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Soil Manuring and Genetic Variation Conjunctively Surmount the Partial Drought Stress in Wheat (*Triticum aestivum* L.)

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ABSTRACT

Crop growth is negatively influenced under water-stress conditions, which is among the most yield-limiting factors significantly decreasing crop yield. This study evaluated the effect of water-deficit stress on physiological, bio-chemical and yield attributes of wheat (*Triticum aestivum* L.) under both constantly wet and water-stressed conditions on two wheat varieties (UJALA-14, SARC-4). Further, the combined impacts of crop genetic variability and organic manuring in soil was studied for overcoming the partial drought stress in wheat. Treatments of different levels of irrigation water alone or with farmyard manure (FYM) @ 20 Mg ha^{-1} were compared as: constantly wet irrigation (control), irrigation intensity equal to field capacity (FC), ½ FC + FYM, and ¼ FC + FYM. Crop growth, physiological and chlorophyll as well as sodium and potassium contents were measured. The findings of current study exhibited that shortage of water had negative effects on growth, physiological, bio-chemical and yield attributes of wheat. Genotype SARC-4 exhibited superior growth response having constantly wet and field capacity condition, on the other hand UJALA-14 gave better growth response under water stress conditions of ½ FC and ¼ FC when treated with FYM amendment. It is concluded that partial drought stress developed tolerance in wheat genotypes particularly in UJALA-14, which was strengthened with organic amendment. Combined use of drought tolerant varieties and application of FYM as a fertilizer is very effective way to enhance crop yield.

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INTRODUCTION

Wheat is the principal food for around 33% of global populace contributing protein and calories greater than any other crop (Singh *et al*., 2018). Climate change has driven drought stress, which in turns threatened global wheat production (Munaweera *et al*., 2022). Globally, water shortage is the most damaging cause for agriculture production in the areas receiving low rainfall (Fernandez *et al*., 2019) which decreases the cultivation land. Wheat production could be enhanced in rainfed areas by choosing wheat varieties having superior adaptation against water-stress (Memon *et al*., 2022). Water stress effects all attributes of plants by transforming the biochemistry, morphology, physiology (Bano *et al*., 2019; Sairam, 1994) and drought being the largest abiotic stress decrease in leaf size, extension of stem and roots growth and ultimately reduces yield. It lessens the efficiency of water usage of plants by disturbing water relation. Low moisture level in soil reduces crop yield by decreasing absorption of active radiation by canopy, reduces efficiency to use light and decreases harvest index (HI) (Wijewardana *et al*., 2018).

Wheat plants facing water shortage have lower relative water content (RWC) as compared to those having enough soil moisture. Water stress in plants causes decline in leaves water potential, transpiration speed and increases leaf temperature (Li *et al*., 2019). Water-stress depends on potential and duration of water shortage, it declines, tillering capability, biomass, grain yield any stage when stress occurs (Kumar *et al*., 2019). Wise usage of water is important in those areas where water availability is limited. Different wheat varieties response differently to water stress circumstances (Nergui *et al*., 2022). Stress tolerant wheat varieties are the viable option for crop yield improvement and stability in water shortage conditions (Akram, 2011).

Appropriate soil management and nutrients availability could increase the tolerance against water stress in the crop. In most parts of the globe canal irrigation is inadequate to fulfil the requirement of wheat crop mainly at the time of critical growth stages (Manzoor *et al*., 2022). Organic manure addition is a beneficial management practice to enhance soil fertility and to minimize water losses. In recent years, addition of organic amendments to conserve the water in soil is getting much consideration. Farmyard manure is an exceptional fertilizer encompassing nitrogen, phosphorus, potassium, and other elements (El-Ghamry *et al*., 2009) Addition of organic residue to soil can improve soil properties viz., structure, water holding capacity, aeration, and water infiltration (Wang *et al*., 2017). For that reason, addition of organic residue even under limited water availability situations may further conserve the irrigation water volumes and sustain the crop growth and yield. Modern interest in manuring has re-emerged due to increased prices of chemical fertilizers, and it ensures longstanding soil productivity besides meeting nutrient requirements and conserving the soil moisture.

Use of organic fertilizer is getting much attention due to depletion in soil fertility and increasing shortage of water globally. Organic amendments like addition of FYM could be used for crop production because it does not only provide essential nutrients but is also reduce the water loss through evaporation by improving soil structure (Awad and Ahmed, 2019). Organic residue addition in soil increases soil fertility and microbial activity variably increasing organic matter contents in the soil (Chen *et al*., 2018) and provides a wide-ranging nutrient that resultantly increase water holding capacity by improving soil structure (Chenu *et al*., 2019). Nutrient-rich material like compost is one of the most attractive materials to increase the plant tolerance against stress conditions. Therefore, farmers are encouraged to shift their prevailing agricultural fields into organic in developed countries (Feber *et al*., 2019). Drought tolerant wheat varieties and conservation of water by different organic amendments like addition of FYM could be the viable option to minimize the effect of water shortage. By considering these facts, a current study was undertaken to reduce the water-stress influence on growth and yield attributes of wheat by using two drought-tolerant verities and organic amendment.

MATERIAL AND METHODS

Study site

The study was undertaken in greenhouse conditions in winter (Rabi) season of 2015-2016 to compare two varieties of wheat, in earthen pot culture at University of Agriculture, Faisalabad. Experiments were carried out in completely randomized design and each treatment replicated thrice.

Pre analysis of soil and farmyard manure

Study soil was sandy loam having pH 8.11, EC 0.61 dS m^{-1}, saturation percentage 28% and field capacity 14%. Farmyard manure analysis revealed organic matter 0.8%, N 0.31%, P 0.13% and K 1.37%.

Treatments plan and fertilizer application

Water-status maintenance treatments / irrigations were as: constantly wet soil condition (control), irrigation intensity equal to field capacity (FC), ½ FC + FYM @ 20 Mg ha^{-1}, and ¼ FC + FYM @ 20 Mg ha^{-1} applied to two wheat varieties, viz., Ujala-08203 and SARC-4. Each pot was irrigated according to the calculated amount of water as per treatment. Five healthy seeds were sown in each pot when soil-water was at field capacity condition, and recommended doses of fertilizers (N-120, P_2O_5-90, K_2O-60 kg ha^{-1}) were applied at the time of sowing. Nitrogen was applied in two dosages, while phosphorus and potassium were given only at the time of sowing.

Soil and plant sample analysis

The FC was measured through tensiometer. Plant leaf samples for biochemical estimation were collected one week before crop maturity and all analyses were carried out at 4°C. Crop data were recorded at two stages viz., 70 days after sowing and at maturity. Growth parameters recorded after 70 days of sowing were: plant height, fresh and dry plant weight. Plant growth and yield parameters recorded at harvest were plant height, fresh and dry plant weight, spike length, spike weight. Drought resistance indices studied were: RWC, and membrane stability index (MSI). Bio-chemical parameter chlorophyll contents (SPAD value), as well as soluble Na^+ and K^+ contents were also assessed. Spikes were picked from marked plants, threshed, and seeds were weighed on electrical balance.

Drought resistance indices were determined from flag leaf samples using the relevant equations.

Relative water content was calculated as suggested by Weatherley (1950):

$$\text{Relative water contents (\%)} = \frac{\text{Fresh Mass} - \text{Dry Mass}}{\text{Turgid Mass} - \text{Dry Mass}} \text{ x } 100$$

Membrane stability index was measured as suggested Premchandra (1990):

$$\text{Membrane stability index} = 1 - \frac{\text{EC1}}{\text{EC2}} \text{ x } 100$$

Where: EC1 = Initial electrical conductivity

EC2 = Final electrical conductivity

Relative chlorophyll contents were measured by Mintola-502 Chlorophyll Meter in terms of SPAD value.

Soluble Na^+ and K^+ contents were determined with Flame Photometer (Sherwood-410) (US. Salinity Lab. Staff, 1954).

$$\text{Na or K (ppm)} = \text{ppm Na or K (from calibration curve) x} \frac{\text{v}}{\text{Wt}}$$

Where: V = Total volume of the extract (mL)

W = Weight of dry plant (g)

Harvest index was determined by the following equation:

$$\text{Harvest Index} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \text{ x } 100$$

Statistical analysis

Data were statistically processed via two-way ANOVA, and treatment means were compared using LSD described by Steel *et al*., (1997). Software used for statistical analysis was Statistix version 8.1, and graphs were drawn in MS Excell version 2010.

RESULTS

Effects of manuring on plant growth attributes under water-stress conditions

When compared to the treatment of constantly wet soil condition (control), data obtained showed an increase of water stress regimes brought about a significant ($P \leq 0.05$) reduction in shoot length of wheat recorded on two growth stages, viz., 70 days after sowing and at harvest (Table 1 and 2). Water stress regimes also caused significant differences between both wheat genotypes, viz., UJALA-14 and SARC-4 as well as among all water regimes at harvest stage. Interaction between irrigation regimes and wheat varieties (I×V) was also statistically significant.

The longest shoots were noted in constantly wet soil, while the least shoot length was under ¼ FC+FYM treatment in both stages, viz., after 70 days and at harvest. Same trend was witnessed in fresh and dry shoot weight among irrigation regimes and between both genotypes. The interaction of I×V also exhibited significant differences for plant shoot length, fresh and dry shoot weight. Reduction in shoot length, fresh and dry weight is attributed to reduction in RWC.

Table 1. Response of plant shoot height, fresh and dry weight to different levels of water-stress and farmyard manure application at 70 days after sowing.

Crop growth attributes	Irrigation regimes (I)	Wheat varieties (V)		Means
		UJALA-14	SARC-4	
Shoot length (cm)	Constantly wet	21.1 ab	26.5 a	23.8 A
	Field capacity	21.3 ab	26.2 a	23.7 A
	½ FC+FYM	18.1 b	18.8 b	18.4 B
	¼ FC+FYM	17.2 b	15.4 b	16.3 B
Means		19.4 B	21.7 A	
LSD $_{0.05}$ for: water stress levels = 3.7; varieties = 1.9; and I×V = 6.6				
Plant fresh weight (g)	Constantly wet	10.65 a	11.83 a	11.24 A
	Field capacity	10.29 ab	10.86 ab	10.57 A
	½ FC + FYM	8.29 b	5.39 c	6.84 B
	¼ FC + FYM	3.12 c	3.07 c	3.10 C
Means		8.07 A	7.79 A	

LSD 0.05 for: water stress levels = 1.66; varieties = 0.88; and I×V = 2.85				
Dry shoot weight (g)	Constantly wet	3.2 a	3.01 a	3.11 A
	Field capacity	2.06 b	2.88 a	2.47 A
	½ FC+FYM	1.57 bc	1.81 bc	1.69 B
	¼ FC+FYM	1.18 c	1.24 c	1.21 C
Means		2.00 B	2.24 A	
LSD 0.05 for: water stress levels = 0.45; varieties = 0.32; and I×V = 0.64				

Means in last column or bottom row bearing different upper-case letter(s), and values for I×V interaction with different lower-case letter(s) show significant difference at $P \leq 0.05$.

Abbreviations: Half of the field capacity, ½FC; One-fourth of the field capacity, ¼FC; Farmyard manure, FYM.

Table 2. Response of plant shoot height, fresh and dry weight to different levels of water stress and farmyard manure application at harvesting stage.

Crop growth attributes	Irrigation regimes (I)	Wheat varieties (V)		Means
		UJALA-14	SARC-4	
Shoot length (cm)	Constantly wet	53.0 c	67.3 a	60.2 A
	Field capacity	48.7 c	60.2 b	54.5 B
	½ FC + FYM	41.1 d	39.0 d	40.0 C
	¼ FC + FYM	24.3 e	21.7 e	23.0 D
Means		41.8 B	47.1 A	
LSD 0.05 for: water stress levels = 3.8; varieties = 28; and I×V = 5.5				
Fresh shoot weight (g)	Constantly wet	14.22 ab	15.37 a	14.79 A
	Field capacity	14.08 ab	14.09 ab	14.08 A
	½FC+FYM	9.84 bc	7.50 cd	8.66 B
	¼FC+FYM	5.64 cd	4.67 d	5.15 B
Means		10.94 A	10.40 A	
LSD 0.05 for: water stress levels = 3.51; varieties = 2.48; and I×V = 4.96				
Plant dry weight (g)	Constantly wet	3.14 ab	3.85 a	3.50 A
	Field capacity	3.39 a	3.55 a	3.47 A
	½ FC + FYM	2.65 bc	2.36 cd	2.50 B
	¼ FC + FYM	1.65 de	1.58 e	1.62 C
Means		2.71 A	2.84 A	
LSD 0.05 for: water stress levels = 0.43; varieties = 0.22; and I×V = 0.74				

Means in last column or bottom row bearing different upper-case letter(s), and values for I×V interaction with different lower-case letter(s) show significant difference at $P \leq 0.05$.

Abbreviations: Half of the field capacity, ½FC; One-fourth of the field capacity, ¼FC; Farmyard manure, FYM

Effects of manuring on crop yield attributes under water-stress conditions

When compared to the treatment of constantly wet soil condition (control), data obtained indicated an increase of water stress regimes brought about a significant ($P \leq 0.05$) fall in spike length and weight of wheat (Table 3). Water stress regimes caused significant differences between both wheat genotypes, viz., UJALA-14 and SARC-4. Interaction between irrigation regimes and wheat varieties (I×V) was statistically non-significant. The longest spike length and weight was noted in constantly wet soil, while the least spike length and weight was under ¼ FC+FYM treatment. This could be due to more assimilates transfer from flag leaf, which increased number of spikelet's and ultimately extended the spike. The same trend was observed in spike weight.

Harvest index (%) expresses the physiological ability of plants to change the fraction of photo-assimilates to grain yield. When compared the obtained data to the treatment of constantly wet soil condition (control), an increase of water stress regimes brought about a significant ($P \leq 0.05$) reduction in HI of wheat (Table 3). Water-stress regimes caused significant differences between both wheat genotypes, viz., UJALA-14 and SARC-4. Interaction (I×V) between wheat genotypes and irrigation regimes was also statistically significant. The highest value was recorded under constantly wet conditions while the lowest values of HI was under ¼ FC+FYM treatment.

Table 3. Response of spike length, weight per spike and harvest index to water stress levels and farmyard manure application.

Crop yield attributes	Irrigation regimes (I)	Wheat varieties (V)		Means
		UJALA-14	SARC-4	
Spike length (cm)	Constantly wet	7.77 b	10.25 a	9.01 A
	Field capacity	6.43 bc	7.76 b	7.18 B
	½ FC+FYM	6.83 bc	5.17 cd	6.00 B
	¼ FC+FYM	3.67 d	4.17 d	3.92 C
Means		6.17 B	6.87 A	
LSD $_{0.05}$ for: water stress levels = 1.28; varieties = 0.67; and I×V = 2.20				
Spike weight (g)	Constantly wet	4.43 a	4.43 a	4.43 A
	Field capacity	3.70 ab	3.79 ab	3.75 A
	½ FC+FYM	1.31 c	2.72 b	2.02 B
	¼ FC+FYM	0.29 c	0.44 c	0.37 C
Means		2.43 B	2.85 A	
LSD $_{0.05}$ for: water stress levels = 0.71; varieties = 0.37; and I×V = 1.21				
Harvest index (%)	Constantly wet	37.63 ab	41.65 a	39.64 A
	Field capacity	34.03 b	36.90 ab	35.46 A
	½ FC+FYM	24.15 c	32.97 b	28.56 B
	¼ FC+FYM	9.62 d	14.14 d	11.88 C
Means		26.36 B	31.42 A	
LSD $_{0.05}$ for: water stress levels = 5.03; varieties = 3.55; and I×V =7.11				

Means in last column or bottom row bearing different upper-case letter(s), and values for I×V interaction with different lower-case letter(s) show significant difference at $P \leq 0.05$.

Abbreviations: Half of the field capacity, ½FC; One-fourth of the field capacity, ¼FC; Farmyard manure, FYM

Effects of manuring on crop drought indices under water-stress conditions

Drought susceptibility index is not depending on yield potential and drought intensity. It is potentially suitable for assessments of drought vulnerability of varieties between drought levels and experiments, because greater values of susceptibility index indicate more drought susceptibility. When compared to the treatment of constantly wet soil condition (control), an increase of water stress regimes brought about a non-significant ($P \leq 0.05$) reduction in MSI of wheat (Table 4). Water stress regimes caused significant differences between both wheat genotypes, viz., UJALA-14 and SARC-4. Interaction (I×V) between wheat genotypes and irrigation regimes was statistically non-significant. The highest value was recorded under constantly wet conditions while the lowest values of MSI was under ¼FC+FYM treatment.

When compared to the treatment of constantly wet soil condition (control), an increase of water stress regimes brought about a non-significant ($P \leq 0.05$) reduction in leaf RWC of wheat (Table 4). Water stress regimes caused significant differences between both wheat genotypes, viz., UJALA-14 and SARC-4. Interaction (I×V) between wheat genotypes and irrigation regimes was statistically non-significant. The highest value was recorded under constantly wet conditions while the lowest values of HI was under ¼ FC+FYM treatment.

Table 4. Response of wheat drought indices to water stress levels and farmyard manure application.

Crop drought indices	Irrigation regimes (I)	Wheat varieties (V)		Means
		UJALA-14	SARC-4	
Membrane stability index (%)	Constantly wet	38.8 ab	52.3 a	45.5 A
	Field capacity	30.4 b	36.8 ab	33.6 A
	½ FC+FYM	38.5 ab	40.9 ab	39.7 A
	¼ FC+FYM	26.2 b	34.9 ab	30.5 A
Means		33.5 B	41.2 A	
LSD $_{0.05}$ for: water stress levels = 15.4; varieties = 10.9; and I×V = 21.8				
Leaf relative water content (%)	Constantly wet	47.6 ab	59.2 ab	53.4 AB
	Field capacity	38.8 b	94.3 a	66.3 A
	½ FC+FYM	16.9 b	55.7 ab	36.3 B
	¼ FC+FYM	32.1 b	44.4 b	38.2 AB
Means		33.9 B	63.4 A	
LSD $_{0.05}$ for: water stress levels = 28.53; varieties = 14.95; and I×V = 48.89				

Means in last column or bottom row bearing different upper-case letter(s), and values for I×V interaction with different lower-case letter(s) show significant difference at $P \leq 0.05$.

Abbreviations: Half of the field capacity, ½FC; One-fourth of the field capacity, ¼FC; Farmyard manure, FYM

Effects of manuring on bio / chemical concentrations under water-stress conditions

When compared to the treatment of constantly wet soil condition (control), an increase of water stress regimes brought about a non-significant ($P \leq 0.05$) reduction in Na^+ contents of wheat (Table 5). Water stress regimes caused significant difference between both wheat genotypes, viz., UJALA-14 and SARC-4. Interaction (I×V) between wheat genotypes and irrigation regimes was statistically non-significant. The highest value was noted under field capacity conditions whereas the lowest values of Na^+ contents was found under ¼ FC+FYM treatment.

When compared to the treatment of constantly wet soil condition (control) an increase of water stress regimes non-significantly ($P \leq 0.05$) reduced K^+ content of wheat (Table 5). Water stress regimes caused non-significant differences between both wheat genotypes, viz., UJALA-14 and SARC-4. Interaction (I×V) between wheat genotypes and irrigation regimes was also statistically non-significant. The highest value was recorded under field capacity conditions while the lowest values of K^+ contents was found under ¼FC+FYM treatment.

When compared to the treatment of constantly wet soil condition (control) an increase of water stress regimes non-significantly ($P \leq 0.05$) affected chlorophyll contents of wheat (Table 5). Water stress regimes caused non-significant differences between both wheat genotypes, viz., UJALA-14 and SARC-4. Interaction (I×V) between wheat genotypes and irrigation regimes was also statistically non-significant. The highest value was recorded under constantly wet soil condition while the lowest values were found under ¼FC+FYM treatment.

Table 5. Response of bio / chemical components in plants to water stress levels and farmyard manure application.

Bio / chemical compounds	Irrigation regimes (I)	Wheat varieties (V)		Means
Na^+ content at harvest (ppm)		UJALA-14	SARC-4	
	Constantly wet	47.7 a	32.0 ab	39.8 AB
	Field capacity	53.0 a	42.0 ab	47.5 A
	½ FC+FYM	48.3 a	29.0 ab	38.7 AB
	¼ FC+FYM	32.0 ab	17.7 b	24.8 B
Means		45.3 A	30.2 B	
LSD $_{0.05}$ for: water stress levels = 18.7; varieties = 13.2; and I×V = 26.5				
K^+ content at harvest (ppm)	Constantly wet	125 abc	119 bc	122 B
	Field capacity	136 ab	145 a	141 A

	½ FC+FYM	104 cd	109 c	107 B
	¼ FC+FYM	78 e	84 de	81 C
Means		110.8 A	114.3 A	
LSD 0.05 for: water stress levels = 16; varieties = 11; and I×V = 23				
Chlorophyll content (SPAD value)	Constantly wet	51.9 a	50.9 a	51.4 A
	Field capacity	51.0 a	49.2 a	50.1 A
	½ FC+FYM	51.2 a	49.7 a	50.4 A
	¼ FC+FYM	51.3 a	51.0 a	51.2 A
Means		51.3 A	50.2 A	
LSD 0.05 for: water stress levels = 3.0; varieties = 1.6; and I×V = 5.2				

Means in last column or bottom row bearing different upper-case letter(s), and values for I×V interaction with different lower-case letter(s) show significant difference at $P \leq 0.05$.

Abbreviations: Half of the field capacity, ½FC; One-fourth of the field capacity, ¼FC; Farmyard manure, FYM

DISCUSSION

Under water-stress condition lower RWC was witnessed that caused decline in turgor and cell volume, which eventually reduced plants growth and development of (Alishah and Ahmadikhah, 2009). Farmyard manure and chemical fertilizer together can render better positive effects on plant growth and yield. Application of sewage and sludge considerably enhanced growth and yield of wheat (Channabasanagowda *et al*., 2008).

Shoot length was reduced in water stress regimes; it might be because of the difference in genetic makeup of both varieties along with insufficient availability of essential nutrients under water-stress. These outcomes are in conformity with the findings of Sarwar *et al*. (2010) stating significant relationship between varieties and levels of irrigation. Application of FYM increased shoot length of wheat (Sharma *et al*. 2005). El-Ghamri *et al*. (2009) stated that maize shoot length in combination with FYM+1/2 NPK fertilizer was statistically comparable to that with full dose of NPK fertilizer. Similarly, Inamullah *et al*., (1999) also revealed that height of plant in wheat varieties was decreased significantly under water stress as compared with normal irrigated conditions. Organic manures provide multiple nutrients to plants depending on the type and quality which in turn increases in spike length (Ahmad *et al*., 2007). Wheat grain yield and yield-attributing parameters (length and weight of spikes) were significantly affected by different water regimes.

Full irrigation rendered the greater spike length as compared to water stress conditions (Klar *et al*., 1990). Grain weight, number of grains, 1000-grain weight and predominantly grain yield was highly drought sensitive than plant height in wheat varieties (Dencic *et al*., 2000). During the decomposition of organic matter, release of nutrients and organic compounds increases growth and yield traits (Hendrix *et al*., 1994). Similar results were reported by Iqbal *et al*. (2010). Shah *et al*. (2022) reported similar results regarding spike length. Mirbahar *et al*. (2009) reported that skipping irrigation at different crop growth stages significantly affects spike length and spike weight of wheat cultivars.

Moisture deficit inside the soil decreases growth and yield of crops thus decreased in HI (Wijewardana *et al*., 2018). The number of grains per spike, number of productive tillers and HI were decreased significantly due to water stress. Different investigators have found that turgor decreases due to water stress conditions, but membrane stability does not get affected under water stress conditions (Jatoi *et al*., 2011). Similar results were reported by (Iqbal *et al*., 2010) for various wheat cultivars under water stress levels.

Relative water contents have been reported as one of the key signs of water stress in plant leaves and is closely associated with cell volume, thus it may more accurately reflects the balance between availability of water to leaves and transpiration rate (Merah, 2001). It affects the ability of plants to recover from drought stress and subsequently affects. Similar observations have been testified in mung bean (Korir *et al*., 2006). Reduction in RWC contents has been linked with reduction in uptake of water by plants under water stress conditions and reduction in RWC also causes reduction in the growth of plant (Cicek and Cakirlar, 2002).

Water stress slightly decreases Na^+ and K^+ content in plant shoots. Due to decrease in Na^+ and K^+ shoot dry matter decreases with increasing water stress (Anjum *et al*., 2003). The reduction of chlorophyll contents is the result of production of reactive oxygen species in chloroplast, which destroys chlorophyll molecules (Mafakheri *et al*., 2010). Previous studies have shown similar outcomes on the effect of irrigation regimes on chlorophyll contents (Lie *et al*., 2006).

CONCLUSION

Results of this study revealed that water stress significantly decreases the growth and yield traits of wheat genotypes. However, application of FYM played very important role in water-deficit stress tolerance and its conservation. Reduction in water content beyond a certain level like $1/4^{th}$ of field capacity without addition of organic amendment decreased the wheat yield by exerting adverse effects on growth and yield components of the crop. Therefore, in areas having shortage of irrigation water like arid and semi-arid regions, farming communities could be encouraged to grow drought tolerant wheat varieties along with application of FYM as soil amendment to harvest appropriate crop yields.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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