Response of six genotypes of wheat (*Triticum aestivum L.*) to water stress under field conditions.

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Abstract. *The field study was conducted at Al-Muradia Research Station, located southwest of the center of Babylon province, at latitude 30 32 North and longitude 39 44 East during the winter season 2019-2020 in a sedimentary soil with a silty loam texture to study the ability to tolerate water stress in the vegetative and reproductive stages of six genotypes from Bread wheat (Triticum aestivum L.).This experiment was applied with The Randomized Complete Block Design (RCBD), split-plot arrangement, and three replications. The water stress treatments (S0) were set as the control treatment without stress and (S1) the stress treatment in the vegetative stage and (S2) treatment of stress in the , in the main plot, while the sub-plot included six genotypes of bread wheat, namely (Hawler 4, Abu Ghraib, Auras, Hewler 2, Nucal and S384).The water was blocked by covering the experimental units to prevent the arrival of rain, as well as cutting off irrigation in stages (between tillering and elongation).and (between flowering and filling the grains), the regular irrigation of the experimental units was conducted after depleting 50% of the available water in the soil, As for the water stress factors, they were left without irrigation for one irrigation and depletion of 75%-80% of the available water, and depending on the moisture description curve of the experimental soil. It was found from the study that the control treatment S0 excelled in the average number of spikes per* m^2*and did not differ significantly from S2, as it was significantly excelled in the average grain yield, while the stress treatment S1 excelled in the weight of 1000 grains and the number of grains in the spike frome S2, and both of them did not differ significantly from the control treatment. The study concluded that the genotype (S384) excelled on the grain yield and gave 4.18 tons.ha*$^{-1}$*, followed by the genotype Nucal which gave 4.056 tons.ha-1.The genotype Nnucal recorded high values for the average number of spikes, which amounted to 367.9 spikes.m*$^{-2}$*. It did not differ significantly from the genotype S384, which gave an average of 367.3 spikes.m*$^{-2}$*. The increase in the number of spikes had a great relationship with the high values of the tillers of the distinct genotypes, so it reached for the genotype Nucal 402.4 tillers .m*$^{-2}$* and for the Auras genotype 400.2 tillers.m*$^{-2}$*,While the genotype S384 gave the highest value of 403.6 tillers.m*$^{-2}$*, the other yield components in the study were not affected by the distinct genotypes, with the exception of genotype S384, which was the highest in the average number of grains in the spike by 43.62 grains.spike*$^{-1}$*.*

Keywords: water stress, *vegetative stage*, *reproductive stage, tillers.m*$^{-2}$.

1.INTRODUCTION

Wheat is at the forefront of global food security crops because of its nutritional importance, as it constitutes a food source for more than 35% of the world's population [1]. The steady increase in the population requires also a steady increase in production, at a percentage not less than 1.6%, to keep pace with the demand for this important crop[2,3] The cultivated areas and yield rates in Iraq have witnessed a remarkable growth in recent years, as the average grain yield reached 3.304 tons / hectare, but it did not rise to the international average[4].Iraq suffers from great environmental, economic, and political challenges, including the agricultural sector's consumption of a large proportion of its fresh water and the continuous shortage of water supplies due to neighboring countries, especially Turkey and Iran, from which the Tigris and Euphrates rivers and their tributaries originate, which coincides with global climate changes and global warming, as well as the lack of proper management of water resources. And the lack of application of modern technologies in irrigation, which poses a great danger to the cultivation of crops in central and southern Iraq, especially wheat, whose cultivation, especially in the irrigated areas of Iraq, requires the application of many field practices that depend on research and studies[5], foremost of which is the cultivation of genetic structures tolerant to water stress and the study of Its performance and in various stages of growth under water stress conditions and screening operations on it, provided that the development of tolerance to water stress goes along with the development of the outcome of these genotypes, which is the basis adopted in studies The purpose of this research was to study drought stress effect in *vegetative and reproductive stages* on some bread wheat genotypes, so that responses of these genotypes can be evaluated in resistance to water stress.

2.MATERIALS AND METHODS

2.1.Experiment location and soil properties

The field experiment was conducted for cultivating the wheat crop (*Triticum aestivum* L.) during the winter season 2019-2020 in the field experiments of the Muradia Agricultural Research Station dedicated to wheat research and belongs to the Babylon Agriculture Directorate. Some physicochemical properties were estimated according to standard methods [6] and as in Table 1.The soil water retention capacity was also estimated by estimating the moisture content of samples taken from the same previous depths and on the basis of dry weight and according to standard methods [7] and at stress 0, 33, 100, 500, 1000 and 1500 kPa, which were graphically represented in the soil moisture description curve Fig. 1 .The soil available water content was calculated from the difference in moisture content at field capacity and wilting point.Soil, analyzes were conducted in the Central Laboratory for Soil, Water and Plant Analysis of the College of Agricultural Engineering Sciences/University of Baghdad.

Table 1. Some physical and chemical properties of soil for depth 0-0.40 m

values	Units	Traits

		Soil Separators	
320	g.kg^{-1} soil	sand	
600	g.kg^{-1} soil	silt	
80	g.kg^{-1} soil	clay	
silty loam	-	texture	
1.51	.Mg.m^{-3}	bulk density	
4.79	ds.m^{-1}	Electrical conductivity (soil paste extractor)	
7.12	-	pH	
214.3	mg.kg^{-1}	availability Potassium (Ammonium Acetate)	
11.35	mg.kg^{-1}	availability phosphorous	
98.3	mg.kg^{-1}	availability Nitrogen	
29.77	kPa	33	moisture tensile
29.2		100	
24.9		500	
17.89		1000	
13.2		1500	

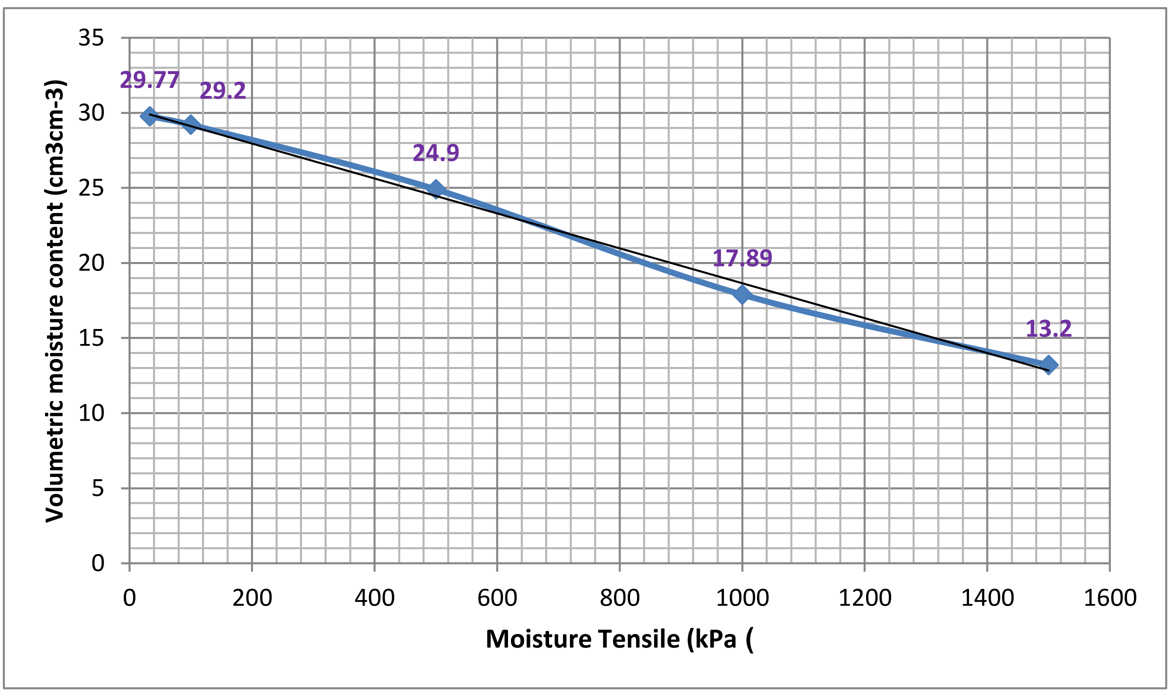

Figure (1) The moisture tensile curve

2.2.Land preparation, experimental design, and treatments

The experimental land was tillage by two orthogonal tillage with a Moldboard plow and smoothed with disc harrows, and it was divided on the basis of the application of the Randomized Complete Block Design (RCBD) , in the arrangement of split-plot, and with three replications[8], 4 m intervals were left between the replicates and 1 m intervals were left between the main units within the replicate and they were well aligned to limit the movement of water between the experimental units, and the experimental parameters were:

control treatment S0 (without stress) irrigation and re-irrigation after depleting (50%) of the available water and the two water stress treatments S1 Water blocking in the vegetative stage between branching and elongation (GSZ32-GSZ21) and S2 Water blocking in the reproductive stage between flowering and grain filling (GSZ79- GSZ61), where these treatments were applied to the main plot, while the sub plot included six genotypes of bread wheat, which are Hawler 4, Abu Ghraib, Auras, Hawler 2, Nucal, S384

2.3.Agricultural operations

The seeds of wheat cultivars were sown in sub plot , which included twelve lines for each plot of 3 m length and 0.25 m distance between one line and another on 12/12/2019 at a seeding rate of 140 kg/ha. Phosphorous fertilizer was added in an amount of 100 kg P per hectare of triple superphosphate fertilizer P2O5 45 when preparing the land,As for nitrogen, it was added in an amount of 200 kg N per hectare in the form of urea fertilizer (46%N) and in two equal batches, the first at planting and the second at the elongation stage (GSZ31)[9] . The weed was controlled manually as needed. The plants were harvested on May 4th, 2020.

2.2.1.control treatment

The irrigation process was conducted using Euphrates River water with an electrical conductivity of 2.7 ds.m-1 and using a water pump installed on its discharge pipe with a meter to measure the amounts of water added for each experimental unit and at each irrigation.After depleting 50% of the available water according to the equation 1 of:[10]

$$d = (\theta_{fc} - \theta_w)D \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

d = depth of water added (mm(

θ_{fc} = = volumetric humidity at field capacity

θ_W =volumetric humidity before watering

D = depth of perfusion

The soil moisture content was continuously monitored using Soil Moisture Meter (model: PMS-714-Lutron Electronic Enterprise CO;LTD.) after calibration and by gravimetric method for measuring soil moisture. After the moisture percentage has been determined upon reaching a point where 50% of the ready water has been exhausted, the panels are re-irrigated by adding water to each panel according to the quantity that is determined according to equations (1) and (2) [11] to reach a moisture content close to the field capacity .-

$$w = a \times \ell b \left[\frac{\%Pw^{f.c} - \%Pw^{w}}{100} \right] \times \frac{D}{100} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

W = the volume of water to be added during irrigation (m3.(

a = irrigated area (m^2)

= Bulk Density (Mg. m^3)

Pwf.c = percentage of soil moisture based on weight at field capacity (after irrigation)

Pww = percentage of soil moisture based on weight before irrigation.

D = Depth of soil to be irrigated (m)

2.2.2 .water stress treatment

The process of irrigating the plot of the two water stress treatments (S1 and S2) was conducted with regular irrigation (as in S0) until reaching the growth stage at which it is intended to withhold water from the plants to cause the process of water stress. The growth stages were determined using the Zadoks et al. (1974) scale. Upon reaching the required growth stage after depleting 50% of the available water, the treatment became at the beginning of entering the required water blocking stage. A cover was placed to prevent rain from arriving using a polyethylene cover (agricultural nylon 2 mm thick) and installed on iron structures made for this purpose.

The plants were covered from above only and the sides were left open to allow air to enter and allow the water vapor from the evaporation process to diffuse into the atmosphere.Upon reaching the point at which more than 75-80% of the prepared water has been depleted, which corresponds to moisture stress of about 900-800 kilopascals, the blocking period has ended, which is approximately equivalent to cutting one irrigation or a little more, and for the two blocking treatments (S2, S1) compared to the S0 tratments. The cover is lifted and the plants are irrigated by adding an amount of water equal to the amount added to the panels that are not exposed to blocking when doing periodic irrigation for S0 treatment and according to the depletion of the moisture content of 50% of the available water.

2.3.Studied traits

The number of tillers per m^{-2}.

The number of tillers in 1 m2 for each secondary experimental unit was calculated by random method.

- Components of the yield

The number of spikes per m^{-2}.

According to the number of spikes in 1 m2 for each secondary experimental unit.

The number of grains in the spike

The number of grains per spike was determined by calculating the average of fifteen grains of spikes that were randomly selected from each secondary experimental unit.

- 1000 grain weight gm

1000 grains were obtained by using a seed counter and weighing them.

Grain yield ton ha^{-1}

Grain weight per square meter was calculated and converted to ton ha^{-1}

3.Results

3.1.Number of tillers per square meter (tillers.m^{-2})

Table 2 showed that the water stress caused a significant decrease in the number of tillers in the vegetative stage, as the average was 344.1 tillers. m^{-2} that is, a percentage decrease of 9.90% compared to the control treatment, while there was no significant differences between S1 and S2.. These results are in agreement with [13] that the number of tillers decreases more in the vegetative stage of wheat plants subjected to water stress compared to the late stages of growth (the reproductive stage). It was also noted from the same table that the genotype S384 gave the highest mean of the phenotype, which reached 403.6 tillers. m^{-2}There were no significant differences between it and the genotypes Nucal and Auras, while the genotype Hawler2 recorded the lowest average for the trait, which amounted to 288.2 tillers. m^{-2}. These results agree with[14] found about the difference in the number of tillers in wheat plants according to the genotypes.

Table2. Effect of genotypes, water stress, and the interaction between them on the number of tillers.m^{-2}

Average	Water stress			Genotype
	S2	S1	S0	
354.20	369.00	328.00	365.70	Hawler 4
369.30	389.70	330.00	388.00	Abu Ghraib
400.20	416.00	367.30	417.30	Auras
288.20	299.00	266.00	299.70	Hawler 2
402.40	410.70	388.70	408.00	Nucal
403.50	414.30	384.00	412.30	S384
-	383.10	344.00	381.80	Arithmetic average
LSD 0.05				
21.10	water stress			
31.90	Genotype			
n.s	Interaction			

3.2.Number of spikes per m^{-2}

Table 3 indicated that the water stress caused a significant decrease in the number of spikes.m^{-2} in the vegetative stage, as it gave an average of 305.8 spikes m^{-2}, i.e. a percentage decrease of 11.72% compared to the control treatment, while there was not significant effect of the water stress in the stage proliferative compared to the control treatment. This study agrees with [15] who show the effect of water stress in reducing the number of spikes in the vegetative stage. Wheat plant was not significantly influenced by this trait in the later stages of the plant's life. Table 3 shows that the genotype Nucal recorded the highest average for the traits of the number of spikes m^{-2}., which amounted to 367.9 spikes m^{-2}. which did not differ significantly from the genotype S384, while the genotype Holier 2 recorded the lowest average of the trait, which amounted to 261.4 spikes. m^{-2}. These results agree with[16] who showed that there is a discrepancy in the genotypes of wheat in the characteristic of the number of spikes due to the different to genotypes branching (the ability to produce tillers)

Table 3. Effect of genotypes , water stress and the interaction between them on the number of spikes per square meter

Average	Water stress			Genotype
	S2	S1	S0	
322.20	334.30	294.30	338.00	Hawler 4
351.90	365.00	322.70	368.00	Abu Ghraib
325.00	343.30	287.30	344.30	Auras
261.40	277.70	231.00	275.70	Hawler 2
367.90	378.00	346.00	379.70	Nucal
367.30	375.70	353.30	373.00	S384
	345.70	305.80	346.40	Arithmetic average
LSD 0.05				
.1510	water stress			
.3230	Genotype			
n.s	Interaction			

3.3.The number of grains per spike (grain .spike $^{-1}$)

Table 4 showed that there was no significant influence of water stress on the number of grains per spike, while it indicated a significant effect of the genotypes of the trait to the genotype S384 excelled by giving it an average of 43.62 grains. Abu Ghraib, Hawler 2 and Nukal did not have any significant differences whth S384, While the genotype Auras recorded the lowest average for the trait, which amounted to 34.75 grains. $Spike^{-1}$ and there were no significant differences between it and the genotype Hawler 4 .These results agreed with the findings of [17] that the number of grains in the spike of wheat plants decreased significantly, and that this decrease differed according to the genotype used in the study.

Table 4. Effect of genotypes , water stress and the interaction between them on the number of grains in the spike

Average	Water stress			Genotype
	S2	S1	S0	
36.99	39.17	36.00	35.8	Hawler 4
43.53	41.80	41.95	46.8	Abu Ghraib
34.75	33.11	36.68	34.46	Auras
42.74	40.49	48.00	39.73	Hawler 2
42.00	40.86	42.61	42.55	Nucal
43.62	42.46	42.07	46.33	S384
	39.65	41.22	40.95	Arithmetic average
LSD 0.05				
n.s	water stress			
3.24	Genotype			
n.s	interaction			

3.4.The 1000 grain weight (g)

Table 5 indicates that there is no significant effect of water stress in the vegetative stage of this trait, while the effect was clear in the reproductive stage, as it gave an average of 27.31 g, which is equivalent to a percentage decrease of 18.40% compared to the control treatment. Therefore, the productive stage was influenced by water stress more than the vegetative stage by giving a percentage amounted to (18.74%). These results agree with[18] regarding the impact of water stress on wheat plants and the difference in the effect according to the growth stage. Table 5 clears that the Hawler 4 genotype recorded the highest average for the trait, which amounted to 38.63 g, while the Nucal genotype recorded the lowest in the average of the trait by recording it an average of 27.98 g. There were no significant differences between it and the Abu Ghraib genotype. These results agree with[19] who found that the difference in weight of 1000 grains according to the genotypes.

Table 5. Effect of genotypes, water stress, and the interaction between them on the weight of 1000 grains (g)

Average	Water stress			Genotype
	S2	S1	S0	
38.63	33.02	39.65	43.22	Hawler 4
28.58	23.92	30.45	31.37	Abu Ghraib

30.32	**24.10**	**37.00**	**29.87**	**Auras**
27.42	**25.43**	**34.02**	**22.81**	**Hawler 2**
27.98	**27.27**	**27.69**	**28.98**	**Nucal**
32.18	**30.13**	**32.87**	**33.55**	**S384**
	27.31	**33.61**	**31.63**	**Arithmetic average**
LSD 0.05				
1.89	**water stress**			
2.08	**Genotype**			
3.56	**interaction**			

3.5.Grain yield (ton.ha^{-1})

Table 6 shows that the water stress caused a reduction in the grain yield in the vegetative and reproductive stage, where it recorded a decrease in the vegetative stage by3.57 ton.ha^{-1} corresponding to a percentage decrease of 11.33% for this stage compared to the control treatment. In the reproductive stage, the arithmetic mean amounted to 3.16 tons ha^{-1}, which is equivalent to a reduction percentage of 21.36% compared to the control treatment, and the results showed that the vegetative stage was characterized by being affected less than reproductive stage by the water stress, and the difference between them was 11.30%. These results agree with[20,21] who showed that water stress caused a decrease in grain yield witch it related to the growth stage that the plant was going through, and that the effect was in the reproductive stages more than in the vegetative stages. Table 6 shows that the S384 genotype recorded the highest average for the trait, which amounted to 4.18 tons.ha^{-1} and there were no significant differences between it and the Nucal genotype, while the Hawler 4 genotype recorded the lowest averages for the trait amounted to 3.14 tons.ha^{-1} and There are no significant differences between it and the Hawler 2 genotype. These results agree with[22] who found that grain yield in wheat plants is influenced by the stability of the genotype.

Table 6. Effect of genotypes, water stress, and the interaction between them on the grain yield (ton ha^{-1})

Average	**Water stress**			**Genotype**
	S2	**S1**	**S0**	
3.14	**2.56**	**3.07**	**3.81**	**Hawler 4**
3.35	**2.84**	**3.40**	**3.82**	**Abu Ghraib**
3.46	**3.04**	**3.46**	**3.90**	**Auras**
3.30	**2.90**	**3.31**	**3.69**	**Hawler 2**
4.06	**3.68**	**4.08**	**4.40**	**Nucal**
4.18	**3.95**	**4.08**	**4.51**	**S384**

	3.16	3.57	4.02	Arithmetic average
LSD 0.05				
0.20	water stress			
0.18	genotype			
n.s	interaction			

4.Discussion

This study showed that the genotype S384 showed more tolerance to water stress than the rest of the genotypes included in this study and in the vegetative and reproductive stages, as genetic tolerance often has a close relationship with the quantity of grain yield obtained under water stress conditions[23] . The S384 genotype showed the highest value for the average of grain yield by recording the lowest yield in the vegetative stage compared to the control treatment as shown in Table 6, the reason was genotype maintained the highest number of grains per spike as shown in Table 4, which is one of the components of the grain yield Principal[24] . The second component of the yield in which this genotype was distinguished is the number of spikes per m2 as shown in Table 3, which is related to the number of tillers as shown in Table 2 that a single plant gives to the genotype per unit area and the ability of these tillers to complete their life cycle and give them spikes[25]. The phenomenon of death of tillers is related to the phenomenon of competition between them for the natural elements of growth (water, light, nutrients). Reducing any of these elements to levels below the minimum requirements of a single plant leads to competition between the tillers of the same plant (internal competition) or between the tillers Neighboring plants per unit area (external competition), so die tillers that do not get their requirements of these elements. Here, water availability or lack thereof was one of the most important elements on which this study was based. This agreed with a number of studies[26,27]

5.Conclusions

The water stress tolerance for the studied genotypes was confirmed by recording them a lowest percentage of reduction in the yield, and this was observed by the genotype S384. The number of grains per spike is the most influential component of the crop on the ability of the S384 genotype to tolerate water stress. The genotypes differed in their tolerance to water stress according to the growth stage, and S384 has highest tolerance to water stress in the reproductive and vegetative stages. The effect of water stress in the reproductive stage was greater than its effect in the vegetative stage of the studied traits.

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