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SUSTAINABLE PRODUCTION OF TWO WHEAT CULTIVARS UNDER WATER STRESS CONDITIONS

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Abstract

This study was undertaken to evaluate the response of two Egyptian wheat cultivars (Sakha-94 and Misr-1) to some soil amendment (hydrogel 30 kgm/feddan and compost 10 ton/feddan individually or mixed) under normal irrigation 100% IR (irrigation water requirements) and water stress 75% IR, which corresponded to 2500 and 1875 water/feddan/season, respectively. A field experiment was conducted in two winter seasons of 2016-2017 and 2017-2018 in the Research and Production Station of the National Research Centre in El-Nubaria El-Behera Governorate, Egypt. The results showed that, the highest values of plant high, **n**umber of spikes/m^2 spike length, number of grains spike, 1000 grains weight (g), grain yield (Ton/fed.), straw yield (Ton/fed.) and biological yield (Ton/fed.) were recorded under 100% IR and treatment with both (compost + hydrogel), while the lowest values were recorded at 75% available IR treated with hydrogel. However, Misr-1 cultivars surpass Sakha-94 in all the previous characters. On the other hand, crude protein content in grains was increased by decreasing the amount of irrigation water. The highest value of water use Efficiency (WUE) was obtained under 75% IR and treated with (compost + hydrogel) in both cultivars. Data of drought index proved that, Misr-1 was more tolerant to water stress. The data clearly showed that addition of compost and hydrogel can enhance wheat production in new reclaimed sandy soil.

***Keywords*:** Water Stress, Wheat Varieties, WUE, Yield.

Introduction

Fluctuations in weather cause large variations in crop yields. Uncertainty in weather creates a risky environment for agricultural production. During the last decades, the application of simulation and system analysis in agricultural research has increased considerably. Water stress is one of the environmental stresses seriously limiting crop production in the majority of agricultural fields of the world and recent global climate change has made this situation more adverse (Al-Ghamdi, 2009). Drought affects morphological, physiological, biochemical and molecular processes in plants resulting in growth inhibition. The extent of these changes is dependent on the time, stage and severity of environmental stress (Cao *et al*., 2011).

Many researcher studied the effect of irrigation regimes on wheat productivity and water use efficiency (WUE). Results showed that irrigation regimes significantly affected grain, straw and biological yields which were significantly increased as the volume of irrigation water increased. In this regards, Seleiman (2011) found that increasing number of irrigations up to five increased grain yield (ton.ha^{-1}), biological yield (ton.ha^{-1}), harvest index, number of spikes/m^2, number of grains/spike and 1000-kernel weight but significantly decrease protein content.

Selecting wheat Cultivars based on their yield performance under drought conditions is a common approach, therefore some drought stress indices or selection criteria have been suggested by different researches (Pireivatlou *et al*., 2010). Development of wheat cultivars with high yield is the main goal of water limited environments countries due to the expected negative impacts of climate changes on both plant and environment (Mirbahar *et al*., 2009).

In this concern, Mohamed (2013) studied that the effect of three levels of irrigation regime (T1=2 irrigations, T2=3 irrigations, T3=4 irrigations and T4=5 irrigations as control) on eight cultivars and lines. He found that Sids 12 cultivar was the highest in yield and its components and the most tolerant to drought stress compared with commercial cultivars (Sakha 93, Sakha94, Gemmeiza10 and Giza 168) and other tested lines. The objectives of this study, therefore, were to improve productivity of two wheat cultivars growing under water stress conditions.

Materials and Methods

A field experiment was carried out at the Agricultural Research and Production Station of the National Research Centre (NRC), El Nubaria Governorate, Egypt, during the two winter seasons 2016-2017 and 2017-2018, to study the effect of compost and hydrogel on productivity of two wheat cultivars grown under water stress conditions in newly reclaimed sandy soil. Soil sample was taken for physical and chemical analyses as described by Chapaman and Pratt (1978) (Table 1). The split split plot design with three replicates was used, where the irrigation requirements (100% and 75% IR) were distributed in the main plots while wheat cultivars (Misr-1 and Sakha-94) were assigned in the subplots and soil amendment treatment (hydrogel 30 kg/ fed, compost 10 ton/fed and hydrogel + compost) were randomly distributed in the sub sub plots. Mineral fertilizers were added as recommended, nitrogen fertilizer was added at a rate of 80 kg/faddan as ammonium sulfate (20.6 % N) in three equal doses at 15, 30 and 45 days after sowing, while phosphorus and potassium were added during seed bed preparation at a rate of 100 kg/faddan for both calcium superphosphate (15.5 % P_2O_5) and potassium sulfate (48 % K_2O), respectively. The meteorological data of temperature, relative humidity, rainfall precipitation, wind speed and soil temperature, were obtained from Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Cairo, Egypt, during the growing seasons of 2016-2017 (Table 2). Total irrigation water (m^3/fed./season) was calculated from the meteorological data of the Central Laboratory for Agricultural Climate (CLAC) depending on

Penman-Monteith equation, the seasonal irrigation water applied was found to be 2500 m^3/fed. (100 % IR) and 1875 m^3/fed (75 % IR). All other agricultural practices of growing wheat were conducted as usually done by the farmers in the district. Irrigation was carried out using sprinkler irrigation system where water was added every 5 days by applying the specified IR (100 and 75%). Analysis of irrigation water is presented in Table (3). Location of the study area and the experimental farm in El Nubaria Region, Egypt are presented in Fig (1 and 2). Vegetative sample were taken after 75 days from sowing to determine chlorophyll a+b (mg/g fresh weight) according to von Wetstein (1957) and proline according to Bates *et al*., (1979). At harvest, one square meter was taken randomly from the middle area of each plot to determine plant high, **n**umber of spikes/m^2 spike length , number of grains spike, 1000 grains weight (g), grain yield (Ton/fed.), straw yield (Ton/fed.) and biological yield (Ton/fed.). Grain crude protein percentage was estimated according the improved Kjeldahl method of AOAC (2010).

Drought indices of the tested wheat cultivars

1. Mean cultivars productivity (MP) = (Yp+Ys)/2 according to and Hossain *et al.,* (1990).
2. Geometric cultivar productivity (GMP) = (Yp× Ys) 0.5 according to Fernandez (1992).
3. Tolerance index (TOL) = Yp – Ys according to Hossain *et al.,* (1990).
4. Stress susceptibility index (SSI) = [1-(Ys/ Yp)] / [1-(Ys/ Yp)] according to Fischer and Maurer (1978).
5. Stress tolerance index (STI) = (Yp + Ys)/ (Yp) according to Fernandez (1992).

Where, Yp, Ys are means grain yield of the same cultivar under 100% and 75% IR treatments, respectively. Where Yp and Ys are means of yield of all cultivars under 100% and 75%, respectively. The water use efficiency (WUE) was calculated according to FAO (1982) as follows: The ratio of crop yield (Y) to the total amount of irrigation water use in the field for the growth season (IR) is WUE (kg/m^3) = Y (kg)/IR (m^3).

Statistical analysis: Data were subjected to statistical analysis of variance as described by Snedecor and Cochran (1990) Mean values of the recorded data were compared by using the least significant differences (L.S.D 0.05).

Table 1: Mechanical and chemical analyses of the experimental soil

Mechanical analysis:	
Sand %	92.3
Silt %	3.1
Clay %	4.6
Chemical analysis:	
$CaCo_3$ %	1.3
Organic matter %	0.3
EC. mmhos/cm^2	0.3
pH	7.4
Soluble ppm	8.1
Available P (ppm)	3.0
Available K (ppm)	19.8

Fig. 1 : Location of the study area (solid red).

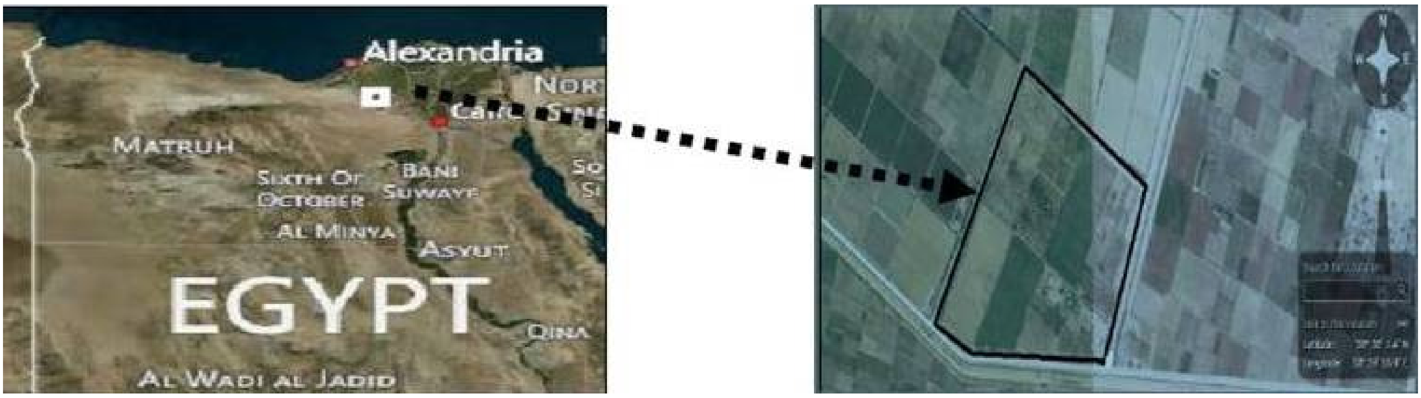

Fig. 2 : Location of the Experimental Farm in El Nubaria Region, Egypt

Table 3 : Chemical characteristics of irrigation water.

pH	EC (dSm^{-1})	Cations and anions (meq/L)								SAR %
		Cations				Anions				
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	
7.32	**0.39**	**0.9**	**0.5**	**2.4**	**0.2**	**--**	**0.1**	**2.7**	**1.3**	**2.8**

Results and Discussion

Effect of hydrogel and organic fertilization on two wheat cultivars grown under water stress conditions

Date shown in Table (4) showed the third order interaction, irrigation requirement x plant cultivars x soil amendments as well as the mean value of each single factor. The highest values for the studied characters i.e. plant high, number of spikes/m^2, spike length, number of grains spike, 1000 grains weight (g), grain yield (Ton/fed.), straw yield (Ton/fed.) and biological yield (Ton/fed.) was recorded in Misr-1 cultivar irrigated with 2500 M^3/ fed. (100% IR) and treated with (compost + hydrogel) as soil amendments. The same table also showed that, decreasing the amount of irrigation water from 2500 to 1875 m^3/fed./season caused a significant reduction in all the previous studied characters. Regardless IR and soil amendments, Misr-1 surpass Sakha-94 in all the previous characters. Moreover, addition of (compost + hydrogel) significantly enhanced wheat production. Similar results were obtained by Badran and Moustafa (2014). In this regards, Seleiman (2011) found that increasing number of irrigations up to five increased grain yield (ton.ha^{-1}), biological yield (ton.ha^{-1}), harvest index, number of spikes/m^2, number of grains/spike and 1000-kernel weight but significantly decrease protein content. Moreover, Zhang *et al.,* (2005) stated that, in the arid region, the formation of spring wheat yield mainly depended on the amount of water supply. Dawood and Kheiralla (1994) stated that irrigation treatment had highly significant effect on plant height. It could be noted that average height of plants was described with imposing more water stress on plant. They added that wheat cultivar (Sakha 69) showed an increase of 13.5% spike/m and 14.8% for the grain yield/fad.

Table 3 : Effect of hydrogel and organic fertilization on two wheat cultivars grown under water stress conditions (combined data of two 2016-2017 and 2017-2018 seasons).

Irrigation requirement	Cultivars	Treatments	Plant height cm	Number of spikes/m^2	Dry weight of spikes g/m^2	Spike length (cm)	Number of grains /spike	1000 grains weight (g)	Grain yield Ton/fed.	Straw yield Ton/fed.	Biological yield Ton/fed.
100% IR	Misr-1	Control	88.36	451.36	492.31	10.65	60.23	45.36	1.83	2.42	4.25
		Organic	95.64	493.56	509.84	12.10	64.70	51.55	2.21	2.72	4.93
		Hydrogel	96.35	479.53	506.30	12.12	63.14	50.50	2.12	2.74	4.86
		Org+Hgel	98.73	504.82	537.87	13.12	66.55	52.81	2.38	2.81	5.19
	Sakha-94	Control	84.35	388.65	401.32	9.60	48.35	37.15	1.65	2.35	4.00
		Organic	89.78	415.86	431.68	9.78	53.25	42.41	2.10	2.45	4.55
		Hydrogel	88.69	405.81	421.55	10.17	52.85	41.34	2.05	2.53	4.58
		Org+Hgel	90.25	422.75	447.77	11.87	57.10	43.50	2.29	2.81	5.10
75% IR	Misr-1	Control	86.35	366.54	384.25	9.55	46.85	38.02	1.26	1.79	3.05
		Organic	91.23	401.20	405.69	9.84	51.23	42.02	1.64	1.87	3.51
		Hydrogel	92.36	387.36	400.36	10.55	53.70	41.52	1.56	2.00	3.56
		Org+Hgel	92.87	429.58	444.36	10.98	55.69	43.65	1.73	2.15	3.88

	Sakha-94	Control	80.22	335.21	341.87	9.12	48.65	35.26	1.13	1.92	3.05
		Organic	86.28	369.54	379.87	9.35	49.80	40.25	1.49	2.06	3.55
		Hydrogel	86.30	358.47	357.65	9.87	50.78	39.50	1.46	2.16	3.62
		Org+Hgel	87.28	388.36	398.36	10.89	53.76	41.54	1.65	2.36	4.01
LSD 5%			NS	12.36	14.23	NS	1.25	1.12	0.06	0.08	0.12
Irrigation requirement mean											
IR mean	100% IR		91.52	445.29	468.58	11.18	58.27	45.58	2.08	2.60	4.68
	75% IR		87.86	379.53	389.05	10.02	51.31	40.22	1.49	2.04	3.53
LSD 5%			NS	10.32	15.36	0.31	1.35	2.30	0.09	0.11	0.23
Cultivars mean											
Cultivars mean	Misr-1		92.74	439.24	460.12	11.11	57.76	45.68	1.84	2.31	4.15
	Sakha-94		86.64	385.58	397.51	10.08	51.82	40.12	1.73	2.33	4.06
LSD 5%			4.36	15.65	18.36	NS	NS	NS	NS	NS	NS
Treatments mean											
Treat. mean	Control		84.82	385.44	404.94	9.73	51.02	38.95	1.47	2.12	3.59
	Organic		90.73	420.04	431.77	10.27	54.74	44.06	1.86	2.27	4.13
	Hydrogel		90.92	407.79	421.47	10.68	55.12	43.21	1.80	2.36	4.16
	Org+Hgel		92.28	436.38	457.09	11.72	58.27	45.37	2.01	2.53	4.55
LSD 5%			NS	17.68	NS	NS	1.42	NS	0.11	NS	0.18

Effect of hydrogel and compost on chl. a+b (mg/g fresh weight) in two wheat cultivars grown under water stress conditions

Data presented in Fig (3) show the effect of each single factor regardless the other two factors. However, decreasing irrigation requirement from 100 to 75% significantly decrease chl. a+b content in both cultivars with superiority to Misr-1. On the other hand, addition of (compost + hydrogel) as soil amendment recorded the highest values for chl. a+b ontent as compared with the other treatment. As for the third order interaction, IR x cultivars x soil amendment, Fig. (2) showed that, the highest chl. a+b content amounting to (6.95) was recorded in Misr-1 cultivar treated with (compost + hydrogel) under (100 % IR). On the other hand, the least content of chl. a+b amounting to (4.85) was recorded in Sakha-94 cultivar treated with (hydrogel) under 75% IR. Similar results were also reported by Raza *et al*., (2012). In this regards, Reddy *et al*. (2004) pointed out that the photosynthetic rate in higher plants decreases more rapidly than respiration rate with increased water stress, since an early effect of water reduction in leaves is usually a partial or complete stomatal closure which markedly decreasing the movement of carbon dioxide into the assimilating leaves and reducing the photosynthetic rate up to ten times, according to the amount of water removal and the sensitivity of the plant. Higher leaves chlorophyll contents is significantly correlated with photosynthesis as well as productivity (Teng *et al*., 2004). It has been reported in many studies that under drought stress Photosynthesis exhibit direct relationship with wheat grain production because less stomata opening frequency and low amount of CO_2 fixation lead to reduction in photosynthetic amount (Bilal *et al*. (2015). Moreover, Farquhar *et al*. (1989) stated that, higher concentration of chlorophyll is essential for plants because it depicts the low quantity of photo-inhibition of the photosynthetic which prevents the carbohydrates losses and eventually enhances growth. Ashraf *et al.* (1994) reported that drought stress reduced concentration of chlorophyll b more than chlorophyll a.

Effect of hydrogel and compost on proline content of two wheat cultivars grown under water stress conditions

Data presented in Fig (5) show the effect of each factor regardless the other two factors. However, decreasing irrigation requirement from 100 to 75% significantly increased proline content in both cultivars with superiority to Misr-1. On the other hand, addition of compost as soil amendment recorded the highest values for proline as compared with the other treatment. As for the third order interaction, IR x cultivars x soil amendment, Fig. (6) showed that, the highest proline content amounting to (23.23) was recorded in Misr-1 cultivar treated with (compost) under water stress (75% IR). These results are in a harmony with those obtained by Nikju (2017). In this concern, Tatar and Gevrek (2008) have considered proline as an osmotolerant whose accumulation in the cell system suggests its active involvement the scavenging of free radicals thus by reducing damage caused by various kinds of oxidative stress. Moreover, Proline is well known to occur extensively in higher crop plants and accumulates in higher concentration in response to different abiotic environmental stresses specially drought stress (Kavi-Kishore *et al*., 2005). Under water deficit condition proline perform many functions like act as osmolyte contribute s in the maintenance of membrane and protein, scavenging free radicals. Furthermore, after the severe damage of stresses proline contents provide adequate reducing agents that assist in mitochondrial oxidative phosphorylation and production of adenosine triphosphate (ATP) for revival from damages of various stresses (Hare *et al.,* 1998).

Effect of hydrogel and compost on crude protein content of two wheat cultivars grown under water stress conditions

Data presented in Fig (7) show the effect of each factor regardless the other two factors. However, decreasing irrigation requirement from 100 to 75% significantly increase CP contents in both cultivars with superiority to Sakha-94. On the other hand, addition of (compost + hydrogel) as soil amendment recorded the highest values for CP as compared with the other treatment As for the third order interaction, IR x cultivars x soil amendment, fig (8) showed that, the highest chl. a+b content amounting to (12%) was recorded in Sakha-94 cultivar treated with (compost + hydrogel) under (75 % IR). On the other hand, the least content of chl. a+b amounting to (10.43%) was recorded in Misr-1 cultivar treated with (hydrogel) under 100% IR. Similar results were also reported by Akhter *et al*. (2004).

Effect of hydrogel and organic fertilization on WUC (kg grains / m^3) of two wheat cultivars grown under water stress conditions

Data presented in Fig (9) show the effect of each factor regardless the other two factors. However, decreasing irrigation requirement from 100 to 75% insignificantly increased WUE in both cultivars with superiority to Misr-1. On the other hand, addition of (compost + hydrogel) as soil amendment recorded the highest values for WUE as compared with the other treatment. As for the third order interaction, IR x cultivars x soil amendment, fig (10) showed that, the highest WUE amounting to (0.92) was recorded in Misr-1 cultivar treated with (compost + hydrogel) under water stress (75% IR). These results are in a harmony with those obtained by Badran and Mustafa (2014). The obtained results reveal that WUE expressed as a kg grains / m^3 of water consumed significantly affected by the different water treatments. WUE may also vary due to soil conditions, agricultural practices including fertilization, and atmospheric factors. Generally, highest water use occurs at the point of highest biomass production (Cox *et al*., 2002). Mesbah (2009) reported that Irrigation wheat plants at 1350 m3/fad achieved a significant increase for the WUE value and it was decreased with increasing irrigation water amount up to 1850 m3/fad ranged from 1.42 and 1.18 and 1.30 to 1.13 kg/m^3 water in the first and second season, respectively.

Drought indices of Misr-1 and Sakha-94 wheat cultivars

Data in Table (5) showed Drought indices data of Misr-1 and Sakha-94 wheat cultivars. However, Misr-1 recorded higher values for Yp, Ys, MP, GMP and STI, which indicating higher yield, while Sakha-94 recorded higher values for TOL and SSI. Which indicate less drought tolerace Several selection indices have been performed to identify drought resistant genotypes considering grain yield potential in both favorable and stress conditions (Bahar and Yildirim, 2010) such as mean productivity (MP) and tolerance (TOL) (Hossain *et al*., 1990), stress susceptibility index (SSI) (Fischer and Maurer, 1978), geometric mean productivity (GMP) and stress tolerance index (STI) (Fernandez, 1992).

Genotypes with low SSI values were considered as stress tolerant, because such genotypes showed a lower reduction in grain yield under stress environment compared to non-stress environment. SSI has been widely used by researchers to identify sensitive and resistant genotypes (Winter *et al*., 1998). In this concern, Gutteri *et al*., (2001) indicated that SSI >1 indicates above-average susceptibility while SSI <1 indicates below-average susceptibility to drought stress. In respect to current study, the lowest value of SSI belonged to Misr-1(0.96), whereas Sakha-94 (1.04) was less to;erant. However, SSI was evaluated based on yield ratio of each variety in stressed conditions to non-stressed conditions as compared with the proportion in the total varieties.

STI was more useful index in order to select favorable cultivars under stressful and stress-free conditions (Moghaddam and Hadi-Zadeh, 2002). Genotypes had high values of STI showed high MP and GMP indices but lower values of SSI and TOL. Therefore, selection based on STI will result in high yielding tolerant genotypes (Fernandez 1992). Results in Table 5 showed that Misr-1 had the highest value (0.81) followed while Sakha-94 recorded (0.77). Sanjari (2000) considered that drought stress tolerance index (STI) is appropriate to select the high yielding and drought tolerant wheat genotypes. On conclusion, results of drought tolerance indices, can be considered for identifying and classifying the tolerant genotypes. Higher values of both MP and GMP Mean can not provides genotypes with increased yield in stress conditions.

Based on these results wheat varieties Misr-1 was found having higher stress tolerance under drought conditions, also better yield potential under normal irrigation conditions of in this district.

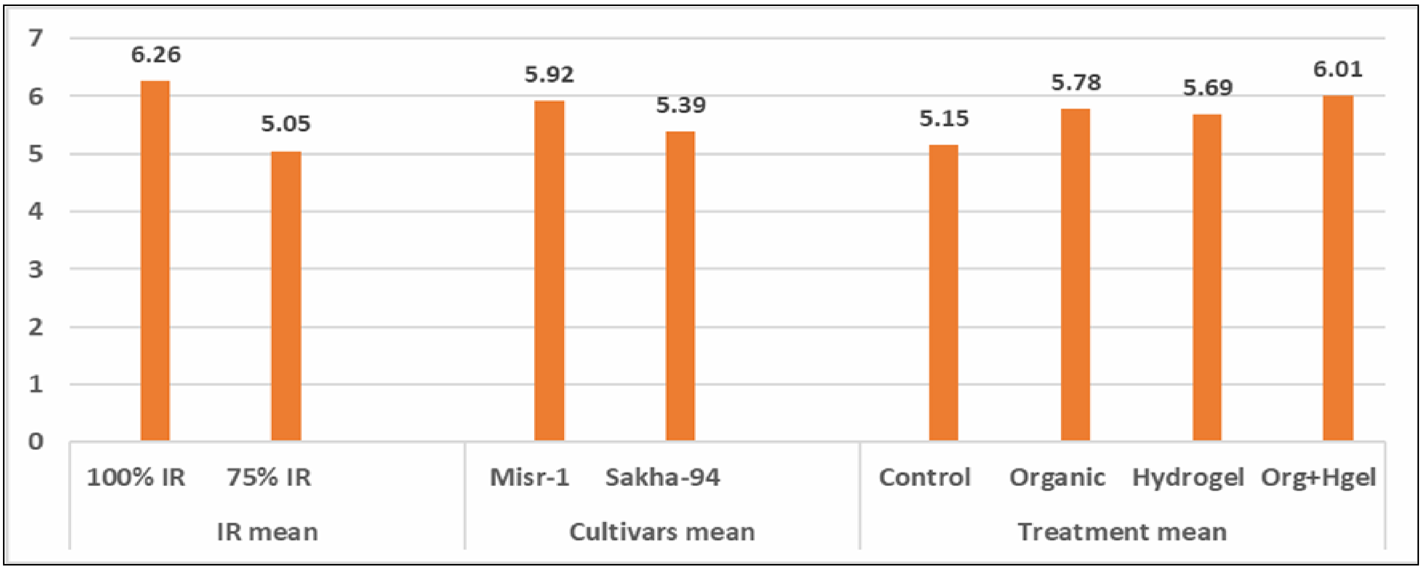

Fig. 3 : Effect of irrigation requirements, cultivars and soil amendment on chl. a+b (mg/g fresh weight) content LSD 5% IR: 0.35, Cultivars: 0.29 and Soil amendment: 0.41

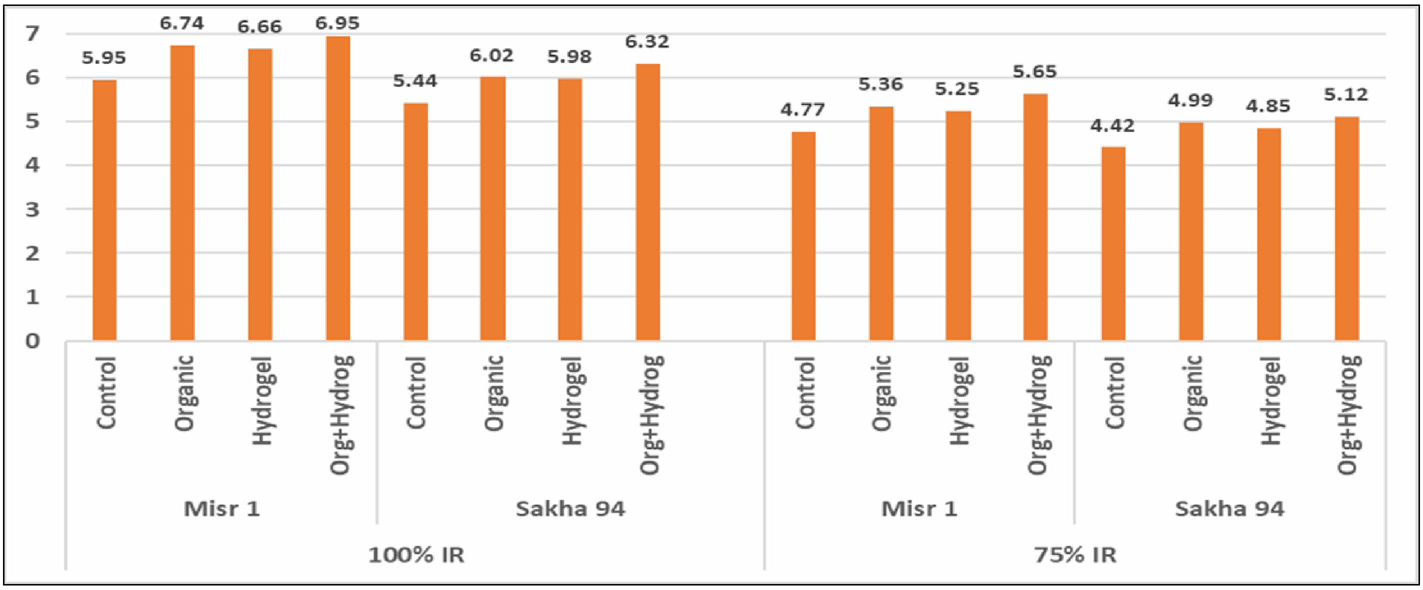

Fig. 4 : Effect of interaction between irrigation requirements x cultivars x soil amendment on chl. a+b (mg/g fresh weight) LSD 5%: 0.53 (combined data of two 2016-2017 and 2017-2018 seasons).

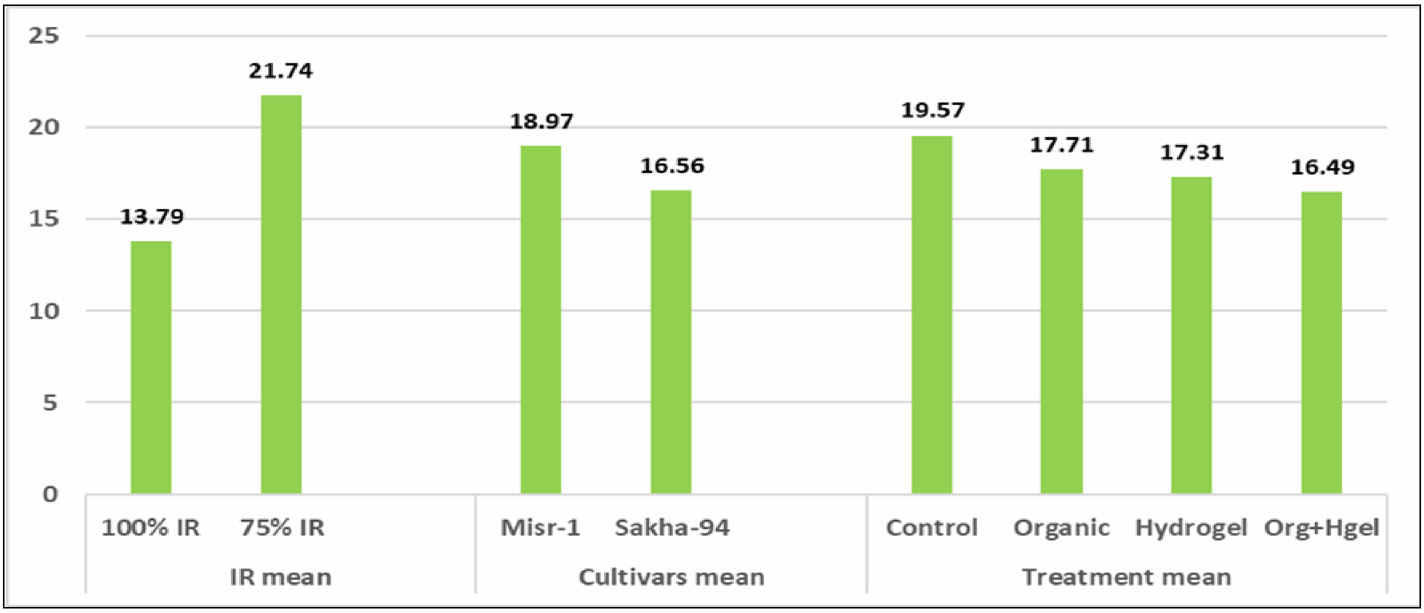

Fig. 5 : Effect of irrigation requirements, cultivars and soil amendment on proline content (µm/g fresh weight) LSD 5% IR: 1.32, Cultivars: 1.24 and Soil amendment: 1.14 (combined data of two 2016-2017 and 2017-2018 seasons).

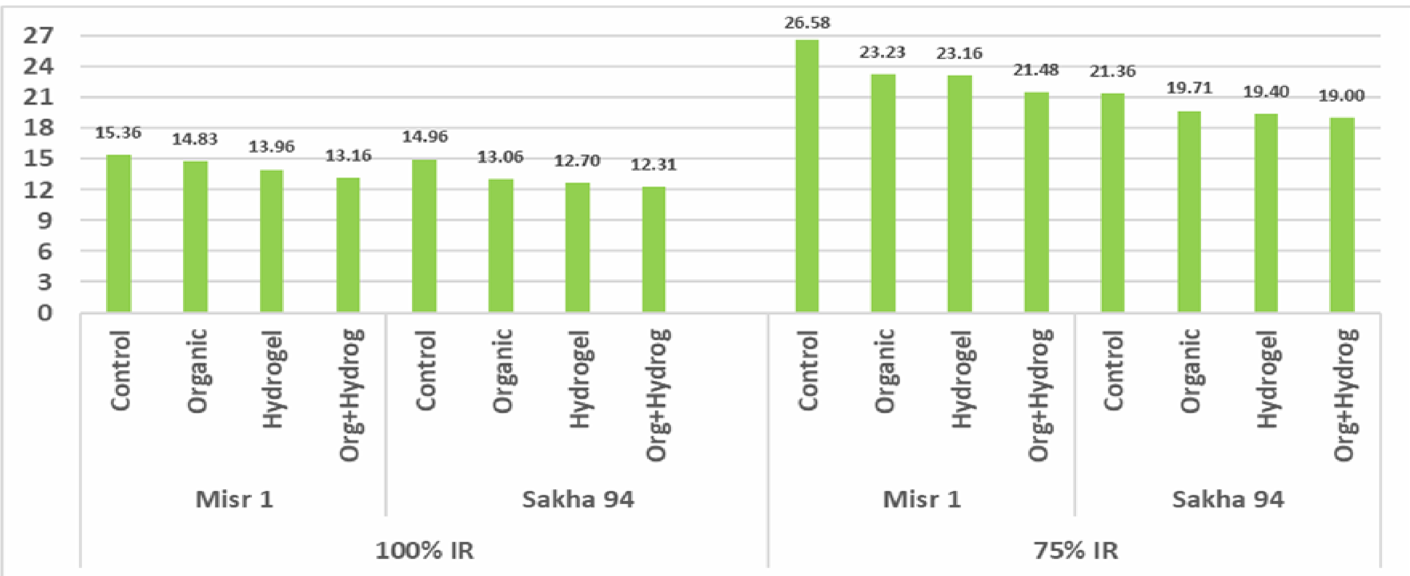

Fig. 6 : Effect of interaction between irrigation requirements x cultivars x soil amendment on proline content (µm/g fresh weight) LSD 5%: 2.35 (combined data of two 2016-2017 and 2017-2018 seasons).

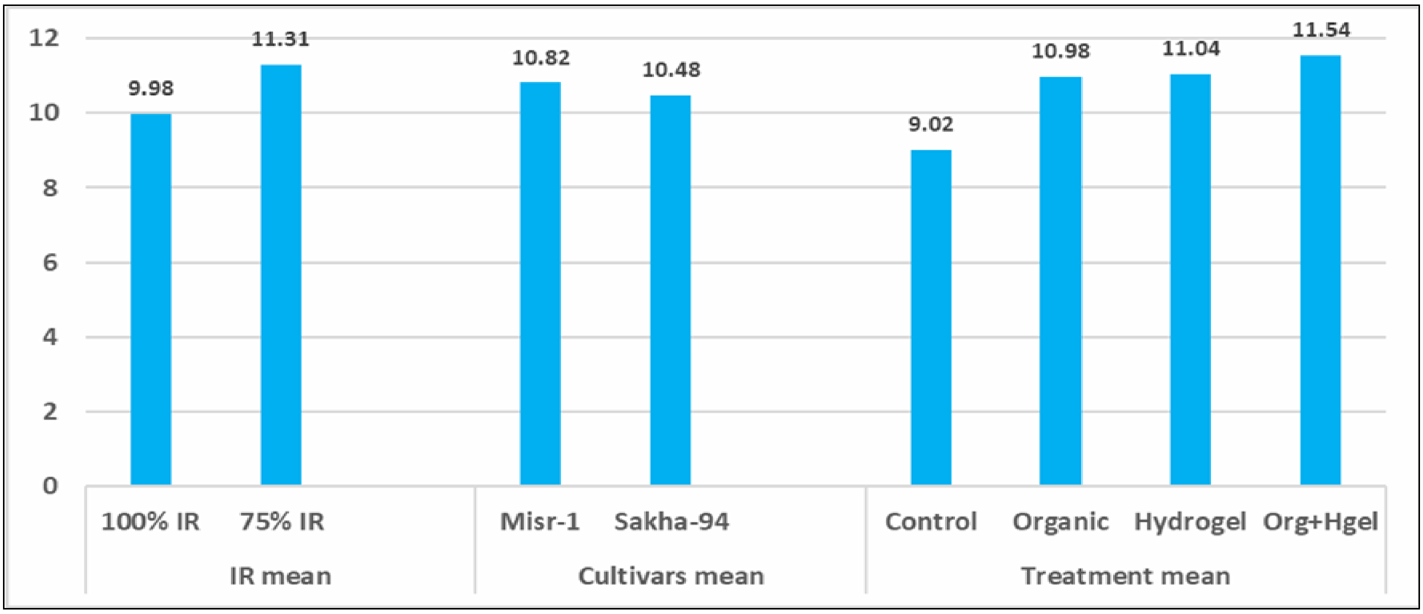

Fig. 7 : Effect of irrigation requirements, cultivars and soil amendment on crude protein content LSD 5% IR:0.62, Cultivars: 0.60 and Soil amendment: 0.63 (combined data of two 2016-2017 and 2017-2018 seasons).

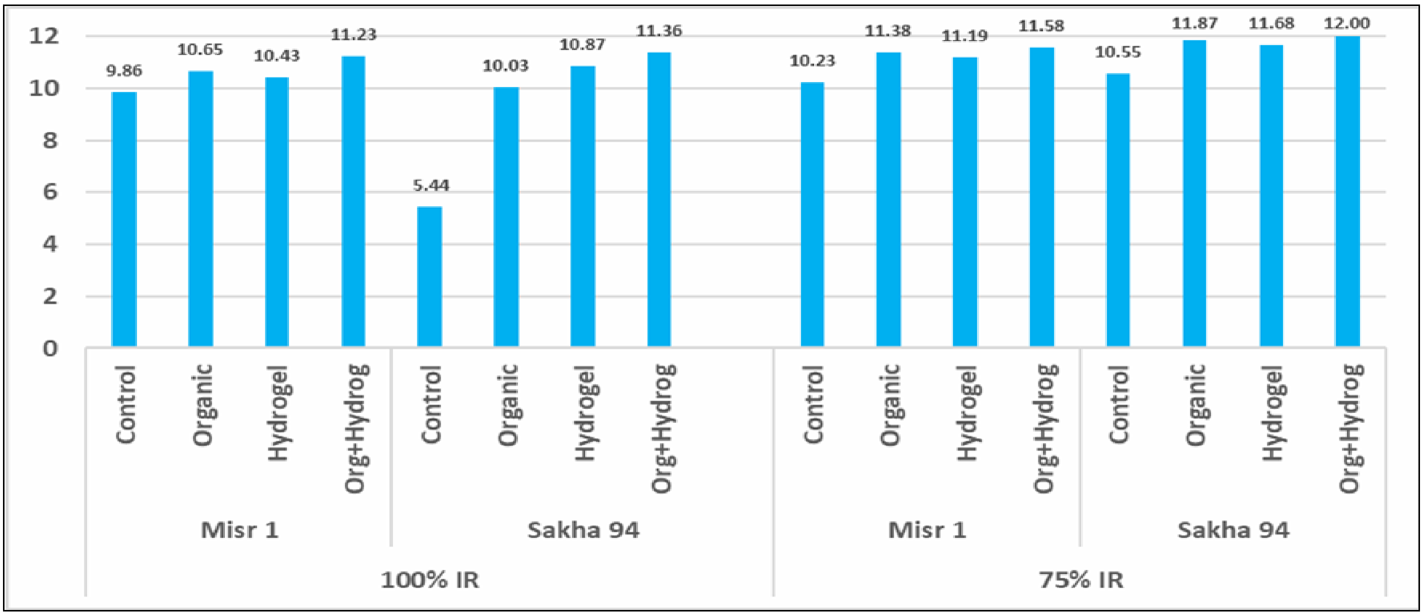

Fig. 8 : Effect of interaction between irrigation requirements x cultivars x soil amendment on crude protein content (LSD 5%: 1.22) (combined data of two 2016-2017 and 2017-2018 seasons).

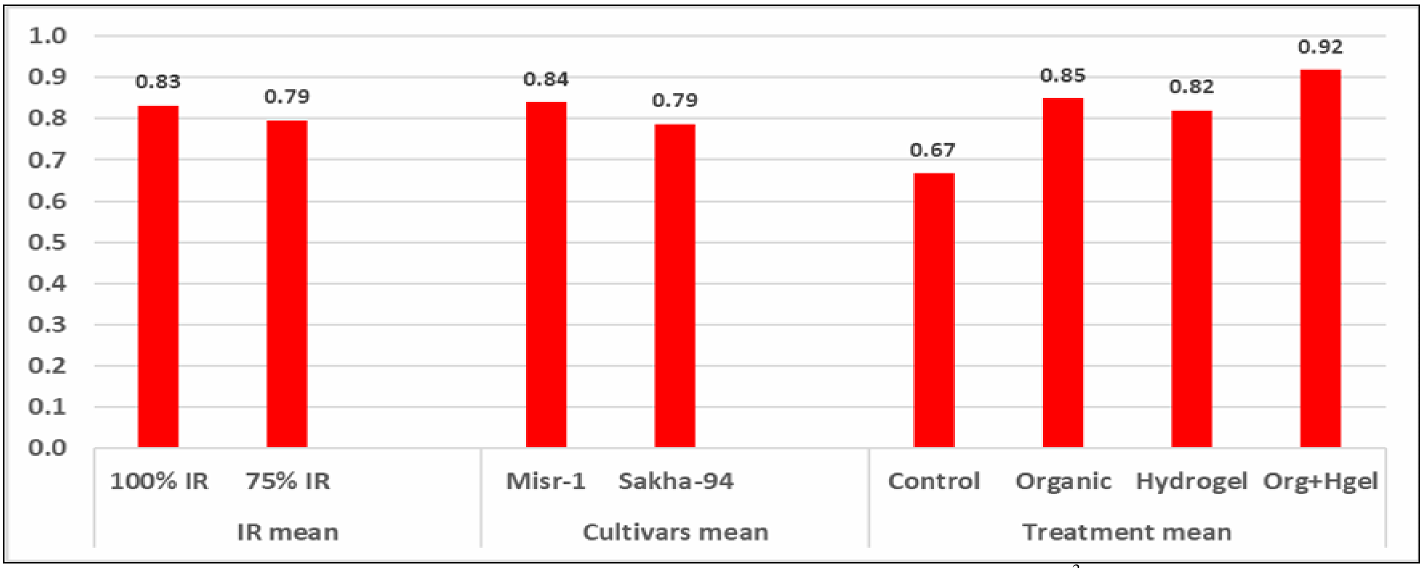

Fig. 9 : Effect of irrigation requirements, cultivars and soil amendment on WUE (kg grains / m^3) LSD 5% IR: NS, Cultivars: NS and Soil amendment: 0.06 (combined data of two 2016-2017 and 2017-2018 seasons).

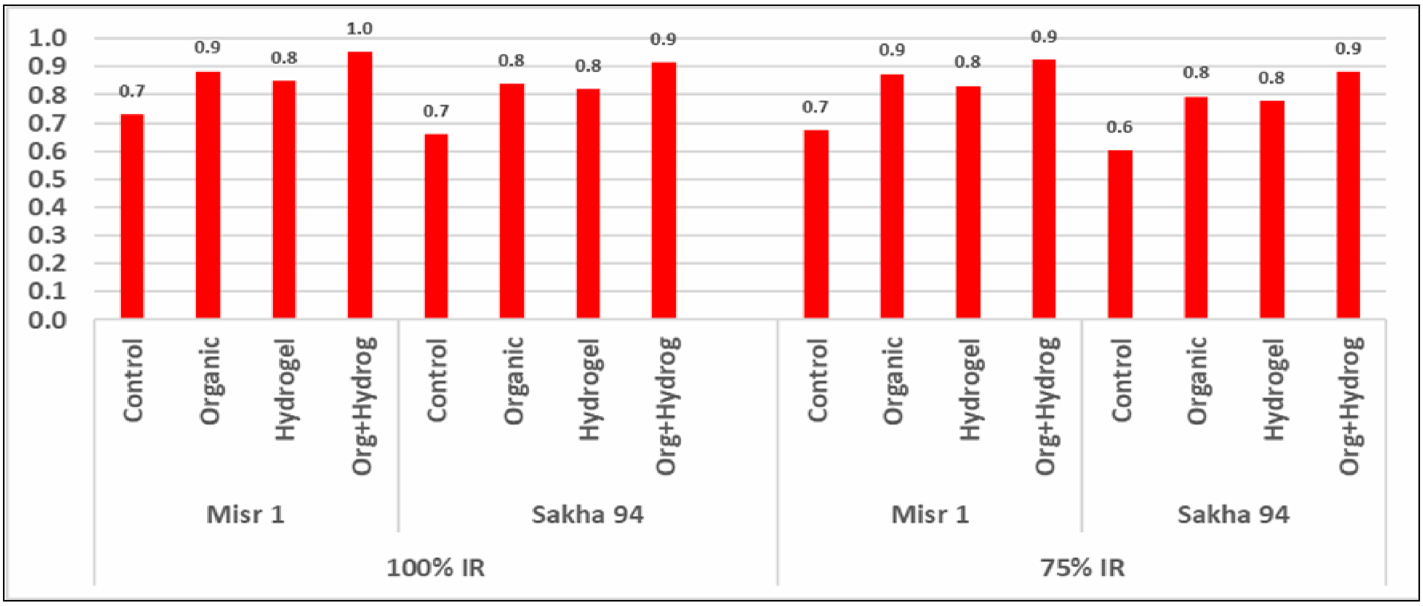

Fig. 10 : Effect of interaction between irrigation requirements x cultivars x soil amendment on WUE (LSD 5%: 0.09) (combined data of two 2016-2017 and 2017-2018 seasons).

Table 5 : Drought indices of Misr-1 and Sakha-94 wheat cultivars

Drought indices	Misr-1	Sakha-94
yield under normal condition (Yp)	2.14	1.55
yield under stress condition (Ys)	2.02	1.43
Mean cultivars productivity (MP)	2.08	1.49
Geometric cultivar productivity (GMP)	2.16	1.11
Tolerance index (TOL)	0.59	0.61
Stress susceptibility index (SSI)	0.96	1.04
Stress tolerance index (STI)	0.81	0.77

Yp= yield under normal condition, Ys= yield under stress condition, MP =mean productivity, GMP = geometric of mean productivity, TOL= tolerance index, SSI= stress susceptibility index, STI=stress tolerance index.

Conclusion

Wheat (*Triticum aestivum* L.) being a most vital cereal crop has always been of area of interest to plant breeders. Since several years, numerous efforts have been made to boost up its productivity under various conditions especially under drought stress condition. This research depicted that drought stress caused extensive decline in all the studied attributes performance. So there is need to explore several helpful attributes and to minimize the harmful effect of water stress on wheat crop productivity through development of genotype having drought tolerant and better performance as well as addition of some soil amendments can help in combating drought stress.

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