) at various stages of wheat varieties

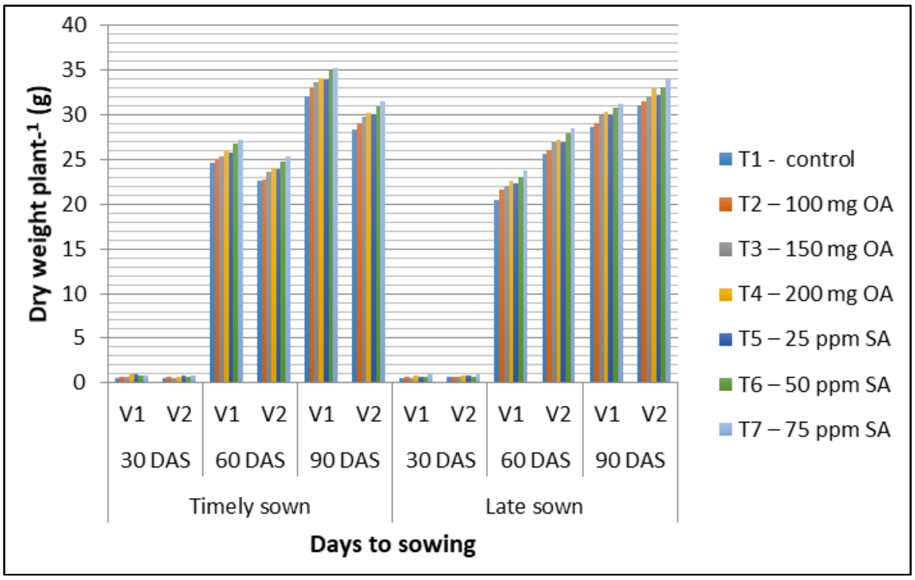

Fig 2: Effect of date of sowing and chemicals on dry weight plant^{-1} (g) at various stages of wheat varieties

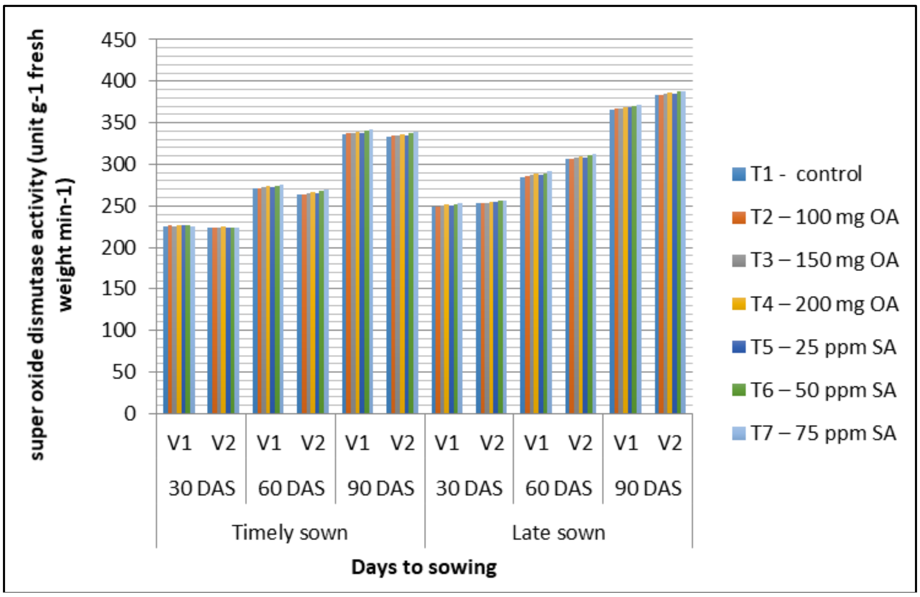

Fig 3: Effect of date of sowing and chemicals on super oxide dismutase activity (unit g^{-1}fresh weight min^{-1}) at various stages of wheat varieties

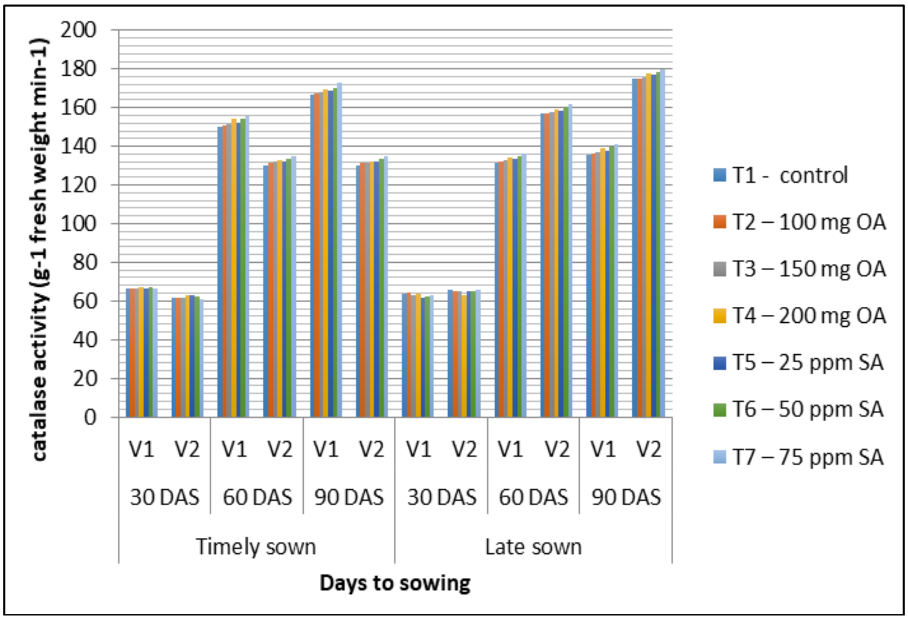

Fig 4: Effect of date of sowing and chemicals on catalase activity (g^{-1} fresh weight min^{-1}) at various stages of wheat varieties

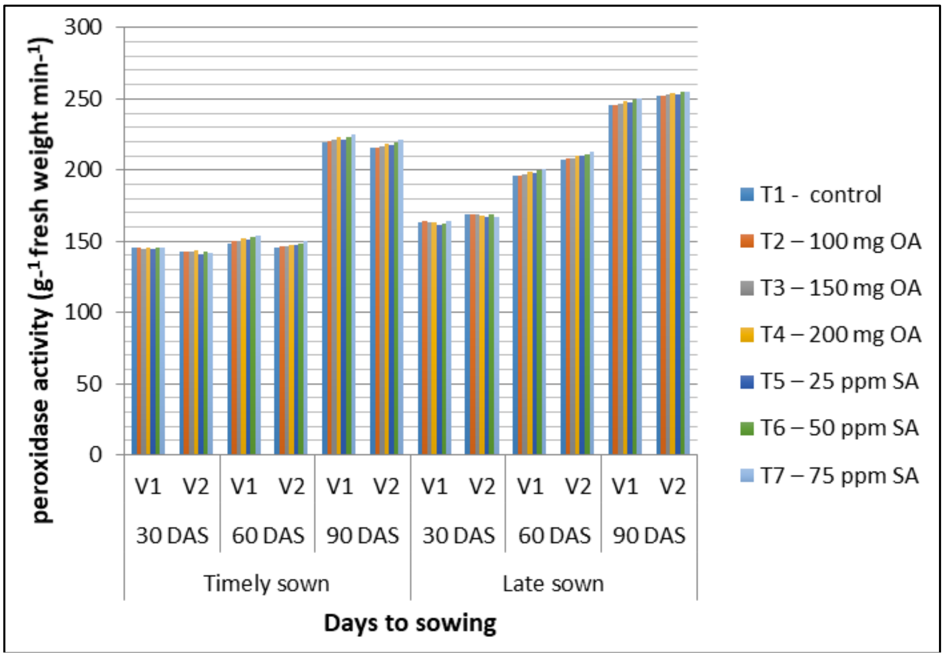

Fig 5: Effect of date of sowing and chemicals on peroxidase activity (g^{-1} fresh weight min^{-1}) at various stages of wheat varieties

Conclusion

Overall growth attributes, biochemical properties as well as antioxidant enzyme activities of wheat crop were adversely affected by time of sowing due to onset of high temperature during crop growth and particularly vegetative stage and reproductive stage. All the oxalic acid and salicylic acid treatments reduced the detrimental effect of terminal heat stress on both the varieties by improving physiological traits which ultimately helped in obtaining higher yield. Higher dose of both the oxalic acid (200 mg) as well as salicylic acid (75 ppm) are helpful in improving thermo-tolerance capability of wheat crop under heat stress environment to achieve high yield. It is recommended that higher doses of oxalic acid (200 mg) as well as salicylic acid (75 ppm) are beneficial for the farmers to minimize yield losses under high temperature environment.

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