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Sorgaab-Induced Modulation in Morpho-Physiological and Chemical Traits of Wheat under Heat Stress Conditions

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ABSTRACT

Crop plants that experience supra-optimal temperatures (heat stress conditions) exhibit significant reduction in yield. This report explores the role of sorgaab (an aqueous sorghum extract) in improving tolerance of wheat (*Triticum aestivum* L.) plants to supra-optimal temperatures. The wheat variety Faisalabad-2008 was sown in pots in a completely randomized design, and treated after 1-month's growth with varying sorgaab concentrations and temperatures. After 30 days of growth with sorgaab and two temperature treatments, various growth parameters were recorded. Physiological parameters were also determined and included measures of leaf photosynthetic pigments, anthocyanins, flavonoids, Na^+, and sulphate. Overall, sorgaab in concentration of 10% had the most beneficial results toward improving growth parameters in plants growing under lower and higher temperatures and had the effect of minimizing the impacts of higher temperature symptoms. Chlorophyll content was observed to increase in sorgaab treated plants. Exposure to higher temperatures significantly reduced Na^+ and sulphate content, and sorgaab treatment significantly ameliorated this response. Overall, sorgaab solution was effective in reducing the damaging effect of higher temperatures in wheat, improving wheat plant growth and physiology.

Keywords: wheat; heat stress, sorgaab application, physiology.

INTRODUCTION

Pakistan is the tenth-largest producer of wheat, a crop currently farmed in 27 different countries. The economy of Pakistan is heavily dependent on agriculture and 42.3% of the workforce is employed by it, and it contributes 22.9% to GDP (Government of Pakistan, 2022-2023). Wheat is the most valuable food crop on the planet. It is extensively grown on 218.54 million hectares of land globally, yielding 771.71 million metric tonnes of grain (Mukhtarzai et al., 2020; Li et al., 2023). More than 60% of people on the globe consume wheat (Sobolewska et al., 2020). As the world's population expands, the demand for wheat is anticipated to increase by 70% between 2020 and 2050 (Vitale et al., 2020). To reduce the possibility of food shortages brought on by the growing global population, wheat output must be significantly increased by 2050. One of the earliest grains to be domesticated, wheat has been grown for thousands of years. For more than 8,000 years, wheat has been a common ingredient in diets in Europe, Asia, and Africa. All economic sectors must consider the impacts of climate change, but the agricultural sector

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is especially vulnerable because of its strong dependence on the environment (Gul et al., 2022). Meeting the nutritional and energy needs of an expanding human population in a warming climate could be a major challenge (Zenda et al., 2021; Liang et al., 2023). Some estimates suggest that climate change has already reduced worldwide agricultural production by 1-5% in each of the three previous decades (Mashizha, 2019). Most wheat-growing locations worldwide experience high-temperature episodes (above optimum), which sharply reduce grain yield, and risk to yield stability may be growing (Zhao et al., 2017; Wang et al., 2018; Ullah et al., 2020). During reproduction, a temperature range of 15 to 20 Celsius is excellent for growth (Shewry, 2009). Wheat is more heat-sensitive during the reproductive stage than it is during the vegetative stage (Ullah et al., 2020). Nevertheless, while optimum heat can promote growth, supra-optimal heat can cause stress and restrict both the reproductive and vegetative development of crop plants (Vu et al., 2019; Desaint et al., 2021). A temperature increases of 10-15°C above ambient 22°C is considered high enough to cause plants to experience heat stress. From germination until harvest, heat stress has a detrimental impact on plant growth, development, and yield (Yang et al., 2019; Ali et al., 2022).

For each 1°C rise in temperature above the optimum, wheat production declines by 6.4 to 27% (Bergkamp et al., 2018). During critical growth stages, a temperature increase results in a 2.5 to 10% reduction (Hatfield et al., 2011), and during the reproductive stage, the decrease is 21% (Barkley et al., 2013). Globally, a 1°C rise in either the lowest or highest temperature during the cropping period leads to a 5.6% reduction in wheat yield (Lobell and Field, 2007). Heat stress affects leaf photosynthesis (Mirosavljevi et al., 2021). Specifically, the thylakoid membranes of the chloroplast, which contain Photosystem II, are extremely vulnerable to damage at high temperatures, resulting in lowered ATP production and electron transport. Heat stress causes the thylakoid membrane to expand and become more permeable, which causes degradation of chlorophyll light-harvesting complex II (Djanaguiraman et al., 2018; He et al., 2024).

Foliar applications of certain plant growth effecting compounds can reduce the amount of stress experienced by the plant. When grown under stressful conditions, it has been shown that the aqueous extracts of the plant sorghum (*Sorghum bicolor*) and moringa (*Moringa oleifera* Lam.) are particularly effective at promoting plant growth and development (Rashid et al., 2020, 2021). Moringa's leaf extract contains numerous phytohormones, including zeatin (Basra et al., 2011), which are known to promote plant growth, development, and grain yield in both normal and under adverse weather circumstances (Khan et al., 2020). Sorgaab is frequently used as a priming agent in seed and/or foliar sprays to promote growth via activation of various metabolic processes, (Farooq et al., 2013a; Zeng et al., 2024).

Sorgaab (sorghum cv. JS-263 aqueous extract), which contains several allelochemicals. For example, ferulic, caffeic, chlorogenic, vanillic, and syringic acids have all been found in water extracts of the sorghum plant's leaves and stems (Weston et al., 2013). Dhurrin is another notable allelochemical found in the sorghum plant extracts (Nielsen et al., 2008). The use of sorghum water extract as allopathic treatments has been shown in several recent investigations (Iqbal and Cheema, 2009). Sorghum extracts have been shown to promote plant growth and development and can, for example, be used as a foliar spray to postpone leaf senescence and boost chlorophyll content (Iqbal et al., 2020). It has been reported that sorgaab and moringa leaf extracts, which are known growth promoters in plants, are also excellent sources of several growth-promoting compounds, including plant hormones like zeatin (Rashid et al., 2022; Du et al., 2024), and these extracts can impact plant growth even at low dosages (Razzaq et al., 2012; Maqbool et al., 2013; Chen et al., 2024). The objective of this study was to determine the role of sorgaab treatments in improving heat tolerance of wheat (*Triticum aestivum* L.).

MATERIAL AND METHODS

The experiment was conducted at Botanical Garden of the University of Agriculture Faisalabad, with plants growing in pots using a potting mix. Temperatures that plants experienced were controlled by shifting half of the pots under a canopy of shade cloth, with temperatures recorded daily. All plants were irrigated to maintain full water capacity. Thirty days after sowing, sorgaab treatments at varying concentrations of 0%, 10%, 20%, and 30%, each at 500 μM, was administered. Half of the pots were subjected to high temperature treatment and the other half to low temperature treatment with plastic bags. At 30 days after treatments were applied, all sampling was carried out, all parameters were measured, and the data was analyzed to evaluate growth and chemical parameters. Growth and chemical indicators, including shoot length, root length, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, chlorophyll content, flavonoid levels, anthocyanin concentration, ascorbic acid content, and various ions such as sodium and sulphate were quantified employing relevant methodologies. Analysis of variance (ANOVA) was carried out to find significant differences in various treatments and pictorial difference of different treatment of sorgaab solution was presented in Figure 1.

Figure 1. Effect of different concentrations of sorgaab solution on wheat grown under higher temperatures

Biochemical Analysis

Chlorophyll Content

The chlorophyll content was determined using the method described by Arnon (1949). With the help of a pestle and mortar, 0.1 g of fresh plant material was ground in 2 mL of 80% acetone. Test tubes were filled with ground samples. At 663, 645 and 480 nm absorbance, chlorophyll a, b and carotenoid were investigated.

Anthocyanin Content

The anthocyanin content was analyzed using the method described by Stark and Wray (1989). A 0.1 g fresh plant sample was ground in 2 mL of acidified methanol. After grinding, the material was placed in test tubes and heated for 1 hour in a water bath at 50°C. A reading was taken at 535nm absorbance.

Flavonoid Content

The flavonoid content was determined by using the method described by Zhishen et al. (1999). A fresh plant sample of 0.1 g was ground in 2 mL of 80% acetone, and then placed in test tubes with 4 ml of distilled water and held 5 minutes at room temperature to cool. The sample was combined with 0.5 ml of 10% aluminium chloride ($AlCl_3$) and 6 mL of 5% sodium nitrate ($NaNO_2$). Following that, 2 mL of 1 M sodium hydroxide (NaOH) was added. The mixture was diluted with 2.4 mL of distilled water. A reading was taken at 510 nm absorbance.

Ascorbic Acid Content

The method described by Mukherjee and Choudari (1983) were used to determine ascorbic acid content. A 0.1 g sample of fresh plant material (root and shoot) was ground in 5 mL of 6% trichloroacetic acid (TCA). In a test tube, 2 mL of extract was combined with 1 mL of 2% dinitrophenylhydrazine. After that, 1 drop of 10% thiourea added and heated for 15 minutes at 90°C, followed by cooling in room temperature ice. Next, 2.5 mL of sulfuric acid (H_2SO_4) at 80% concentration was added. The absorbance was measured at 530 nm. As a control, 6% trichloroacetic acid (TCA) was used.

Content of Ionic Compounds

Digestion

A sample of 0.1 g oven dried plant material is used for digestion, and each sample was put into a digestion flask. 10 mL of nitric acid (HNO_3) was mixed in each flask. This solution was heated on a hot plate, filtered (becoming colourless) and the volume adjusted to 50 mL with purified water.

Estimation of Sodium Content

An Atomic Absorption Spectrum was used to determine the sodium concentrations. A flame photometer was used to determine sodium content.

Sulphate ($SO_4^{-2}S$) Content

To calculate the amount of sulphate ($SO_4^{-2}S$) in wheat samples, a total of 10 mL of digested extract was first combined with 1 mL of 6N hydrogen chloride (HCl). Then 0.5 mL of gum acacia solution was added and the solution vortexed. Finally, 0.5 g of barium chloride was combined and again vortexed. The absorbance was measured at 440 nm using a spectrophotometer.

Statistical Analysis

The experiment used three replications and was set up in a completely randomized design (CRD). The data analysis was carried out using Statistix 8.1 statistical software and graphical explanation was done by OriginPro-2021 software. LSD test was used, to differentiate treatments means at 5% probability.

RESULTS AND DISCUSSION

Effect of temperature and sorgaab on root and shoot length

Root and shoot length are highly affected by heat stress and we report here statistically significant effects of heat treatment and different concentration of sorgaab solution ($P \leq 0.05$), and their interactions. Root and shoot length were longest (14.2 cm and 30.13 cm respectively) at H0S1 where 10% sorgaab solution was applied, whereas the shortest root and shoot length (9.67 cm and 22.86 cm) was observed in H_1S_o treatment where the plants were exposed to highest temperatures but no sorgaab solution was applied (Figures 2a, 2b).

Effect of temperature and sorgaab on root, shoot fresh and dry weight

Results for shoot and root fresh and dry weight under heat stress and different concentrations of sorgaab solution exhibited a significant response ($P \leq 0.05$). For fresh weight of roots and shoots, the highest value (0.07 g, 1.02 g) was observed in HoS^{-1} treatment where 10% sorgaab solution was applied and plants were exposed to the lowest temperatures, whereas the lowest fresh weight of roots and shoots were recorded in the H_0S_0 treatment where plants were exposed to the lowest temperatures and no sorgaab solution was applied (Figures 2c, 2d). Results for dry weights of roots and shoots highlighted that the maximum dry root and shoot weights were observed in the H_0S_1 treatments and the minimum dry root and shoot weights (0.013 g and 0.20 g) was observed in H1S0 treatments where plants were exposed to lowest temperatures and no sorgaab was applied (Figures 2e, 2f).

Effect of temperature and sorgaab on leaf area and shoot diameter

Leaf area was highly influenced by the level of heat stress and application of sorgaab solution, and the impacts were statistically significant. The combined effect of temperature treatment and concentration of sorgaab solution was significant and the results revealed that the maximum leaf area (10.43 cm^2) was found in plants exposed to the lowest temperature and with 10% sorgaab solution treatment. The application of 10% sorgaab solution also led to the highest leaf area when compared to the other treatments of 0%, 20%, and 30% foliar application (Figure 1g). The highest shoot diameter (2.63 cm) was recorded in plants exposed to the lowest temperature with no sorgaab (Figure 2h).

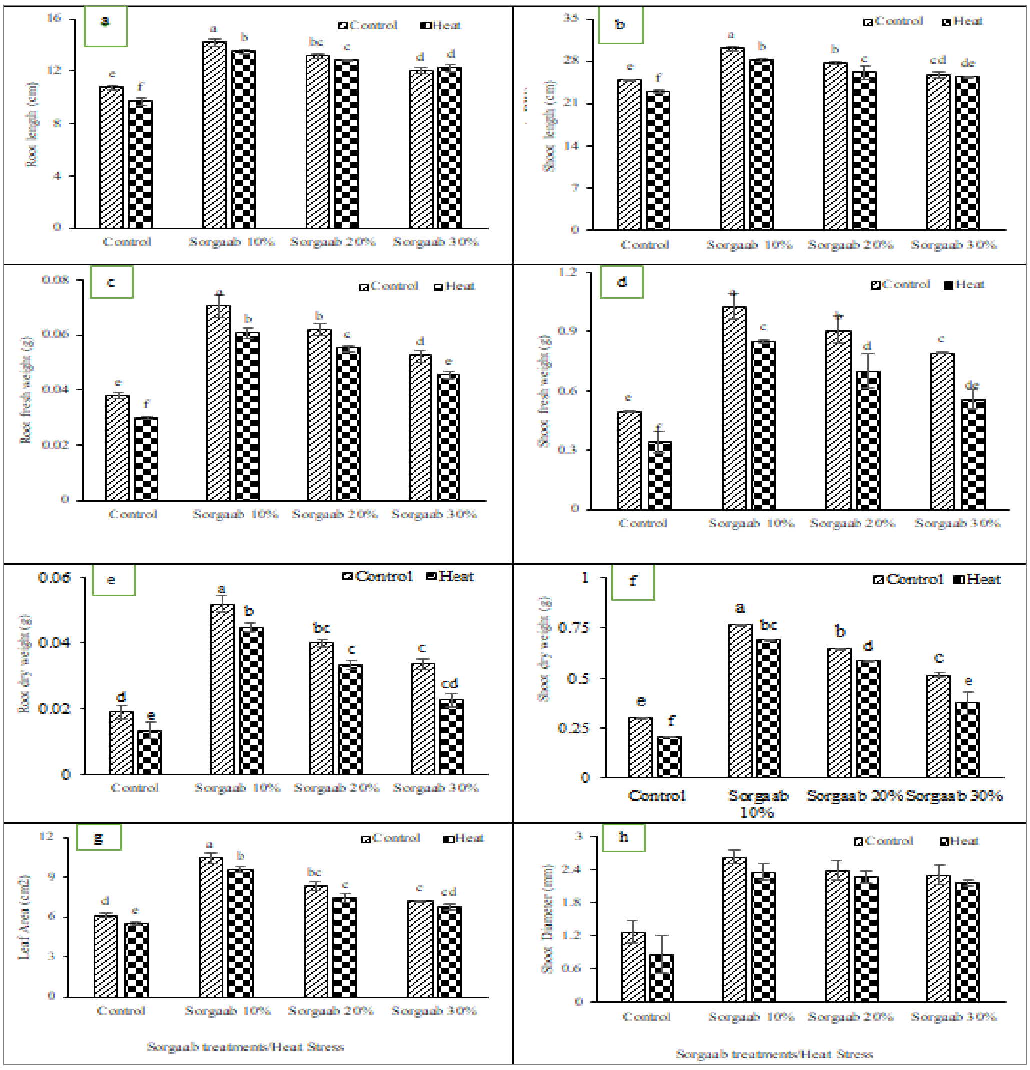

Figure 2. Effect of temperatures and sorgaab solution concentration at 30-days after application on root length (a), shoot length (b), root fresh weight (c), shoot fresh weight (d), root dry weight (e), shoot dry weight (f), leaf area (g), shoot diameter (h)

Effect of temperature and sorgaab on shoot and root sulphate

Results regarding sulphate accumulation in shoots and roots showed significant ($p \leq 0.05$) impacts for temperature and sorgaab solution treatment, with the maximum sulphate being recorded in shoots and roots exposed to the lowest temperatures with no sorgaab treatment. The highest sulphate (11.34 and 11.70 mg/g DW, respectively) was recorded in shoots and roots of plants where 10% sorgaab solution was applied as compared to the higher 20 and 30% foliar application of sorgaab (Figures 3a, 3b).

Effect of temperature and sorgaab on shoot and root sodium

Sodium accumulation in the shoots and roots of plants was significantly impacted ($p \leq 0.05$) by temperature and sorgaab solution treatments. For temperature treatments, the highest sodium was accumulated in shoots and roots of plant exposed to the lowest temperatures whereas the lowest sodium was found in plants exposed to the highest temperatures. For sorgaab solution treatments, the maximum sodium was observed with 10% sorgaab solution as compared to other doses. As such, increasing concentrations of sorgaab solution negatively affect the sodium concentration in shoots and roots (Figures 3c, 3d).

Effect of temperature and sorgaab on shoot and root flavonoid

For temperature treatments, our results showed that the highest flavonoid content in shoots and roots (7.03 and 6.57, respectively) occurred for the lower than higher temperature treatments. For sorgaab treatments, the maximum flavonoid content was observed in shoots and roots given 10% sorgaab solution treatment, whereas the lowest flavonoid was observed when no sorgaab was applied (Figures 3e, 3f).

Effect of temperature and sorgaab on shoot and root anthocyanin

Results for shoot and root anthocyanin content showed significance differences ($p \leq 0.05$) under varied temperatures and sorgaab solution treatments, with the highest anthocyanin being observed in shoot and root growing under the lowest temperatures. The maximum anthocyanin levels were observed in shoots and roots treated with 10% sorgaab solution as compared to all other foliar applications of sorgaab (Figures 3g, 3h).

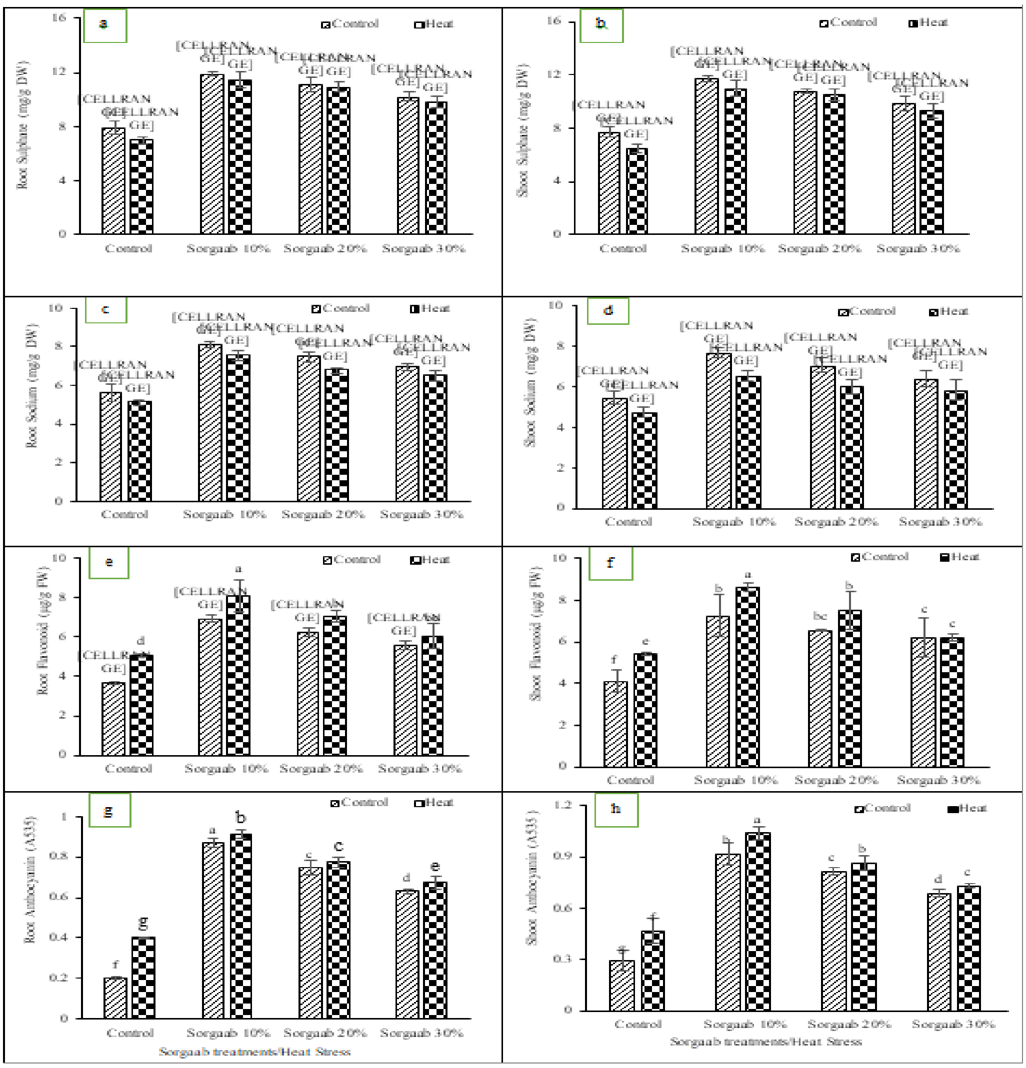

Figure 3. Effect of higher and lower temperatures and sorgaab solution concentration 30-days after application on root sulphate (a), shoot sulphate (b), root sodium (c), shoot sodium (d), root flavonoid (e), shoot flavonoid (f), root anthocyanin (g), shoot anthocyanin (h)

Effect of temperature and sorgaab on shoot and root ascorbic acid

The highest shoot and root ascorbic acid content (3.92 and 3.52 µg/g FW), respectively, was observed in plants grown under the lowest temperatures rather than the higher temperature environment. For sorgaab solution treatments, the maximum ascorbic acid was found in shoots and roots where 10% sorgaab solution treatment was applied, whereas the minimum was observed in the 0% sorgaab treatment (Figures 4a, 4b).

Effect of temperature and sorgaab on chlorophyll *a* and *b* content

Results for chlorophyll *a* and *b* content analysis in wheat plants revealed a significant impact of temperature and and foliar application of sorgaab solution. The highest chlorophyll *a* and *b* content (2.07 and 2.80 mg g^{-1} FW, respectively) was observed in HoS_1 treatment where 10% sorgaab foliar application was applied to wheat grown at the lowest temperature, whereas the lowest chlorophyll *a* and *b* content was observed in H_1S_o treatments where foliar of sorgaab was not applied and plants were exposed to the highest temperatures (Figures 4c, 4d).

Effect of temperature and sorgaab on carotenoid and nitrate content of roots

Temperature and foliar application of sorgaab produced significant effects on carotenoid and nitrate content in roots of wheat. The highest carotenoid content (5.05 mg g^{-1} FW) was observed in H_oS_1 treatments wherein 10% sorgaab was applied through foliar application of plants exposed to the lowest temperatures, whereas the lowest carotenoid accumulation was observed in H_1S_o treatment wherein plants lacked sorgaab application and were exposed to the highest temperatures (Figures 4e). For root nitrate, the highest concentration was observed in HoS_1 treatments, and the lowest concentration was being found in H_1S_o treatments (Figures 4f).

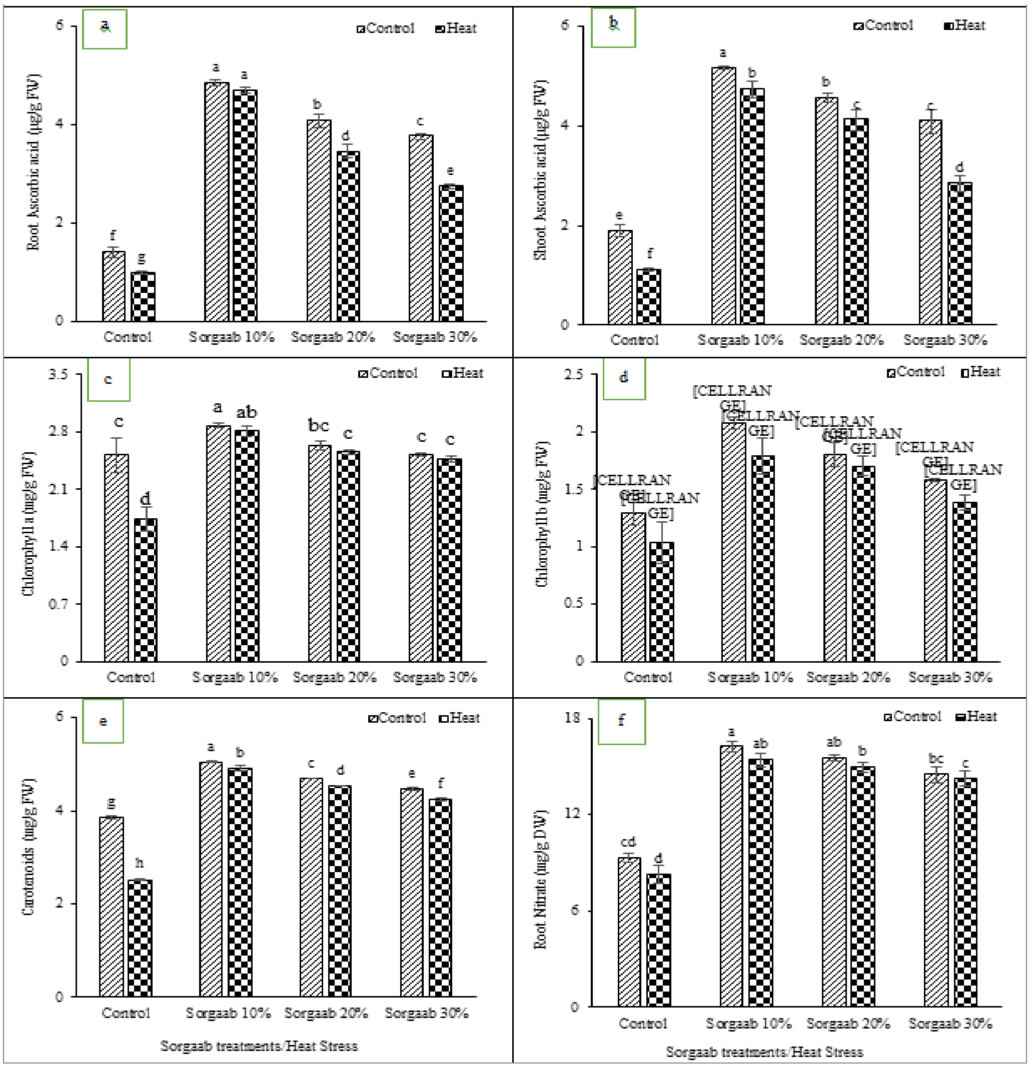

Figure 4. Effect of higher and lower temperatures and sorgaab solution concentration 30-days after application on root ascorbic acid (a), shoot ascorbic acid (b), chlorophyll a (c), chlorophyll b (d), carotenoid content (e), root nitrate (f)

Pearson correlation analysis of physiological and agronomic traits of wheat

Results exposed that root anthocyanin has strong significant positive correlation with shoot fresh weight, shoot dry weight, root dry weight, shoot length, root length, leaf area, and stem diameter, but negatively correlated with shoot anthocyanin, which means that with the increasing concentration of anthocyanin in the root, the concentration of anthocyanin in shoot will decrease (Figure 5). A similar trend was observed for other variables like flavonoid in shoot, flavonoid in root with anthocyanin in shoot.

Principal component analysis:

A principal component analysis was performed on the data collected for all morphological and physiological attributes (Figure 5). In this study, the first PCA-1 contributed 87.3% to the overall variation containing the traits. The traits contributing the most are shoot flavonoid, root flavonoid, and root anthocyanin in PCA-1. In case of PCA-2, these contributed only 6% towards variation and only one trait which is shoot anthocyanin. The angles between two vector represents association among the traits. When the angle between two variables is less than 90°C they are considered highly positive correlated. In this case shoot flavonoids and root flavonoid are closely related to each other whereas negative correlation is found between shoot anthocyanin with chlorophyll a and carotenoid. Regarding the distribution of traits and treatment on the biplot, the diversity increases as it moves further from the centre. Treatment closer to the variable vector but farther from the centre signified high diversity for that treatment.

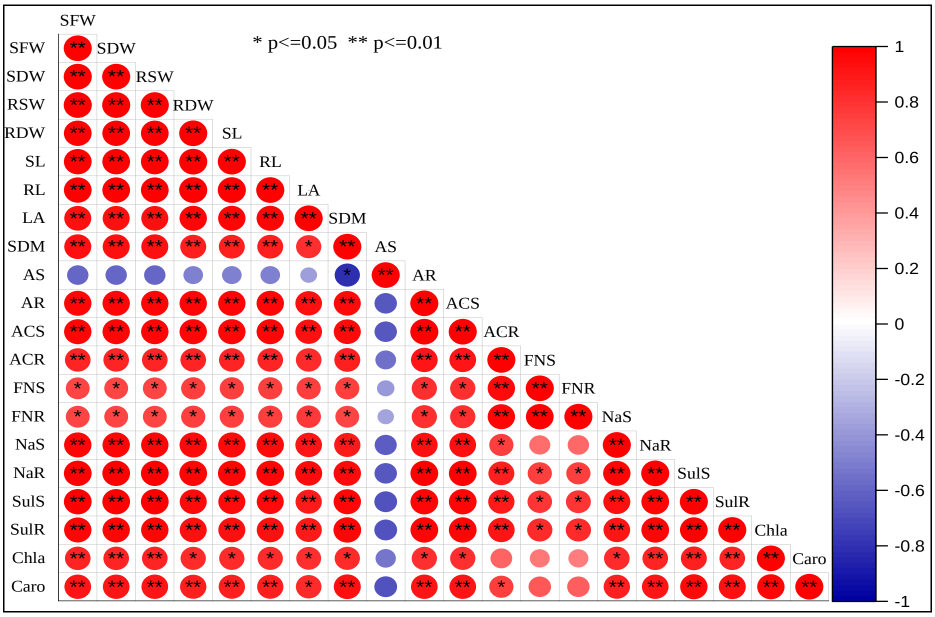

Figure 5. Evaluation of the correlation between traits
SFW = Shoot fresh weight, SDW = Shoot dry weight, RSW = Root fresh weight, RDW = Root dry weight, SL = Shoot length, RL = Root length, LA = Leaf area, SDM = Shoot diameter, AS = Shoot Anthocyanin, AR = Root Anthocyanin, ACS = Shoot Ascorbic acid, ACR = Shoor Ascorbic acid, FNS = Shoot Flavonoids, FNR = Root Flavonoids, NaS = Sodium content in shoot, NaR = Sodium content in root, SulS = Shoot Sulphate, SulR = Root Sulphate, Chla = Chlorophyll a, Caro = Carotenoids.

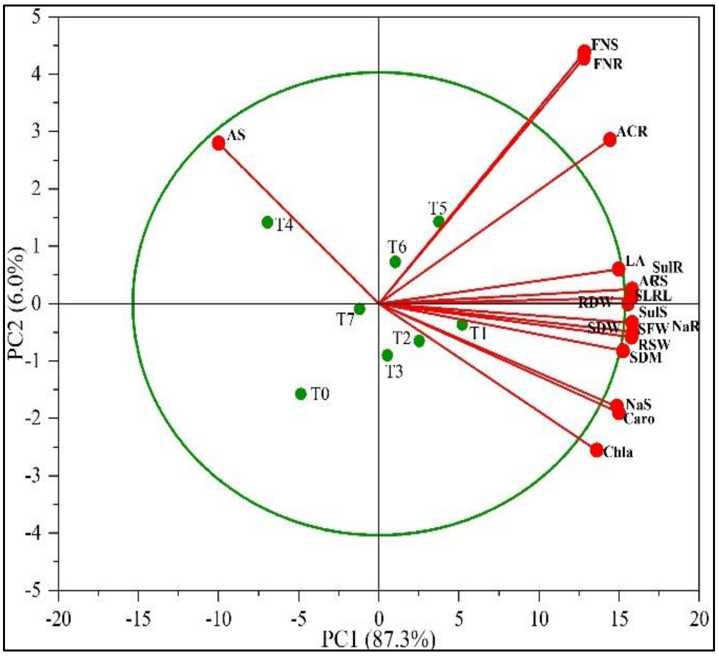

Figure 6. Principal component and heatmap analysis of traits i.e.
SFW = Shoot fresh weight, SDW = Shoot dry weight, RSW = Root fresh weight, RDW = Root dry weight, SL = Shoot length, RL = Root length, LA = Leaf area, SDM = Shoot diameter, AS = Shoot Anthocyanin, AR = Root Anthocyanin, ACS = Shoot Ascorbic acid, ACR = Root Ascorbic acid, FNS = Shoot Flavonoids, FNR = Root Flavonoids, NaS = Sodium content in shoot, NaR = Sodium content in root, SulS = Shoot Sulphate, SulR = Root Sulphate, Chla = Chlorophyll a, Caro = Carotenoids, T_0 = Control, T_1 = 10% SORGAAB, T_2 = 20% Sorgaab, T_3 = 30% Sorgaab, T_4 = Control + heat stress, T_5 = 10% Sorgaab + Heat stress, T_6 = 20% Sorgaab + Heat stress and T_7 = 30% Sorgaab + Heat stress.

Wheat (*Triticum aestivum* L.), a member of the Poaceae, is an important food crop worldwide due to its high nutritional content. It contains carbohydrates as well as proteins. Among abiotic stresses, heat stress has become an increasing threat to wheat production and yield. Wheat has played an essential role in decreasing famine worldwide, providing food security to people on both a large and small scale (Sramkova et al., 2009; Strugnell, 2018). After maize and rice, wheat ranks first in total harvested area and third in production (Asseng et al., 2017).

Changing climatic factors worldwide have been shown to decrease wheat yield via increases in disease damage such as caused by blast diseases, as well as plant damage from abiotic stresses such as those caused by supra-optimal temperatures, drought, and irregular weather events (Islam, 2020). Furthermore, a meta-analysis has revealed that in sub-tropical and temperate regions, a decrease in wheat yield could occur with even a 1°C rise in temperature (Asseng et al., 2015).

Lal et al. (2021) posited that the impact of heat stress on the physiological and morphological aspects of plants is substantial, ultimately leading to a reduction in both root and shoot growth. The findings of the current investigation align with their conclusions, as the experimental results demonstrate a notable decrease in both root and shoot length, with statistical significance ($P<0.05$) being observed for both variables.

Iqbal et al. (2019) indicated that heat stress resulted in a decline in the plant fresh mass, dry mass, root length, shoot length, and root number in comparison to unstressed plants. Similarly, leaf area, leaf fresh mass, dry mass, and leaf number were also diminished under the same heat stress conditions. The reduction in growth attributes could potentially be attributed to alterations in cell division or cell elongation (Singh et al., 2014). The results presented in this paper are consistent with their findings, revealing a significant negative impact on numerous growth and morphological characteristics. Phenolic compounds in sorgaab have been shown to have growth promoting properties, even low concentrations of foliar applied sorgaab can enhance plant growth and morpho-physiological qualities (Farooq et al., 2013; Maqbool et al., 2013).

Ibrahim et al. (2022) provided evidence that application of a sorgaab solution can yield positive effects on various morphological parameters, including the fresh weight of the root, shoot, as well as their corresponding dry weights. The outcomes of research presented here unequivocally align with those of Ibrahim et al. (2022), as the application of specific sorgaab solutions in this study resulted in noticeable increases in wheat growth and many related morphological parameters. Specifically, both the weight of the wheat root and shoot experienced significant growth in response to the sorgaab solution, while the dry weight of the shoot also exhibited a marked increase. Hasanuzzaman et al., (2012) provided evidence that when plants are exposed to high temperatures, the concentration of chlorophyll decreases because of the high levels of H_2O_2 present in the cells. Results of the current study are consistent with this. We observed a reduction in the levels of chlorophyll a and carotenoids in wheat grown in higher temperatures.

Kamran et al. (2019) conducted an examination which revealed that the sorghum water extract at lower rather than higher concentrations exhibited the greatest impact. The presence of a lower concentrations of sorgaab solution resulted in the highest production of chlorophyll and carotenoids. Our results revealed that chlorophyll a and carotenoid concentration increased when a 10% sorgaab solution was utilized but was lower in 20% and 30% sorgaab solutions The application of sorgaab resulted in an increased concentration of chlorophyll, likely owing to the presence of certain secondary metabolites and phenolics within the sorgaab extract (Iqbal et al., 2020).

It appears that both moringa leaf extracts and sorgaab possess nutrients that can be accessed from applied foliar sprays and augment the nutritional state of both the leaves and roots (Batool et al., 2020; Khan et al., 2020; Zhang et al., 2025). The availability of nutrients through foliar spray assumes a pivotal role in the developmental processes of plants (Rashid et al., 2020). The findings presented in this report correspond to their claims, as our foliar sprays with sorgaab yielded observable enhancements in the levels of essential elements such as sulphate and sodium.

The results of the present investigation are consistent with those of Ma et al. (2008) and Babu and Deveraj (2008) who observed an increased level of ascorbic acid in apple leaves and French bean seedlings, respectively, when exposed to high temperatures compared to lower temperatures. Mehlhorn et al. (1996) reported an increase in the content of ascorbic acid under conditions of oxidative stress, which is thought to function as a protective mechanism for plants against oxidative damage caused by aerobic metabolism and various biotic and abiotic stresses (Smirnoff and Pallanca, 1996).

Basra et al. (2011) concluded that application of moringa leaf extract led to improved grain yield of wheat and attributed this to the presence of antioxidant compounds such as flavonoids, phenolic acids, and ascorbic acid. These compounds exhibit the capacity to enhance crop growth and productivity, especially under conditions of abiotic stress. In the findings of this report, the implementation of the sorgaab solution also enhanced the content of ascorbic acid in wheat exposed to higher temperatures.

Due to the existence of phenolic compounds in sorgaab, the growth and development of plants, as well as their morphological and physiological attributes, can be enhanced with the application of low concentrations of the sorgaab solution (Cheema et al., 2003). We report similar findings and conclude that heat stress led to a decrease in all growth, physiological, biochemical, and ionic parameters in wheat, whereas application of sorgaab solution enhanced all growth, physiological, biochemical, and ionic parameters.

CONCLUSIONS

Heat stress is a detrimental abiotic stress that adversely affects the growth of plants. In this research, we applied varying concentrations of sorgaab solution to wheat plants to enhance their ability to withstand heat stress. The outcomes of this study were evaluated by examining multiple parameters after a month's growth post treatment. It was observed that growth in higher temperatures resulted in a decline in various growth parameters, while simultaneously increasing the levels of flavonoids, ascorbic acid, and anthocyanins. Notably, the application of sorgaab solution had a positive influence on the length of both shoots and roots under both the lower and higher temperatures. Moreover, sorgaab significantly improved numerous growth parameters for plants growing under higher temperatures, with the 10% sorgaab solution yielding the most beneficial results. Our findings also revealed that the chlorophyll content in sorgaab treated plants was higher compared to plants lacking sorgaab treatment, indicating the beneficial impact of sorgaab solution on the plant's physiology. We conclude that the sorgaab solution effectively mitigated the negative effects of heat stress on the plants and exhibited positive overall effects on plant growth and development at all temperatures tested.

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