

Influence of Foliar Applications of Synthetic Compounds on Wheat Grain Quality During Terminal Heat Stress

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Article history: Received: 28 Jan., 2024 Revised: 27 Mar., 2025 Accepted: 5 Apr., 2025

Citation: Singh T, C Singh, Nandeesh C.V. and A.G. Pansuriya. 2025. Influence of Foliar Applications of Synthetic Compounds on Wheat Grain Quality During Terminal Heat Stress. *Journal of Cereal Research* **17** (1): 105-111. <http://doi.org/10.25174/2582-2675/2025/159851>

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Climate change and global warming have a direct impact on agricultural production as well as on quality by increasing the frequency and magnitude of several stresses. Cereals are mostly affected by this changing environment of Earth and have effect adverse effect on yield and quality. The high temperature during the flowering and grain filling stages can cause considerable damage to the wheat reproductive system, leading to a reduction in the grain yield (Farooq *et al.*, 2011; Jamil *et al.*, 2019; Matsunaga *et al.*, 2021; Ullah *et al.*, 2022). Wheat under harsh terminal heat stress has serious impairments in the photosynthetic process and starch metabolism (Cao *et al.*, 2019). Due to the incomplete transit of photosynthates it causes denaturation/aggregation of critical enzymes linked with pathways and the creation of tiny starch granules in the endospermic tissue (Kumar *et al.*, 2018). Due to domestication and its role as the world's main crop for staple foods, wheat is placed first among important cereals (Iqbal *et al.*, 2021). It also contains a lot of vitamins, minerals, and fibre aside from the carbohydrates. In addition to disrupting the ratios of amylose to amylopectin in the endospermic tissues, it has been discovered that elevated environmental temperature significantly lowers the nutritional density of the grains. Under HS, even the cereals' storage proteins' quality is severely diminished (Kumar *et al.*, 2018). In wheat, heat stress limits resource

translocation to developing grains (Al Masruri *et al.*, 2023), causing a reduction in grain size (Kamara *et al.* 2021), grain yield (Zhao *et al.*, 2020), kernel appearance (Jamil *et al.*, 2017), the functional properties of wheat grain protein (Zhao *et al.*, 2022), starch (Mahdavi *et al.*, 2022), minerals (Panigrahi *et al.*, 2022), kernel hardening (Elhadi *et al.*, 2021; Mahdavi *et al.*, 2022), and baking quality (Fleitas *et al.*, 2020; Mahdavi *et al.*, 2022). Heat stress generates complex changes at the genetic level that influence the physiological and biochemical pathways of wheat quality. Several researchers reported the effect of heat stress and climate change on wheat quality parameters (Fleitas *et al.*, 2020; Nagy-Réder *et al.*, 2021; Helal *et al.*, 2022; Mahdavi *et al.*, 2022; Panigrahi *et al.*, 2022; Zahra *et al.*, 2023).

Terminal heat stress affects the late-planted wheat crop during the anthesis and grain filling period (Hays *et al.*, 2007). Farmers, particularly those who are growing wheat in the same field after harvesting of the previous crop, are facing this problem very frequently because they often get compelled to sow the wheat under delayed conditions after harvesting of long long-duration previous crop and it also effects the quality of grain. When salt concentrations or temperatures are adverse, osmoprotectants help to increase osmotic pressure in the cytoplasm and can also stabilise proteins and membranes (Yancey, 1994). Mitigation of terminal heat stress improved by



exogenous application of various synthetic compounds. These comprises of inorganic salts like potassium nitrate, sulfhydryl compounds like thiourea, thioglycolic acid (TGA), dithiothreitol (DTT), secondary metabolites like putrescine and salicylic acid and NO donor like sodium nitroprusside (SNP). Literature says that these compounds mitigate the adverse effects of high temperature stress in plants through various mechanisms like preventing the degradation of chlorophyll, reducing electrolytic leakage from cells etc. and it also increases the quality of wheat grain *viz.* protein, starch, gluten, moisture, sedimentation value and hectolitre weight.

To determine the role of osmo-protectant in response to mitigate terminal heat stress and their effect on quality of wheat grain was conducted at Wheat Research Station, Junagadh Agricultural University, Junagadh (21.5° N latitude and 70.5° E longitudes) during *rabi* season, 2019-20. At the site of experiment soil was medium black and calcareous varying from 25 to 75 cm in depth. The annual temperature ranges from 15° C in winter to 45° C in summer with an average minimum of 17.9° C and maximum of 34.8° C. The experiment was laid out in a split-plot design with three replications. The dimension of each sub-plot was 2.5 m × 1.0 m. The wheat crop was sown on 18th December, 2019 which is considered as late-sown. In this study, two wheat cultivars, *viz.*, GW 11 and GW 496 were taken as main-plot treatment and foliar application of synthetic compounds *viz.*, thiourea (TU), sodium nitroprusside (SNP), potassium nitrate (KNO₃), thioglycolic acid (TGA), dithiothreitol (DTT), salicylic acid (SA) and Putrescine were randomized in the subplots with two different concentrations. These synthetic compounds applied at flowering and grain filling stages. Quality characters of wheat such as protein (%), moisture (%), starch (%), gluten (%) and sedimentation value (ml) were determined by Infratec™ 1241 Grain Analyzer at Main Wheat Research Station, Vijapur (Gujarat).

The data regarding quality characters as influenced by genotype, treatments and their interaction effects are presented in Table 1 and Table 2. The data indicated that wheat genotypes and treatments and their interaction

found significant influence on protein (%). The higher and lower protein (%) was found in the genotype GW-11 (12.6750 %) and GW-496 (12.0313 %) respectively. Among foliar treatments T5 (SNP @400µg/ml), T6 (SNP @800µg/ml) and T8 (DTT@50ppm) which was 12.45 (%); while significantly lowest protein (%) was recorded in no spray (control) T15 (12.30 %). But in interactions highest protein (%) was found in genotype GW-11 with T1 (Thiourea@20mM) (13.00 %) while lowest protein (%) was found in T1 (Thiourea@20mM) (11.80 %) of GW-496. Genotypes found non-significant influence on moisture (%) but treatments have significant effect on moisture (%). The highest moisture (%) was found in the treatment T₁₀ (Salicylic acid@200ppm) (11.25 %); while significantly the lowest moisture (%) was recorded in T₂ (Thiourea@40mM) and T₃ (KNO₃@1%) which was 10.70 (%). And for treatment and genotype interactions shows highest moisture (%) in genotype GW-496 with T₁₀ (Salicylic acid@200ppm) and T₁₁ (TGA@200ppm), which was 11.60 (%); while lowest moisture (%) found in T₂ (Thiourea@40mM) (10.50 %) of GW-11 and T₃ (KNO₃@1%) (10.50 %) of GW-496. The highest starch (%) was found in the treatment T₂ (Thiourea@40mM) and T₃ (KNO₃@1%) which was 63.45 (%); while significantly the lowest starch (%) was recorded in T₁₃ (Putrescine@4mM) (62.80 %). While for effect of genotype on starch (%) shows nonsignificant results but starch (%) showed a significant interaction effect between genotype and treatments. Interaction was highest for starch (%) in genotype GW-496 with T₃ (KNO₃@1%) (64.40 %); while the lowest starch (%) was found in T₅ (SNP @400µg/ml) (61.80 %) of GW-11.

Effect of genotype on gluten (%) shows nonsignificant results but treatment shows significant results with highest gluten (%) was found in the treatment T₃ (KNO₃@1%) and T₈ (DTT@50ppm) which was 31.90 (%); while significantly the lowest gluten (%) was recorded in no spray (control) T₁₅ (31.40 %). Furthermore, interactions showed significant results and it was highest in genotype GW-11 with T₄ (KNO₃@2%) (32.90 %); while lowest gluten (%) found in T₁ (Thiourea@20mM) and T₇ (DTT@25ppm) which was 30.70 (%) of GW-496.



Table 1. Ameliorative response of different synthetic compounds on protein (%), moisture (%) and starch (%) of wheat genotypes under terminal heat stress

Genotypes and Treatments	Protein %	Moisture %	Starch %			
Genotypes						
V ₁ : GW 11	12.6750	10.8438	62.7125			
V ₂ : GW 496	12.0313	11.0250	63.5125			
S.Em. ±	0.0505	0.0773	0.4463			
CD (p=0.05)	0.3072	NS	NS			
Treatments						
T ₁ - Thiourea@20mM	12.40	10.80	63.25			
T ₂ - Thiourea@40mM	12.40	10.70	63.45			
T ₃ - KNO ₃ @1%	12.40	10.70	63.45			
T ₄ - KNO ₃ @2%	12.40	10.85	63.05			
T ₅ - SNP@400µg/ml	12.45	11.00	62.90			
T ₆ - SNP@800µg/ml	12.45	10.75	63.35			
T ₇ - DTT@25ppm	12.30	10.95	62.95			
T ₈ - DTT@50ppm	12.45	10.95	63.05			
T ₉ - Salicylic acid@100ppm	12.25	10.95	63.05			
T ₁₀ - Salicylic acid@200ppm	12.35	11.25	62.85			
T ₁₁ - TGA@200ppm	12.25	11.20	62.95			
T ₁₂ - TGA@250ppm	12.20	11.00	63.15			
T ₁₃ - Putrescine@4mM	12.35	11.15	62.80			
T ₁₄ - Putrescine@6mM	12.35	11.05	63.05			
T ₁₅ - No spray(control)	12.30	10.85	63.25			
T ₁₆ - Spray of water	12.35	10.80	63.25			
S.Em. ±	0.0007	0.0011	0.0019			
CD (p=0.05)	0.0019	0.0030	0.054			
Quality parameters	Protein %		Moisture %		Starch %	
Interaction (T x V)	V1	V2	V1	V2	V1	V2
T ₁ - Thiourea@20mM	13.00	11.80	10.70	10.90	62.50	64.00
T ₂ - Thiourea@40mM	12.70	12.10	10.50	10.90	63.40	63.50
T ₃ - KNO ₃ @1%	12.90	11.90	10.90	10.50	62.50	64.40
T ₄ - KNO ₃ @2%	12.90	11.90	10.90	10.80	62.10	64.00
T ₅ - SNP@400µg/ml	12.90	12.00	11.20	10.80	61.80	64.00
T ₆ - SNP@800µg/ml	12.80	12.10	10.80	10.70	62.80	63.90
T ₇ - DTT@25ppm	12.70	11.90	11.00	10.90	62.30	63.60
T ₈ - DTT@50ppm	12.80	12.10	11.10	10.80	62.20	63.90
T ₉ - Salicylic acid@100ppm	12.40	12.10	10.90	11.00	62.70	63.40
T ₁₀ - Salicylic acid@200ppm	12.60	12.10	10.90	11.60	62.80	62.90
T ₁₁ - TGA@200ppm	12.60	11.90	10.80	11.60	63.00	62.90
T ₁₂ - TGA@250ppm	12.40	12.00	10.70	11.30	63.20	63.10



T ₁₃ - Putrescine@4mM	12.50	12.20	11.00	11.30	62.70	62.90
T ₁₄ - Putrescine@6mM	12.60	12.10	10.70	11.40	63.10	63.00
T ₁₅ - No spray(control)	12.60	12.00	10.70	11.00	63.00	63.50
T ₁₆ - Spray of water	12.40	12.30	10.70	10.90	63.30	63.20
S.Em. $\pm$	0.0010		0.0015		0.0027	
CD (p=0.05)	0.0027		0.0042		0.0077	

Table 2. Ameliorative response of different synthetic compounds on gluten (%), sedimentation value (ml) and hectolitre weight (kg/hl) of wheat genotypes under terminal heat stress

Genotypes and Treatments	Gluten (%)	Sedimentation value (ml)	Hectolitre weight (kg/hl)
Genotypes			
V ₁ - GW 11	32.3563	45.1250	76.9938
V ₂ - GW 496	31.0188	41.8750	78.7188
S.Em. $\pm$	0.2241	0.1780	0.3179
CD (p=0.05)	NS	1.0829	NS
Treatments			
T ₁ - Thiourea@20mM	31.75	44.50	78.60
T ₂ - Thiourea@40mM	31.65	46.00	77.75
T ₃ - KNO ₃ @1%	31.90	46.00	77.55
T ₄ - KNO ₃ @2%	31.75	43.50	76.05
T ₅ - SNP@400 μ g/ml	31.65	44.00	78.50
T ₆ - SNP@800 μ g/ml	31.70	45.00	77.60
T ₇ - DTT@25ppm	31.55	42.50	77.90
T ₈ - DTT@50ppm	31.90	42.50	78.40
T ₉ - Salicylic acid@100ppm	31.55	42.50	78.15
T ₁₀ - Salicylic acid@200ppm	31.75	43.00	78.55
T ₁₁ - TGA@200ppm	31.70	41.50	77.65
T ₁₂ - TGA@250ppm	31.65	42.00	78.45
T ₁₃ - Putrescine@4mM	31.75	42.50	77.65
T ₁₄ - Putrescine@6mM	31.60	43.50	77.30
T ₁₅ - No spray(control)	31.40	44.00	78.45
T ₁₆ - Spray of water	31.75	43.00	77.15
S.Em. $\pm$	0.0012	0.0070	0.0032
CD (p=0.05)	0.0034	0.0197	0.0090

Quality parameters	Gluten (%)		Sedimentation value (ml)		Hectolitre weight (kg/hl)	
Interaction (T x V)	V1	V2	V1	V2	V1	V2
T ₁ - Thiourea@20mM	32.80	30.70	48.00	41.00	76.80	80.40
T ₂ - Thiourea@40mM	32.40	30.90	49.00	43.00	77.00	78.50
T ₃ - KNO ₃ @1%	32.70	31.10	47.00	45.00	76.80	78.30
T ₄ - KNO ₃ @2%	32.90	30.60	45.00	42.00	75.60	76.50
T ₅ - SNP@400 μ g/ml	32.50	30.80	45.00	43.00	77.70	79.30



T ₆ - SNP@800µg/ml	32.20	31.20	45.00	45.00	76.90	78.30
T ₇ - DTT@25ppm	32.40	30.70	44.00	41.00	77.50	78.30
T ₈ - DTT@50ppm	32.70	31.10	43.00	42.00	77.70	79.10
T ₉ - Salicylic acid@100ppm	31.90	31.20	43.00	42.00	77.80	78.50
T ₁₀ - Salicylic acid@200ppm	32.60	30.90	45.00	41.00	77.70	79.40
T ₁₁ - TGA@200ppm	32.40	31.00	44.00	39.00	76.30	79.00
T ₁₂ - TGA@250ppm	32.00	31.30	44.00	40.00	77.00	79.90
T ₁₃ - Putrescine@4mM	32.30	31.20	43.00	42.00	76.90	78.40
T ₁₄ - Putrescine@6mM	32.10	31.10	46.00	41.00	76.40	78.20
T ₁₅ - No spray(control)	31.90	30.90	47.00	41.00	77.50	79.40
T ₁₆ - Spray of water	31.90	31.60	44.00	42.00	76.30	78.00
S.Em. ±	0.0017		0.0099		0.0045	
CD (p=0.05)	0.0049		0.0289		0.0127	

The data indicated that wheat genotypes had a significant influence on sedimentation value (ml). The higher and lower value was found in the genotype GW-11 (45.1250 ml) and GW-496 (41.8750 ml) respectively. And effect of treatments shows highest sedimentation value (ml) was in the treatment T₂ (Thiourea@40mM) and T₃ (KNO₃@1%) which was 46.00 (ml); while significantly the lowest sedimentation value (ml) was recorded in T₁₁ (TGA@200ppm) (41.50 ml); while interaction was higher for sedimentation value (ml) in genotype GW-11 with T₂ (Thiourea@40mM) (49.00 ml); but lowest sedimentation value (ml) found in T₁₁ (TGA@200ppm) (39.00 ml) of GW-496.

The highest hectolitre weight (kg/hl) was found in the treatment T₁ (Thiourea@20mM) (78.60 kg/hl); while significantly the lowest hectolitre weight (kg/hl) was recorded in T₄ (KNO₃@2%) (76.05 kg/hl) while for genotype and treatment interaction it shows higher hectolitre weight (kg/hl) in genotype GW-496 with T₁ (Thiourea@20mM) (80.40 kg/hl); while lowest hectolitre weight (kg/hl) found in T₄ (KNO₃@2%) (75.60 kg/hl) of GW-11. But the effect of genotype on hectolitre weight (kg/hl) shows non-significant results.

The quality character of wheat was adversely affected by high temperatures. The variation of some quality traits it could be attributed to grain filling process that is harmfully affected by high temperatures and grains reaching to maturity stage before complete filling (Subedi *et al.*, 2007). Quality characters such as protein (%), gluten (%), and sedimentation value (ml) were higher in heat-tolerant variety (GW-11) than heat susceptible variety (GW-496). The favourable growing condition during

timely sown crop induces more of an increase in nitrogen accumulation than in dry matter leading to higher protein content. Similar results have been reported earlier by Jat *et al.* (2013). But moisture (%), starch (%) and hectolitre weight (kg/hl) was more in GW-496 than GW-11.

The data shows that protein content of grain was significantly influenced as a result of all synthetic compounds treatments as compared with control (no spray) and there was a significant difference between treatments and all the treatments increased the quality of grain over control. The highest value of grain protein content was obtained from foliar application of SNP @400µg/ml, SNP @800µg/ml, and DTT@50ppm. This increase in protein content might be the outcome of increased concentration of nitrogen in the grain of wheat by foliar application of synthetic compounds which promote protein synthesis, similar findings was observed by Kousar *et al.* (2018) and Sofy (2015).

High moisture content leads to storage problems because it encourages fungal and insect problems, respiration and germination. However, moisture content in the growing crop is naturally high and only starts to decrease as the crop reaches maturity and the grains are drying. The moisture content of wheat grain was significantly lowest in treatment thiourea@40mM and KNO₃@1%. Slow settling (higher sedimentation values) indicates a high protein quantity and stronger gluten protein. Sedimentation values usually correlate positively with protein content and loaf volume. So, a higher sedimentation value represents a greater volume of baked bread. Starch content and sedimentation value were significantly highest in



treatments thiourea@40mM and KNO_3 @1%. Gluten as the miraculous net that holds bread together; it helps dough rise by trapping gas bubbles during fermentation and gives bread its unique texture for bread making gluten content is important. The gluten content of wheat grain was significantly highest in KNO_3 @1% and DTT@50ppm. While hectolitre weight is a good indication of grain-soundness and the higher the hectoliter weight of wheat, the higher the amount of dry matter and flour yield. Hectoliter weight was found to be significantly highest in thiourea@20mM.

Based on current study, it can be concluded that terminal heat stress adversely affects the grain quality of the both wheat genotypes. While the susceptible genotype more affected by terminal heat stress but tolerance genotype not affected as much, so that protein (%), gluten (%) and sedimentation value were higher in heat tolerant genotype (GW-11). When different synthetic compounds applied on plant for heat stress mitigation, it also alters grain quality like protein (%) and gluten (%) were recorded as highest in (SNP, DTT) and (KNO_3 , DTT) respectively; while starch and sedimentation value were recorded as highest in thiourea and KNO_3 . For hectolitre weight highest value was recorded in thiourea treatment. So based on all the observations, we can reveal that these osmoprotectants not only increase the heat stress mitigation but are also beneficial to plants for quality increment.

Author Contributions

CK and TS conceived and designed the research. TS and NCV conducted the experiment and collected the data. TS, CK and NCV did the statistical analysis. TS wrote the primary draft of the manuscript. CK and AGP reviewed and improved the manuscript.

Conflict of Interest

Authors declare no conflict of interest

Ethical Approval

The article doesn't contain any study involving ethical approval.

Generative AI or AI/Assisted Technologies use in Manuscript Preparation

No

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