The effect of Mannitol and Nano Urea on terminal heat stress on wheat (*Triticum aestivum* L.)

Abstract

The present investigation was conducted during Rabi season, 2022-23 at the student instructional farm (SIF) of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya- 224229 (U.P.). The experiment was conducted in randomized block design with three replications, seven treatments and wheat variety (HD 2967). The treatment was comprised of control distilled water spray, Mannitol 25, 50, 100ppm and Nano urea 25, 50, 100 ppm respectively, which was foliar sprayed at 30 DAS. The observations have been studied on growth, bio-chemical, yield and yield attributes of wheat. Observations were recorded at 60, 90DAS and at maturity stages for timely sowing (15 November) and late sowing (15 December). However, yield and yield parameters were taken at the time of harvesting of the crop.Foliar spray of mannitol and nano urea were performed well at 60, 90 DAS and at maturity parameters. Foliar application of nano urea with 25 ppm was recorded superior on plant height (cm), dry weight plant^{-1} (g), chlorophyll content in leaves (SPAD value),Catalaseactivity (g^{-1}freshweightmin^{-1}), Peroxidase activity (mg g^{-1}freshweightmin^{-1}), Super oxide dismutase activity (mg g^{-1}freshweightmin^{-1}) However, yield and yield attributes viz length of spike, number of tillers plant^{-1}, number of grains spike^{-1}, grain yield plant^{-1}It is concluded from the result that foliar spray of nano urea 25 ppm was found most effective to increasing all characters and yield parameters of wheat.

Keywords: yield parameters, cereal crop, foliar spray,Mannitol

Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop. Wheat is a member of the poaceae family and placed under genus *Triticum*. It is an annual, long day and self-pollinated plant. Wheat is the most important food cultivar at the global level than any other crop. It is staple diet for more than one third of the world population. Wheat crop occupies 21.8% of the total area under food grains. About 36% of the world population depends directly on wheat to fulfill its calories requirements. It provides 21% caloric and 10-12% protein requirements to about 4.5 billion peoples of the world. Most of them belong to developing countries. In 2021, wheat was cultivated on an area of 215.9 million hectares in the world, and 765.8 million tonnes production was obtained with an average yield of 35.4 qha^{-1}, respectively. India has about 31.61 mha area with the production of 109.52 mt and productivity of 34.64 qha^{-1}. Uttar Pradesh has about 9.85 mha area, 31.16 mt production and productivity are 32.42 qha^{-1}, respectively. Uttar Pradesh ranks first in area (32.89%) and production (31.88 %) of wheat in the country (Agricultural Statistics at a Glance 2021). The production and other yield attributing characters of wheat are greatly affected by hyperthermal conditions (Gupta *et al*., 2013). The optimum temperatures during the anthesis and grain filling were determined to be 23 °C and 21.3 °C respectively, crop exposure to temperatures above the optimum causes a yield reduction (Farooq *et al*., 2011). The optimum temperature for photosynthesis in wheat is around 20 to 30°C, and the rate of photosynthesis declines rapidly at temperatures above 30°C (Narayanan, 2018). The heat labile cell components are thylakoid membrane and PS-II. The damage to thylakoid by heat leads to chlorophyll loss (Ni *et al*., 2018). High temperature stress is a major cause of yield loss in cereal crops throughout many of the world's cereal growing areas, including India. High temperature causes dehydration in plant tissue which ceases the growth and development of plants. Heat stress increases the soil water content threshold *i.e.*, the amount of water that the plant can extract (Haworth *et al*., 2018). High temperature stress often favours accumulation of reactive oxygen species (ROS) such as hydrogen peroxide (H_2O_2), superoxide radical (O^{2-}), hydroxyl ion (OH^-) and oxygen (O^{-1}) in plant tissues (Lai and He, 2016). The reactive oxygen species generated due to stress in chloroplast, mitochondria and peroxisome can disrupt the normal metabolism through oxidative damage of proteins, lipids and nucleic acid leading to damage of cell structure (Qaseem *et al*., 2019). Osmoprotectants or compatible solutes are small molecules having low molecular weight, electrically neutral, highly soluble and non-toxic at molar concentrations (Ahn *et al*., 2011). They help plants to survive in extreme osmotic environment (Lang 2007). Plant stress tolerance has been widely reported to be improved with the exogenous application of mannitol. Mannitol, an important osmolyte, is normally synthesized in large amount in many plant species (Su *et al*., 1999 and Mitoi*et al*., 2009). Nano Urea (Liquid) contains nano scale nitrogen particles which have more surface area Nano urea prepared by nanotechnology contains nano scale particles of Nano Urea. One nano urea liquid particle is 30 nano meters in diameter, with 10,000 times higher surface area to volume size than normal granular urea (Deepika *et al.*, 2022). Average physical size of Nano Urea particles is in the range of 20 -50 nm. Nano Urea contains 4 % nitrogen by weight in its nano form. Nitrogen present in Nano Urea effectively meets the crop nitrogen requirement. It has better use efficiency than conventional urea.

Materials and Methods

During the *Rabi* season of 2022-23, the inquiry was conducted at the Acharya Narendra Deva University of Agriculture and Technology's Student Instructional Farm, Narendra Nagar, Kumarganj, Ayodhya (U.P.).Kumarganj is located at 26.47° north latitude and 81.12° east longitude, at an elevation of 113 meters, in the gangetic alluvium of eastern Uttar Pradesh.The experimental site is located in the Indo-Gangatic plains, in a sub-tropical climate with scorching summers and freezing winters. The monsoon season, which runs from July to September, receives over 80% of the total rainfall, with only a few showers in the winter.The design is Randomised Block Design (R.B.D.) with seven treatments, three replications and variety HD 2967. Concentrations of Mannitol (25, 50, 100 ppm) and nano urea(25, 50, 100 ppm) foliar spray along with untreated control. Osmoprotectant and nano urea was sprayed at 52 DAS.The significance of various treatments was judged byThe Fisher method of analysis of variance was used to analyze data collected on various growth and yield parameters (Fisher and Yates 1949).

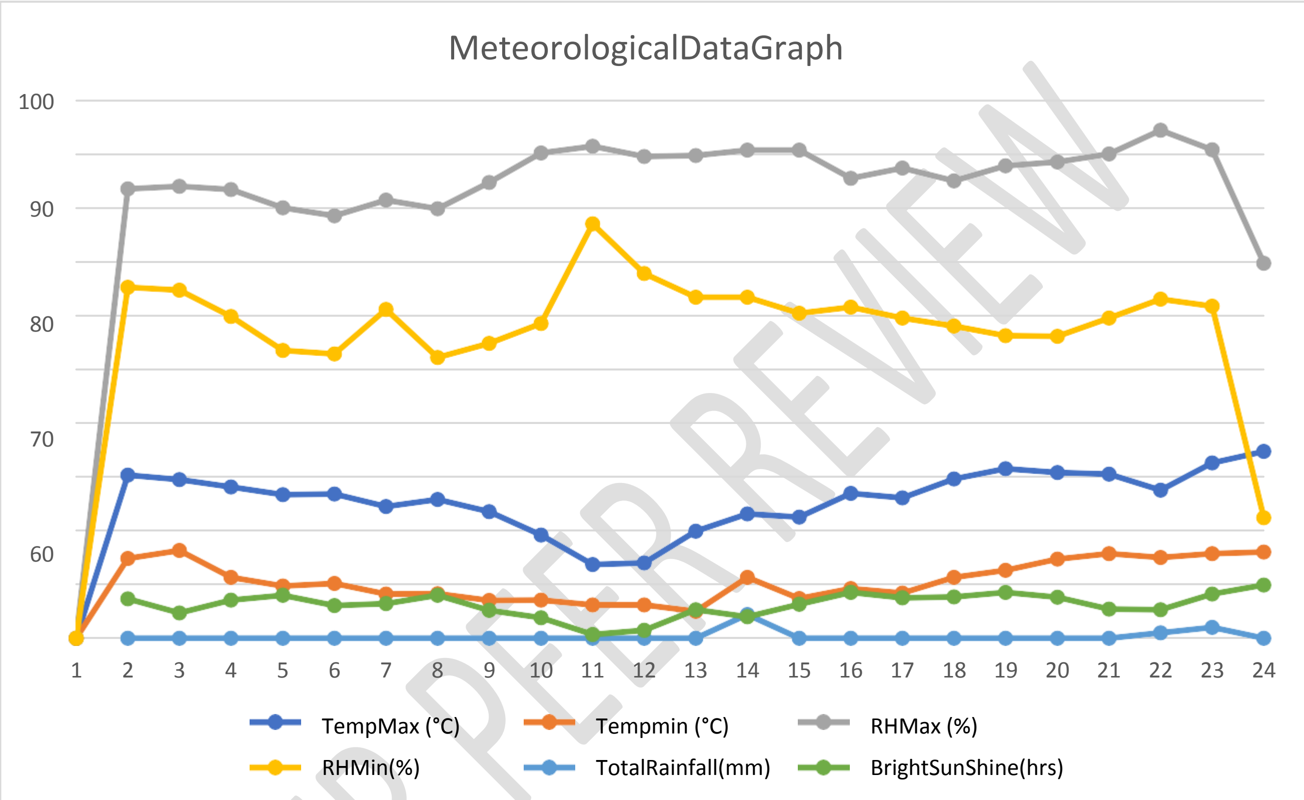

Fig1 :- Meteorological chart during crop period 2021 - 22

Result and Discussion

Growth Parameters

4.1.2 Plant Height (cm):

Data pertaining to plant height as affected by various plants growth nutrients recorded at different growth stages have been presented in table. all the treatments showed statistically significant increase in plant height was recorded with foliar spray of Nano Urea 25ppm timely sowing (75.22, 97.83 and 100.44 cm), late sowing (69.96, 93.64 and 96.32 cm) at 60 DAS, 90 DAS and at maturity stage respectively over rest of the treatments. The minimum plant height was found with foliar spray of Mannitol 25ppm timely sowing (63.56, 88.32and

90.71cm), late sowing (60.52, 86.46 and 87.38 cm) respectively at 60, 90 DAS and at maturity stages of observation over control. The data conclude that the application of mannitol and nano urea significantly shows positive response to plant height of wheat, because of nitrogen and mannitol provide mechanical strength to the stem and increase their elongation. This result is similar to Shamary and Ansari (2022), the height of wheat crop is influenced by nutrient applications and nano fertilizers.

Table 1 :Variability in plant height in different treatments

Treatments	PlantHeight(cm)					
	Timely sown			Late sown		
	60DAS	90DAS	Maturity	60DAS	90DAS	Maturity
T1– Control	58.14	83.81	85.55	56.21	81.24	82.43
T2–Manitol (25ppm)	63.56	88.32	90.71	60.52	86.46	87.38
T3 -Mannitol(50ppm)	69.24	90.80	92.88	63.62	89.45	90.13
T4-Mannitol(100ppm)	62.81	88.73	91.72	62.11	85.23	90.76
T5 -Nano urea(25ppm)	75.22	97.83	100.44	69.96	93.64	96.32
T6-Nanourea (50ppm)	67.92	87.78	90.09	67.34	82.87	93.65
T7-Nanourea (100ppm)	65.21	85.94	88.03	68.71	82.21	87.14
S.Em±	0.16	0.53	0.28	0.13	0.51	0.25
C.D.5%	0.48	1.65	0.85	0.43	1.59	0.83

4.1.4 Dry weight plant-1 (g):

Observations were recorded on dry weight plant^{-1} as effected by various foliar spray of plant nutrient at different growth stages have been presented in table. All the foliar applications showed statistically significant increase in dry matter at all the stages of crop over control. The maximum increased in plant dry weight was recorded with foliar spray of nano urea 25ppm timely sowing (27.54g, 37.05g and 35.71g), late sowing (27.37, 37.31 and 35.68 g) at 30, 90 and at maturity stage. Whereas, minimum plant dry biomass was found with foliar spray of mannitoltimely sowing (25.32g, 34.55g and 32.66g), late sowing (24.26, 33.73 and 31.62 g) respectively at all the stages of observation over the control. According to the observed result, dry weight of plant was increases continuously till 90 DAS but decreases about 8-10 % at maturity stage (Kumar et al., 2018). With the increase the dose of nitrogen the dry weight of plant will also increases. These similar results were also reported by Ahmed and Abdul (2022)

Table 2 :Variability in Dry weight plant in different treatments

Treatments	Dryweightplant^{-1}(g)					
	Timely sown			Late sown		
	60DAS	90DAS	Maturity	60DAS	90DAS	Maturity
T1– Control	24.88	32.30	31.30	22.45	30.26	30.19
T2–Manitol (25ppm)	25.32	34.55	32.66	24.26	33.73	31.62
T3 -Mannitol(50ppm)	26.94	35.95	34.65	25.71	34.49	33.35
T4-Mannitol(100ppm)	26.21	35.25	33.74	25.98	35.85	33.92
T5 -Nano urea(25ppm)	27.54	37.05	35.71	27.37	37.31	35.68
T6-Nanourea (50ppm)	25.71	34.71	33.87	26.53	35.22	32.11
T7-Nanourea (100ppm)	25.11	34.19	33.68	25.62	33.67	33.42
S.Em±	0.33	0.09	0.12	0.31	0.06	0.11
C.D.5%	1.03	0.28	0.37	1.01	0.26	0.33

4.2.1 Total chlorophyll content in leaves (SPAD value):

The critical analysis of data presented in the table. clearly indicate that all the foliar spray of different plant nutrients increase chlorophyll content in leaves up to 60, 90 DAS. The maximum increase of chlorophyll was observed with foliar application of nano urea 25ppm timely sowing (23.65, 20.15 SPAD value), late sowing (22.85, 21,03 SPAD value) at 60 and 90 DAS, respectively over rest of the treatments. However, minimum chlorophyll was found with foliar spray of mannitol25ppmtimely sowing (19.12 and 15.29 SPAD value), late sowing (16.51, 14.74 SPAD value)respectively among all the treatments over control. Chlorophyll content in leaf is positively influenced by the plant nutrients and nano fertilizers, due to increase in nitrogen content the plant chlorophyll content will also increases. The similar findings were also reported by Muhammad et al. (2022)

Table 3 :Total chlorophyll content in leaves

Treatments	Totalchlorophyll(SPADValue)			
	Timely sown		Late sown	
	60DAS	90DAS	60DAS	90DAS
T1– Control	16.19	10.84	14.63	10.22
T2–Manitol (25ppm)	19.12	15.29	16.51	14.74
T3 -Mannitol(50ppm)	20.70	16.09	19.36	15.97
T4-Mannitol(100ppm)	20.25	12.85	20.26	13.61

T5 -Nano urea(25ppm)	23.65	20.15	22.85	21.03
T6-Nanourea (50ppm)	20.14	14.59	20.47	13.86
T7-Nanourea (100ppm)	19.91	13.32	18.53	12.17
S.Em±	0.70	1.15	0.67	1.12
C.D.5%	2.17	3.55	2.03	3.49

4.1.1 Catalaseactivity (g^{-1}freshweightmin^{-1})inleaves:

Thecriticalanalysisofdatapresentedinthe Table.clearlyindicate that all the foliar spray of different plant nutrients increase catalase activity in leavesupto60,90DAS.Themaximumincreaseofcatalaseactivitywasobservedwith foliarapplication of nano urea 25ppm timely sowing (155.08 and 171.23), late sowing (136.41 and 141.29) at 60 and 90 DAS, respectivelyoverrestofthetreatments.However,minimumcatalaseactivitywasfoundwithfoliarsprayofMannitol25 ppmtimely sowing (152.36and164.52),late sowing (132.17 and 136.12)respectivelyamongallthetreatments over control. The activities of enzymes *viz,* catalase, nitrate reductase etc.graduallyincreasewiththeageofcropupto90DASunderdifferentfoliarapplicationofplantnutrients.Inordertolimitoxidativedamageunderstressconditionplantshavedeveloped a series of detoxification system that break down highly toxic reactiveoxygenspecies(**Ezzat-OllahEsfandiari*etal.* 2007).**

Table 4 :Catalase activity (g-1 fresh weight min-1) in leaves

Treatments	**Catalaseactivity (g^{-1}freshweightmin^{-1})**			
	Timely sown		**Late sown**	
	60DAS	**90DAS**	**60DAS**	**90DAS**
T1-Control	151.12	162.35	131.58	135.58
T2–Manitol (25ppm)	152.36	164.52	132.17	136.12
T3 -Mannitol(50ppm)	154.80	167.12	132.95	136.67
T4-Mannitol(100ppm)	153.35	165.36	133.87	137.87
T5 -Nano urea(25ppm)	155.08	171.23	136.41	141.29
T6-Nanoурea (50ppm)	154.53	167.30	134.10	139.70

T7-Nanourea (100ppm)	153.76	165.24	135.11	138.85
S.Em±	0.82	1.08	0.97	1.12
C.D.5%	2.36	3.11	2.77	3.21

4.1.2 Peroxidase activity (mg g^{-1}freshweightmin^{-1})inleaves:

ThecriticalanalysisofdatapresentedintheTable.clearlyindicate that all the foliar spray of different plant nutrients increase Peroxidase activity in leavesupto60,90DAS.ThemaximumincreaseofPeroxidase activity wasobservedwithfoliarapplication of nano urea 25ppm timely sowing (145.87 and 225.83), late sowing (200.36 and 250.21) at 60 and 90 DAS, respectivelyoverrestofthetreatments.However,minimumcatalaseactivitywasfoundwithfoliarsprayofMannitol25 ppmtimely sowing (152.36and164.52), late sowing (196.15 and 246.08)respectivelyamongallthe treatments over control. The similar findings were also reported by Sharma et al (2021).

Table 5 :Peroxidase activity (mg g-1 fresh weight min-1) in leaves

Treatments	**Peroxidase activity (mg g^{-1}freshweightmin^{-1})**			
	Timely sown		**Late sown**	
	60DAS	**90DAS**	**60DAS**	**90DAS**
T1-Control	144.12	219.35	195.74	245.50
T2–Manitol (25ppm)	144.36	220.52	196.15	246.08
T3 -Mannitol(50ppm)	143.80	220.12	196.87	246.95
T4-Mannitol(100ppm)	144.35	219.36	197.89	247.33
T5 -Nano urea(25ppm)	145.87	225.23	200.36	250.21
T6-Nanourea (50ppm)	143.53	221.30	199.88	249.58
T7-Nanourea (100ppm)	144.76	223.24	198.89	248.87
S.Em±	1.38	1.74	1.39	1.68
C.D.5%	3.97	4.78	4.02	4.83

4.1.3 Super oxide dismutase activity (mg g^{-1}freshweightmin^{-1})inleaves:

ThecriticalanalysisofdatapresentedintheTable.clearlyindicate that all the foliar spray of different plant nutrients increase Super oxide dismutase in leavesupto60,90DAS.ThemaximumincreaseofSuper oxide dismutase activity wasobservedwithfoliarapplication of nano urea 25ppm timely sowing (226.87

and 275.23) late sowing (291.08 and 371.16) at 60 and 90 DAS, respectivelyoverrestofthetreatments.However,minimumcatalaseactivitywasfoundwithfoliarsprayofMannitol25 ppmtimely sowing (152.36and164.52), late sowing (286.11 and 367.10)respectivelyamongallthe treatments over control. The similar findings were also reported by Karki et al. (2021).

Table 6 :Super oxide dismutase activity (mg g-1 fresh weight min-1) in leaves

Treatments	Super oxide dismutase activity (mg g^{-1}freshweightmin^{-1})			
	Timely sown		Late sown	
	60DAS	90DAS	60DAS	90DAS
T1-Control	224.45	270.35	285.10	366.11
T2–Manitol (25ppm)	226.11	271.52	286.11	367.10
T3 -Mannitol(50ppm)	225.80	271.12	286.67	367.89
T4-Mannitol(100ppm)	226.35	273.36	287.65	368.96
T5 -Nano urea(25ppm)	226.87	275.23	291.08	371.16
T6-Nanourea (50ppm)	226.53	274.30	289.50	370.37
T7-Nanourea (100ppm)	225.76	275.14	288.15	369.20
S.Em±	1.61	1.86	1.68	2.07
C.D.5%	4.60	5.33	4.83	5.92

4.1.1 Lengthof spike(cm)

Itisevidentfromthedatapresentedintableclearlyindicatethatallthefoliarsprayofdifferentplantnutrientsenhancesthelengthofspikeascomparetocontrol.Themaximumlengthofspike wasmeasuredwithfoliarsprayofnanourea25ppmtimely sowing (11.47cm),late sowing (10.73) overrestofthetreatments.However,minimumlengthofspikewasmeasured with foliar spray of mannitol 25ppm timely sowing (10.33), late sowing (9.54) among all the treatmentsandalsocontrol.Duetopositiveinflationdifferentplantnutrients,thatdirectlyaffectthe yield growth of crops like length of spikes etc. The similar result was reported by **Satish*et al.* (2022).**

4.1.2 Numberof effectivetillers plant^{-1}:

Itisevidentfromthedatapresentedintable.clearlyindicatethatall the foliar spray of different plant nutrients increases the number of effective tillersplant^{-1} as compare to control. The maximum number of effective tillers plant^{-1} wasrecorded with foliar spray of nano urea 25ppm timely sowing (9.33), late sowing (8.73) over rest of the treatments.However, minimum number of effective tillers plant^{-1} was recorded with foliar sprayofmannitol 25ppmtimely sowing (8.33),late sowing (7.83) amongallthetreatmentsovercontrol.Thenumberoftillers were also affected by plant nutrients but the greater number of tillers plants^{-1}wasfoundinnanoureaapplicationbecauseofaccumulationnitrogenincreasenumberoftillers. Theseresults areaccordancewith**Arif*etal* (2017).**

4.1.3 Numberof grainsspike^{-1}:

Itisevidentfromthedatapresentedintable.clearlyindicatethatall the foliar spray of different plant nutrients significantly increases the number ofgrains spike^{-1} as compare to control. The maximum number of grains spike^{-1} wasrecorded with foliar spray of nano urea 25ppm timely sowing (47.67), late sowing (45.83) over rest of the treatments.However, minimum number of grains spike^{-1} was recorded with foliar spray of mannitol 25ppm timely sowing (37.67), late sowing (36.79) among all the treatments over control. Number of grainsspike^{-1} was also positively influenced by plant nutrients; it enhances the number ofgrains in spikes due to their biochemical activities. The similar data was reported by**Ahmedand Abdul (2022).**

Table 7 :effective tillers and grains spike measurements

Treatments	length ofspike(cm)		Number ofeffectivetillers plant^{-1}		Number of grainsspike^{-1}	
	Timely sown	Late sown	Timely sown	Late sown	Timely sown	Late sown
T1–Control	8.57	7.12	7.00	6.19	33.33	32.33
T2–Manitol (25ppm)	10.33	9.54	8.33	7.83	37.67	36.79
T3 -Mannitol(50ppm)	11.50	10.29	9.00	8.70	41.67	39.91
T4-Mannitol(100ppm)	10.93	9.04	8.33	6.99	41.00	40.64

T5 -Nano urea(25ppm)	11.47	10.73	9.33	8.73	47.67	45.83
T6-Nanourea (50ppm)	10.57	8.65	8.66	7.89	43.67	42.74
T7-Nanourea (100ppm)	10.17	9.28	8.33	7.13	39.67	38.36
S.Em±	0.15	0.13	0.31	0.29	1.01	0.98
C.D.5%	0.47	0.42	1.02	1.01	3.13	3.11

4.1.4 Grainyieldplant^{-1}(g):

The result presented in Table. clearly indicate that all the foliarspray of different plant nutrients significantly increases the grain yield plant^{-1} ascompare to control. The maximum grain yield plant^{-1} was recorded with foliar sprayof nano urea 25ppm timely sowing (9.23g), late sowing (8.48g) over rest of the treatments. However, minimum grainyieldplant^{-1}wasrecordedwithfoliarsprayofmannitol25 ppmtimely sowing (6.94g), late sowing (5.31g)amongallthe treatments over control. Due to accumulation of nitrogen and osmoprotectant, grain yieldplant^{-1}positivelyinfluencedandshowpositiveresults*i.e.*increaseinweightofgrainsplant^{-1}.Theseresults are accordancewith**Jat*at al.* (2013).**

4.1.5 Testweight(g):

Data collected on 1000 seed weight in each foliar spray are presented in Table.Thefoliarsprayofdifferentplantnutrientsrevealthatincrementinseedweight over the control. The maximum seed weight was registered with foliar sprayofnanourea25ppmtimely sowing (44.53g),late sowing (43.39g) overrestofthetreatments.However,theminimumseedweight was registered with foliar spray of mannitol25 ppm timely sowing (40.92g), late sowing (40.23g) over rest ofthe treatments including control. The weight of seed is also increased due to bio-chemical activities of osmoprotectant and nitrogen. The similar findings were also given by**Satish *et al.* (2022).**

Table 8 :Grain yield and test weight analysis

	Grain yield plant^{-1}(g)	**Testweight(g)**

Treatments	Timely sown	Late sown	Timely sown	Late sown
T1–Control	5.71	4.49	40.92	39.38
T2–Manitol (25ppm)	6.94	5.31	41.72	40.23
T3 -Mannitol(50ppm)	8.73	7.82	43.93	42.94
T4-Mannitol(100ppm)	7.79	6.99	43.07	43.15
T5 -Nano urea(25ppm)	9.23	8.48	44.53	43.39
T6-Nanourea (50ppm)	8.30	7.73	41.13	40.02
T7-Nanourea (100ppm)	8.08	7.94	42.43	41.74
S.Em±	0.14	0.12	0.56	0.48
C.D.5%	0.44	0.40	NS	NS

4.1.1 Grainyield(q h^{-1}):

Grain yield quintals per hectare have been presented in table. allthe foliar spray of different plant nutrients significantly increases the grain yield q h^{-1}overthecontrol.Significantly,themaximumgrainyieldqh^{-1}wasrecordedwithfoliarspray of nano urea 25ppm timely sowing (55.85q h^{-1}), late sowing (54.99q h^{-1}) over rest of the treatments. However, theminimum grain yield q h^{-1} was recorded with foliar spray of mannitol 25 ppmtimely sowing (50.97q h^{-1}), late sowing (49.63q h^{-1}) among all the treatments over control. Due to increment in grain yieldplant^{-1} thereby, increment in grain yield (q h^{-1}). The similar result was also found by**Partha*et al*. (2017).**

4.1.2 Harvestindex(%):

The data presented in table. clearly indicate that non-significantvariables were found due to foliar spray of plant nutrients. Maximum harvest index(41.88%) was observed with foliar treatment of nano urea 25ppm over the allothertreatmentincludingcontrol.Harvestindexwasalsoinfluencedbythefoliarapplicationsofplantnutrients.Nutrient-useefficiencyreferstotheabilityofplantstotransport and utilize nutrients effectively for growth and yield. Thereby they canallocate resources more efficiently towards grain production, leading to an increasedharvestindex.Thesimilarfindingswereobservedby**Mohd. Arif*et al.*(2019).**

Table 9 :Grain yield and Harvest index

Treatments	Grainyield ($q\ h^{-1}$)		Harvestindex(%)	
	Timely sown	Late sown	Timely sown	Late sown
T1– Control	48.68	47.39	39.15	37.84
T2–Manitol (25ppm)	50.97	49.63	39.25	38.57
T3 -Mannitol(50ppm)	53.84	51.19	41.34	40.29
T4-Mannitol(100ppm)	52.51	52.08	39.95	38.05
T5 -Nano urea(25ppm)	55.85	54.99	42.58	42.14
T6-Nanourea (50ppm)	54.66	53.26	41.55	40.82
T7-Nanourea (100ppm)	53.27	52.74	39.38	38.94
S.Em±	0.04	0.03	NS	NS
C.D.5%	0.14	0.12	NS	NS

Conclusion

Present investigation clearly indicate that Foliar spray of mannitol and nano urea were performed well at 60, 90 DAS and at maturity parameters. Foliar application of nano urea with 25 ppm was recorded superior on **Plant height (cm), dry weight plant^{-1} (g), chlorophyll content in leaves (SPAD value), Catalaseactivity (g^{-1}freshweightmin^{-1}), Peroxidase activity (mg g^{-1}freshweightmin^{-1}), Super oxide dismutase activity (mg g^{-1}freshweightmin^{-1})** However, yield and yield attributes viz length of spike, number of tillers plant^{-1}, number of grains spike^{-1}, grain yield plant^{-1} It is concluded from the result that foliar spray of nano urea 25 ppm was found most effective to increasing all characters and yield parameters of wheat. Present finding needs further validation.

Reference

Ahn C, Park U and Park P.B., 2011. Increased salt and drought tolerance by D-ononitol production in transgenic Arabidopsis thaliana. *BiochemBiophys Res Commun*415:669–674.

Anjum F, Wahid A, Javed F and Arshad M. 2011. Potential of foliar applied thiourea in improving salt and high temperature tolerance of bread wheat (*Triticum aestivum* L.). *International Journal of Agriculture and Biology* 13: 251–6.

Chaurasiya, A., Singh, D., Dutta, S.K. and Roy, A., 2018. Growth and yield enhancement of wheat through foliar spray of Osmoprotectants under high temperature stress condition. *Journal of Pharmacognosy and Phytochemistry*, *7*(3), pp.2819-2825.

Farooq M., Bramley H., Palta J.A., Siddique K.H.M. 2011. Heat stress in wheat during reproductive and grain-filling phases. Critical Reviews in Plant Sciences, 30: 491–507.

Iqbal, M., Raja, N.I., Yasmeen, F., Hussain, M., Ejaz, M. and Shah, M.A., 2017. Impacts of heat stress on wheat: a critical review. *Adv Crop Sci Technol*, *5*(1), pp.01-09.

Iqbal, M.J., 2018. Role of osmolytes and antioxidant enzymes for drought tolerance in wheat. *Global Wheat Production*, *51*.

Karki, P., Subedi, E., Acharya, G., Bashyal, M., Dawadee, N. and Bhattarai, S., 2021. A review on the effect of heat stress in wheat (*Triticum aestivum* L.). *Archives of Agriculture and Environmental Science*, *6*(3), pp.381-384.

Khajuria, P., Singh, A.K. and Singh, R., 2016. Effect of heat stress on grain weight in bread wheat. *Ind J App Res*, *6*(1), pp.323-327.

Lang F (2007) Mechanisms and significance of cell volume regulation. *J Am Coll Nutr*26:613S–623S

Narayanan, S., 2018. Effects of high temperature stress and traits associated with tolerance in wheat. *Open Access J. Sci*, *2*(3), pp.177-186.

Narendra, M.C., Roy, C., Kumar, S., Virk, P. and De, N., 2021. Effect of terminal heat stress on physiological traits, grain mannitol and iron content in wheat (*Triticum aestivum* L.). *Czech Journal of Genetics and Plant Breeding*, *57*(2), pp.43-50.

Poudel, H., Khanal, B., Poudel, K., Dhungana, M., Pandey, R. and Dhungana, S., 2021. Effect of Heat Stress in Wheat: A Review. *Agric. Environ*, *2*, p.63.

Rawate, D., Patel, J.R., Agrawal, A.P., Agrawal, H.P., Pandey, D., Patel, C.R., Verma, P. and Chandravanshi, M., 2022. Effect of nano urea on productivity of wheat (*Triticum aestivum* L.) under irrigated condition.

Raza, M.A.S., Saleem, M.F., Shah, G.M., Khan, I.H. and Raza, A., 2014. Exogenous application of glycinebetaine and potassium for improving water relations and grain yield of wheat under drought. *Journal of soil science and plant nutrition*, *14*(2), pp.348-364.

Sahu, T.K., Kumar, M., Kumar, N., Chandrakar, T. and Singh, D.P., 2022. Effect of nano urea application on growth and productivity of rice (*Oryza sativa* L.) under midland situation of Bastar region.

Sharma, P., Singh, R., Dahiya, M., Kumar, V., Kumar, A. and Sharma, A.K., 2021. Screening of Heat Stress Tolerant in Early Stage of Wheat Seedling using Morphological Parameters. *Asian Journal of Biological and Life Sciences*, *10*(3), p.667.

Suryavanshi, P., Buttar, G.S. and Brar, A.S., 2016. Effect of osmoprotectants on performance of wheat (*Triticum aestivum* L.) under terminal heat stress condition of North-West India. *Indian J. Agric. Sci*, *86*, pp.1037-1042.

Yang, X., Tian, Z., Sun, L., Chen, B., Tubiello, F.N. and Xu, Y., 2017. The impacts of increased heat stress events on wheat yield under climate change in China. *Climatic Change*, *140*(3), pp.605-620.

Zulkiffal, M., Ahsan, A., Ahmed, J., Musa, M., Kanwal, A., Saleem, M., Anwar, J., ur Rehman, A., Ajmal, S., Gulnaz, S. Heat and Drought Stresses in Wheat (*Triticum aestivum* L.): Substantial Yield Losses, Practical Achievements, Improvement Approaches, and Adaptive. *Plant Stress Physiology*, *3*.

Su J, Chen PL, Wu R. 1999. Transgene expression of mannitol-1-phosphate dehydrogenase enhanced the salt stress tolerance of the transgenic rice seedlings. *Sci Agric Sin*. 32:101 3.