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Enhanced Wheat Yield: Fulvic Acid Application's Impact on Yield Factors under Heat Stress

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Abstract: Terminal thermal stress, occurring under various climatic conditions, significantly reduces wheat yield by disrupting fertilization and grain filling processes. Biostimulants offer a potential solution to mitigate the impact of terminal heat stress on wheat crops. This research aims to alleviate the effect of heat stress on wheat through the application of fulvic acid. The wheat crop was subjected to elevated temperature stress during the booting and grain initiation stages under field conditions, with heat stress at staggered intervals in the main plot. Fulvic acid was applied at different concentrations (water spray, 1.25 mg L^{-1}, 2.50 mg L^{-1}, and 3.75 mg L^{-1}) in field and heat stress conditions upon booting (H_1) and grain initiation (H_2) stage. Results revealed that heat stress H_1 and H_2 stages significantly decreased the spike length (22.59% & 21.45%), spikelets per spike (14.35% & 6.66%), grains per spike (27.9% & 20.23%), grain weight per spike (40.24% & 32.54%), test weight (17.84% and 15.69%), biological (41.19% & 32.61%) and straw yield (31.20% & 19.16%), and harvest index (9.8% & 8.31%) as compared to control (H_0). The impact was more pronounced during the booting stage compared to the grain filling stage. Application of fulvic acid at concentrations of 3.75 mg L^{-1} during heat stress at the booting stage and 2.50 mg L^{-1} upon heat stress at grain initiating stages substantially enhanced the recorded parameters compared to the foliar application of water and 1.25 mg L^{-1} fulvic acid. These findings revealed that foliar application of fulvic acid promotes thermotolerance in wheat, positively influencing yield and yield-contributing factors during heat stress.
Keywords: Wheat, Fulvic Acid, Yield components, *Triticum aestivum*

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1. Introduction

Pakistan, primarily agrarian, heavily relies on its agriculture sector, which employs 45% of the population. Wheat (*Triticum aestivum* L.) is one of the most important globally cultivated cereal crops. It holds significant importance as a staple food, contributing 8.97% to agricultural value added and 1.8% to GDP. In the 2021-22 period, wheat cultivation spanned 8.97 million hectares, yielding 26.39 million tons (Government of Pakistan, 2022).

Wheat production experiences several biotic and abiotic leading to the minimum wheat yields, including uncertified seeds, late sowing, traditional methods, inadequate land preparation, poor weed management, unpredictable rainfall, waterlogging, salinity, and marketing challenges Among these, terminal heat stress emerges as a significant future threat, exacerbated by climate change (Nagar *et al*., 2015). Rising temperatures adversely affect crop growth and yield, accelerating plant development, shortening life cycles, reducing stature, and affecting reproductive cycles, ultimately leading to decreased yields (Jerry and Prueger, 2015). In recent years, multiple studies have explored alternative agricultural practices to increase wheat yield potential in different stress conditions. Semenov (2009) predicts increased terminal heat stress for wheat. The reproductive stage is particularly vulnerable, resulting in reduced grain number and weight (Wollenweber *et al*., 2003).

Elevated temperatures affect global and Pakistani crop production. As temperatures exceed optimal levels, vegetative development accelerates (Jerry and Prueger, 2015). Terminal heat stress affects crucial processes such as flowering, pollen viability, photosynthesis, and translocation, leading to decreased grain weight, number, and quality (Reynolds *et al*., 2012; Gonzalez-Navarro *et al*., 2015). High temperatures notably affect photosynthesis (Wahid et al., 2007), reducing grain growth and yield (Mondal *et al*., 2013). Heat tolerant wheat varieties exhibit improved physiological processes like chlorophyll contents, membrane stability index, photosynthesis rate, yield attributes, and antioxidant performance (Dwivedi *et al*., 2024).

Addressing heat stress involves breeding strategies, genetic engineering, molecular markers, and management practices like moisture conservation through no-tillage and stubble mulching (Farooq *et al*., 2011). Application of nitrogen, phosphorus, and potassium can aid plant growth during mild heat stress (Dupont *et al*., 2006). Early sowing is beneficial, though challenges arise due to cropping systems.

Exogenous application of osmolytes, signaling compounds, inorganic salts, and biostimulants offers another approach. Biostimulants like humic acids, fulvic acids, microbial inoculants, protein hydrolysates, amino acids, and seaweed extracts have shown promise (Oosten *et al*., 2017). Recently the application of Fulvic acid has gained the attention of researchers, as it is linked with increased productivity and enzyme activity and may mitigate abiotic stresses (Ali *et al*., 2015). Multiple studies have demonstrated that the application of fulvic acid improves the wheat yield potential (Oosten *et al*., 2017; Ali *et al*., 2015). However, its specific effects on Pakistani wheat under heat stress remain unknown. The hypothesis suggests that fulvic acid could alleviate terminal heat stress by improving yield and yield components during heat stress. The objective of this study is to evaluate the effectiveness of fulvic acid in improving the performance of wheat crops.

Present investigations were conducted to explore the impact of fulvic acid application on different yield factors of wheat under heat stress conditions. By covering important insights into the potential benefits of fulvic acid supplementation, this study seeks to contribute to the development of sustainable strategies for enhancing wheat productivity and escalating climate challenges.

The findings of this research not only strengthen the understanding of fulvic acid's role in mitigating heat stress effects but also provide practical guidance for farmers to optimize wheat production in the context of climate change. Ultimately, the successful integration of fulvic acid-based interventions could offer a promising avenue for ensuring food security and agricultural sustainability in heat-prone regions worldwide.

2. Materials and Methods

2.1. Experimental site and layout plan

A research project was conducted at the Research Area within the Department of Agronomy, University of Agriculture Faisalabad, during the winter (Rabi) season of 2016-17. Punjab-2011 wheat variety was manually sown using a hand drill, following the recommended seed rate of 100 kg ha^{-1}, with rows spaced 22.5 cm apart. Phosphorus and Nitrogen were applied at rates of 60 kg ha^{-1} and 75 kg ha^{-1}, respectively, and placed as bands in the soil at sowing. An additional 75 kg of nitrogen per hectare was applied with the first irrigation. The field received irrigation at critical wheat growth stages.

The experimental design employed a Randomized Complete Block Design (RCBD) with a split-plot arrangement, replicated three times. Each net plot measured 3.0 m × 0.90 m and contained four

Table 1. Analysis of variance for effect of foliar applied Fulvic acid on yield and yield components of heat stressed wheat (MEANS SUM OF SQUARES)

SOV	DF	SL	SPS	GPS	GWPS	TW	BY	SY	HI
Blocks	2	6.31	0.69	2.78	0.013	10.60	0.040	0.04	2.03
Heat Stress(H)	2	18.76*	24.11**	579.53**	2.124**	190.54**	58.158**	10.55**	79.77**
Error I	4	1.23	0.61	4.24	0.023	5.06	0.336	0.40	10.26
Fulvic Acid (F)	3	3.46**	1.26^{NS}	54.56**	0.175**	15.25**	2.895**	0.82**	6.77^{NS}
H × F	6	2.16*	0.04^{NS}	8.97*	0.053**	8.51**	0.943**	0.28^{NS}	8.88^{NS}
Error II	18	0.28	0.53	2.97	0.005	1.58	0.189	0.15	8.54

* = Significant ($p \leq 0.05$); ** = Significant ($p \leq 0.01$); NS = Non-significant; SL = Spike Length; SPS= Spikelets per Spike; GPS= Grains per Spike; GWPS= Grain Weight per Spike; TW= 1000-GW; BY= Biological Yield; SY= Straw Yield; HI= Harvest Index

rows of wheat. Main plots were designated for heat treatments (H_0= No heat stress, H_1= Heat stress at booting stage, H_2= Heat stress at grain initiation stage), while sub-plots received foliar applications of fulvic acid (F_0= Water spray, serving as control, F_1= 1.25 mg L^{-1}, F_2= 2.50 mg L^{-1}, F_3= 3.75 mg L^{-1}). Heat stress was induced by covering plots along perforated polythene sheets, and foliar spray was administered one week after applying heat stress at the grain initiation stage. All other crop management practices remained consistent across all treatments.

2.2. Procedure for recorded observations

The average length (excluding awns) of randomly taken 10 spikes at harvest maturity from each treatment was taken with the help of measuring tape and considered as spike length. Some spikelets of 10 spikes, selected randomly from each experimental unit were counted and their average was taken for consideration as spikelets per spike. For several grains per spike, Grains of 10 spikes selected randomly were separated manually from the spike and were counted. The average was taken as the number of grains/spike. They were separated manually from 10 randomly selected spikes and weighed by an electrical weighing balance. The average was taken as grain weight per spike. Three sub-samples each of 1000 grains were taken from each experimental unit and weighed by electrical weighing balance. The average was taken as 1000-Grain weight. Each plot was harvested at harvest maturity and was tied by a rope and weighed with the help of spring balance. This yield was converted in tonnes per hectare by unitary method.

Table 2: Effect of foliar applied Fulvic acid on yield and yield components of heat stressed wheat

Treatments	SPS	SY (kg/ha)	HI (%)
Heat stress (H)			
H_0 (No heat stress)	19.5 A	5.95 A	48.68A
H_1 (Heat stress at booting stage)	16.7 C	4.09 B	43.89 B
H_2 (Heat stress at grain initiation stage)	18.2 B	4.81 B	44.63 AB
Tukey's HSD ($p \leq 0.05$)	**1.13**	**0.924**	**4.664**
Fulvic acid foliar spray (FA)			
F_0 (Control)	17.7	4.50 B	46.01
F_1 (1.25 mg L^{-1})	18.0	5.10 A	44.45
F_2 (2.50 mg L^{-1})	18.6	5.09 A	46.06
F_3 (3.75 mg L^{-1})	18.2	5.11 A	46.40
Tukey's HSD ($p \leq 0.05$)	**NS**	**0.514**	**NS**

Means not sharing a letter in common differ significantly at $p \leq 0.05$; FLA = SPS= Spikelets per Spike**;** SY= Straw Yield; HI= Harvest Index

After subtracting grain yield from the biological yield of each plot straw yield was calculated in tonnes per hectare by unitary method. The ratio of grain yield (GY) to biological yield (BY) was taken as harvest index (HI) for each plot and is given in percentage by using the formula

$$HI = \left(\frac{GY}{BY}\right) \times 100$$

Where; HI= Harvest Index, GY= Grain Yield, BY= Biological Yield.

3. Statistical analysis

The recorded data underwent statistical analysis using Fisher's Analysis of Variance technique, and the means of treatments were compared using Tukey's Honestly Significant Difference (HSD) test at a 5% probability level (Steel et al., 1997).

4. Results

Spike length determines the production potential of wheat; the better the size of the spike, the more will be number of grains and yield. According to data in Table (3) height stress significantly decreased the spike length. The minimum spike length (8.77 cm) was recorded in treatment H_1 (Heat stress at the booting stage) where no fulvic acid was applied, while in control treatment where no fulvic acid and heat stress was applied spike length was recorded up to 11.33 cm. The decrease in spike length was 22.59% due to heat stress at the booting stage (H_1) while it was 21.45% due to heat stress at the grain initiation stage (H_2) in comparison to control (H_0). Interactive effects of heat stress and FA show that FA concentrations show different behavior in different heat stress treatments. During H_0 (No Heat stress) FA did not increase spike length significantly. In treatment, H_1 (Heat stress at the booting stage) FA @ 3.75 mg L^{-1} produced the highest spike length of 10.47 cm. During heat stress at the grain initiation stage (H_2) FA @ 2.50 mg L^{-1} produced the highest (11.73 cm) spike length which was statistically similar to treatment F3 (FA @ 3.75 mg L^{-1}). FA increased spike length up to 19.38% over control during heat stress at the booting stage (H_1) and 31.79% over control during heat stress at the grain initiation stage (H_2).

According to data in Table (2) number of spikelets per spike was reduced significantly as heat stress was applied. Minimum spikelets per spike (16.7) were observed when heat stress was applied at the booting stage, while maximums were recorded, where heat stress was not applied followed by treatment with heat stress at the grain initiation stage. Reduction in spikelets per spike was 14.35% under heat stress application at the booting stage and 6.66% under heat stress application at the grain initiation stage, while FA did not affect the spikelets per spike and interactive effects of FA and heat stress were also non-significant.

Several grains/spikes are yield determining component and according to the data table (3) it was significantly affected by heat stress and fulvic acid. Treatment H_1 where heat stress was applied at the booting stage showed the highest decrease (27.9%) in grain number followed by H_2 (20.23%) where heat stress was applied at the grain initiation stage in comparison to control treatment (H_0) where no heat stress was applied. Fulvic acid being organic acid improves the number of grains per spike as it then dissolves minerals and nutrients so it increases carbohydrates in the cell which helps to accumulate soluble sugars in a plant cell. The significant interactive effect shows that fulvic acid levels' performance differs in different heat stress treatments. Results show that in the control treatment (H_0) fulvic acid (FA) @ 1.25 mg L^{-1} showed the highest number of grains (49) which is 12.24% as compared to the control; in H_1 treatment FA @ 3.75 mg L^{-1} produced the highest number of grains per spike (36) which is 13.88% more as compared to control whereas in H_2 treatment FA @ 2.50 mg L^{-1} produced highest grains per spike (42.3) which is 18.91% higher than control. Overall results show that heat stress decreased grains per spike up to 29.42% while FA increased it upto12.63%.

Grain weight per spike is indicator of yield performance of wheat. More grain weight per spike may indicate the better grain yield of wheat. Data in table (3) showed reasonable decline in grain weight per spike due to application of heat stress. In case of control (No fulvic acid) and under no heat stress grain weight per spike was 1.69 g but was reduced to 1.14 g under heat stress application at grain initiation stage and minimum was recorded as 1.01 g under heat stress application at booting stage. These data showed that grain weight was decreased by 32.54% upon heat stress at grain initiation and 40.24% upon heat stress application at booting stage. Significant interactive effects of FA and heat stress expressed that FA showed different behavior in different heat stress treatments. In treatment H_0 (No heat stress) F1 (FA @ 1.25 mg L^{-1}) produced highest (2.12 g) grain weight per spike followed by F2 (FA @ 2.50 mg L^{-1}) which was statistically similar to F_1, while minimum was recorded in treatment F_0 (Control). Under H_1 (Heat stress at booting stage F_3 (FA @ 3.75 mg L^{-1}) produced maximum (1.29 g) grain weight followed by F_2 (1.13 g) which was statistically at par to F_3, while minimum (1.01) was in F_0 treatment. Under H_2 (Heat stress at grain initiation stage) F_2 produced highest (1.59 g) followed by F_3 which were similar statistically while minimum (1.14 g) was recorded in F_0 treatment. Improvement in grain weight per spike due to foliar applied FA was 25.44%, 27.72% and 39.47% under H_0, H_1 and H_2 treatments.

Test-weight or 1000-grain weight is also one of yield determining components and plays significant role. Data in table (3) show that heat stress significantly reduced 1000-grain weight. More decrease (17.84%) was recorded in H_1 treatment upon heat stress at booting stage than in H_2 (15.69%) treatment during heat stress at grain initiation stage. Significant results of interaction show that FA performed differently in different heat stress levels. In H_0 treatment FA @ 1.25 mg L^{-1} produced highest (43.2 g) 1000-grain weight (9.5%) followed by FA @ 2.50 mg L^{-1} which was statistically at par while minimum (39.5 g) was observed in control. In H_1 treatment heat stress was applied at booting stage, F_3 (FA @ 3.75 mg L^{-1}) produced highest (35.7 g which is 10% more over control) 1000-grain weight followed by F2 (FA @ 2.50 mg L-1) which was statistically similar to F_3. In H_3 treatment where heat stress was applied at grain initiation stage F_2 produced highest 1000-grain weight (37.54 g which is 12.73% more than control) and is statistically similar to F_3, while minimum was observed in control F_0 (water spray). Overall decrease in 1000-grain weight was recorded up to 18.53 % because of the heat stress at booting stage and 13.89% because of heat stress at grain initiation stage while overall improvement in 1000-grain weight due to FA was recorded by 8.4 %.

Biological yield is termed as total biomass produced by a crop which includes grain and straw yield. Data in table (3) shows that heat stress decreased biological yield significantly. Decrease in yield from 11.07 to 6.51 t ha^{-1} was recorded under heat stress applied at booting stage which was 41.19% while under heat stress application at the

Table 3. Effect of foliar applied Fulvic Acid on yield and yield components of heat stressed wheat

Treatments	SL (cm)	GPS	GWPS	TW(g)	BY (kg/ha)
H_0 (No heat stress)					
F_0 (Control)	11.33 a	43.0 b	1.69 c	39.50 b	11.07 b
F_1 (1.25 mg L^{-1})	12.47 a	49.0 a	2.12 a	43.27 a	12.30 a
F_2 (2.50 mg L^{-1})	11.87 a	48.3 a	2.07 a	42.74 a	11.55 ab
F_3 (3.75 mg L^{-1})	11.37 a	47.3 a	1.88 b	39.77 b	11.41 ab
H_1 (Heat stress at booting stage)					
F_0 (Control)	8.77 b	31.0 b	1.01 b	32.45 b	6.51 c
F_1 (1.25 mg L^{-1})	8.83 b	32.0 b	1.05 ab	32.72 b	6.81 bc
F_2 (2.50 mg L^{-1})	8.97 b	33.3 ab	1.13 a	33.79 ab	7.56 ab
F_3 (3.75 mg L^{-1})	10.47 a	36.0 a	1.29 a	35.70 a	8.18 a
H_2 (Heat stress at grain initiation stage)					
F_0 (Control)	8.90 c	34.3 c	1.14 b	33.30 b	7.46 b
F_1 (1.25 mg L^{-1})	10.20 b	38.0 bc	1.30 b	34.13 b	8.78 a
F_2 (2.50 mg L^{-1})	11.73 a	42.3 a	1.59 a	37.54 a	9.48 a
F_3 (3.75 mg L^{-1})	11.40 ab	40.7 ab	1.52 a	37.33 a	9.03 a
Tukey's HSD ($p \leq 0.05$)	**1.222**	**3.97**	**0.163**	**2.902**	**1.003**

Any two means not sharing a letter in common within a column differ significantly at $p \leq 0.05$; NS = Non-significant; SL = Spike Length; GPS= Grains per Spike; GWPS= Grain Weight per Spike; TW= 1000-GW; BY= Biological Yield

grain initiation stage it was from 11.07 to 7.46 t ha^{-1} which was 32.61% on comparison to control treatment. Significant interactive effects of FA and heat stress showed that FA @1.25 mg L^{-1} produced the highest grain yield in H_0 (No heat stress), FA @ 2.50 mg L^{-1} produced the highest yield in H_2 (Heat stress at grain initiation stage) and FA @ 3.75 mg L^{-1} produced highest in treatment H_1 (Heat stress at the booting stage). Biological yield in treatment H_0 and H_2 was statistically similar with foliar applied FA @1.25, 2.50 and 3.75 mg L^{-1} and minimum in control, while in H_1 FA @ 2.50 and 3.75 mg L^{-1} were statistically at par and minimum in control. Improvement in biological yield due to FA was 25.65% and 27.07% under heat stress at the booting stage and heat stress at the grain initiation stage respectively. The overall decline in yield due to heat stress was

37.27% and 25.02% under heat stress at the booting stage and grain initiation stage respectively, and improvement due to FA was 14.38%.

Straw yield is also an indicator of total biomass allocation in crop plants. The results of study in table (2) indicate the decreased straw yield under heat stress. Maximum straw yield (5.95 t ha^{-1}) was noticed in control treatment H_0 (without heat stress) followed by H_2 (Heat stress at grain initiation stage) and then H1 (Heat stress at booting stage) which produced 4.81 t ha^{-1} and 4.09 t ha^{-1}, respectively. Decline in straw yield was 31.26% under heat stress application at booting stage and 19.16% under heat stress application at grain initiation stage. FA application improved the straw yield regardless of its different foliar applied concentrations. Improvement in straw yield was up to 13.55% as compared to treatment F_0 (control). Interactive effect of FA and heat stress was non-significant.

The harvest index is the ratio of grain yield to biological yield. More harvest index is an indicator of more grain yield than straw yield. Data in table (2) indicated the decline in the harvest index under heat stress. Maximum harvest index (48.68%) was calculated in treatment H_0 (No heat stress) followed by treatment H_2 (Heat stress at grain initiation stage) (44.63%) which was statistically at par with treatment H_0 and minimum (43.89%) was recorded in treatment H_1 (Heat stress at booting stage). The decrease in harvest index as compared to treatment H_0 (No heat stress) was 9.8% under heat stress application at booting stage and 8.31% under heat stress application at grain initiation stage. FA did not affect the harvest index; likewise interactive effect of FA and heat stress was also non-significant.

4. Discussion

Plants facing no stress and with better nourishment give more spike length. The decrease in spike length might be due to reduced development of rachis during heat stress at a booting stage which shortened the spike length and during heat at grain initiation stage it might be due to disrupted source-sink relationship due to the production of ROS and lesser photosynthates accumulation in rachis and in grains which also produced shrunken grains causing spike to remain shorter. Kumar et al., (2016) reported the reduced spike length of wheat genotypes under heat stress which resulted in lesser grains per plant and low yield. FA improved spike length during heat stress at the booting and grain filling stage which might be due to improvement in photosynthates translocation after the alleviation of heat stress, a greater number of grains per spike, and more grain weight. As

Anjum *et al*., (2011) reported the increase in cob length of maize by application of FA under drought stress, so increase in spike length might be the same response of FA as it showed in maize. FA acts as an antitranspirant in plants hereby increasing water use efficiency and plant tissue water status and enabling the plant to withstand heat stress (AbdAllah *et al*., 2018).

Reduction in spikelets per spike may be because of the initiation of reactive oxygen species which cause membrane damages and cause programmed cell death under heat stress condition. As FA was applied at later stage so it did not influence the number of spikelets per spike. An increase in heat stress results the production of reactive oxygen species which causes membrane leakage, pollen sterility, destruction of photosynthesis apparatus and chlorophyll contents and lipid peroxidation (Farooq *et al*., 2011) and ultimately decreases grains per spike. These results are supported by Ghaffari et al., (2015) who conducted experiment for inducing thermos-tolerance in wheat cultivars. Improvement in number of grains/spike by application of FA was supported by Anjum et al., (2011) who stated the increase in kernals/cob in maize.

Decrease in grain weight per spike might be due to decrease in current photosynthesis, increased respiratory activity, less grain number due to pollen sterility, grain size, grain filling duration and less photosynthates translocation to grain under heat stress. Significantly higher respiratory rate of flag leaf was observed by Almeselmani et al., (2012) under heat stress. Hedhly et al., (2009) described the production of abnormal anthers and nonfunctional florets under heat stress. Increase in grain weight per spike could be result of improved photosynthesis, more grain number, grain filling duration and remobilization of non-structural carbohydrate reserves under foliar application of FA as described by Zhang et al., (2016).

Decrease in 1000-grain weight could be due to reduced photosynthesis and less photosynthates translocation towards grain under heat stress. Dias et al., (2008) reported the shrinking of wheat grains due to higher temperature at reproductive stage and causing structural damage to endosperm and aleurone layer. Reduction might be due to increased grain filling rate and decreased duration (Dias and Lidon, 2009 a) ultimately reduced storage of photosynthates in grain. But FA helped to increase the grain weight that could be due to increased production of non-structural carbohydrates (NSC) in grain, and by protecting membranes from leakage under heat stress. This role of FA was confirmed by Zhang et al., (2016) who reported the increased production of NSC under stress at heading stage of wheat.

Under heat stress decline in biological yield might be due to complex effects, such as increased membrane leakage, lipid peroxidation, oxidative stress (Wang *et al*., 2011) and decline in photosynthesis (Ashraf and Harris,2013), metabolic activities (Farooq *et al*., 2011), chlorophyll contents, relative water contents (Hasanuzzaman *et al*., 2013), grain number (semenov, 2009), size and weight. FA Increased biological yield under normal and heat stress situation. That increase might be directly proportional to increase in yield components and biomass allocation in crop. According to Anjum et al., (2011) FA improved yield and yield determining components in maize under drought stress. Moreover Zhang et al., (2016) stated the role of FA in improvement of wheat growth, biomass allocation and yield performance. So FA might have same effects on wheat under heat stress which it showed under drought stress.

Heat stress declined the crop growth, development, biomass allocation, water relations of crop and biological yield which also caused decline in straw yield of wheat. Reduced leaf area and decreased fresh and dry weight of leaf and peduncle under heat stress might be responsible for declined straw yield under heat stress. Hedhly et al., (2009) described the loss in fresh and dry weight of wheat under heat stress at reproductive stage. The improvement in straw yield due to FA might be due to improvement in all above mentioned characters of wheat under normal and heat stress conditions.

A decrease in harvest index might be due to reduced translocation of photosynthates towards grains by disruption of apoplastic and symplastic path-ways of assimilate translocation under heat stress (Talukder *et al*., 2013). Lipiec et al., (2013) described the reduced seed setting and filling under heat stress due to source-sink limitations. N remobilization towards grain also stops under heat stress situations. So harvest was decreased under heat stress. FA did not increase the harvest index which was contradictory to the results of Zhang et al., (2016) who stated an increase in the harvest index in wheat, and also to Anjum et al., (2011) who stated increased harvest index due to FA in maize under drought stress.

5. Conclusion

Based on the findings mentioned earlier, it can be inferred that fulvic acid helps alleviate heat stress by boosting yield and yield components of wheat. Consequently, it is suggested that fulvic acid could be used as a foliar spray on wheat, both during regular conditions and particularly when the crop faces heat stress in later growth stages. The role of Fulvic acid may further be evaluated to mitigate heat stress on crops especially those grown during the summer season.

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