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Full Length Research Paper

Growth and Water use efficiency in wheat genotypes grown under water stress condition

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The pot culture experiment was conducted in net house at NIA Tandojam, to observe growth and water use efficiency (WUE) in wheat genotypes grown under water stress. Four wheat genotypes (DH-13, DH-18, DH-20 and LU-26s) were tested along with local drought tolerant check (Chakwal-86). Drought treatment was imposed one month after sowing, by holding the irrigation only @ 30% field capacity. While control pots were irrigated regularly to maintain soil moisture at 100% field capacity.Experiment was terminated at crop maturity and growth and yield observations were recorded. Water use efficiency (WUE) was calculated on the basis of total amount of water use to increase per unit biomass per unit area i.e. (g/m$^{2/}$mm).The results showed that under water stress conditions, the genotype DH-18 performed well. Studies on water use efficiencies (WUE,) showed that under water stress condition the genotype DH-20 use water more efficiently to produce maximum biomass (1.65 g/m$^{2/}$mm), followed by DH-18(1.58 g/m$^{2/}$mm). Better response of DH-18 under drought is encouraging for its recommendation in drought prone areas.

Keywords: Water use efficiency, Wheat; Genotype; Drought; Growth yield;

INTRODUCTION

Wheat (Triticum aestivum) is among the main cereal crops of Pakistan, It is grown in an area of about 9.04 million hectares and the production is about 23.86 million tons (Anonymous, 2012). Pakistan is among the10 largest wheat growing countries of the world. The growing conditions are quite favors its cultivations throughout Pakistan. According to Colleman and Faruqee (1996), it is grown by 80% of the farming community and cover about 40% of the cropped area of Pakistan. It is reported that about 95 % of irrigated areas in Pakistan contribute towards total national wheat production and the remaining 5 % areas contribute by rain-fed (Anonymous, 2011). However its production had significantly affected due to various biotic and abiotic stresses. Among them water stress is serious threat to its production. According to Kramer (1980), the worldwide losses in crop yield from water stress exceed the losses from all other classes combined. Even a temporary drought can cause a substantial loss in crop yields and sometimes can amount to many million dollars (Moseley, 1983).Apart from the world best irrigation system in Pakistan, large area under wheat cultivation is depends on rainfall. In the recent decade less availability of water had affected its production significantly.

For improving crop production under limited water regime there is a need to select suitable genotypes having effective use of water. According Ejaz and Ahmed, (2010), under limited supply of water, there is less water absorption at root level, thus reducing transpiration rate due to stomatal closer which limits the intake of CO_2 by leaves and thereby reducing photosynthetic rate which results in reduce biomass production. The enhancement of biomass production under drought stress can be achieved primarily by maximizing soil water capture, while diverting the largest part of the available soil moisture towards stomatal transpiration. Bierhuizen and Slatyer (1965) studied interrelations between growth, yield and transpiration characteristics of cotton leaves. They concluded that plant growth is directly proportional to transpirational water use, but inversely dependent on atmospheric vapour pressure deficit. Yield under water-limited conditions is also dependent on genetic factors (e. g. capacity for developing longer roots under stress) controlling yield potential, and/or drought resistance,

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and/or WUE (Blum, 2005). Therefore the development of genetically improved varieties need to be evaluated for their growth performance and water use efficiency (WUE) under limited water supply, to get maximum output from these high yielding genotypes. It is therefore the present study was carried out to compare the growth and water use efficiency (WUE) of some newly developed wheat genotypes under water stress conditions.(figure 1)

MATERIAL AND METHODS

The study was conducted in pot house at Nuclear Institute of Agriculture (NIA), Tandojam. Four wheat genotypes (DH-13, DH-18, DH-20 and Lu-26s) were tested along with local drought tolerant check (Chakwal-86). The soil used was silt loam and river sand (mixed in 1:1 ratio). Each pot was filled with equal weight of soil (10kg).five plants were maintained in each pot after germination. There were two treatments T1= Control @100% field capacity and T2 drought @ 30% field capacity. Drought treatment was imposed one month after sowing, by holding the irrigation only @ 30% field capacity. While control pots were irrigated regularly to maintain soil moisture at 100% field capacity. All the treatments were arranged in randomize manner using completely randomize design (CRD), replicated thrice. Experiment was terminated at crop maturity. Growth observations recorded were Plant height (cm), Plant biomass (gm), Spike length (cm), No: of Grains/ plant, Grain weight/ plant and 100 grain weight. Water use efficiency (WUE) was calculated on the basis of total amount of water use to increase per unit biomass in different wheat genotypes per unit area (i.e. $g/m^{2/}mm.$), based on Ehdaie & Waines, (1994), method, using following equation.

WUE ($g/m^{2/}mm$) = Biological Yield/Unit area/ Total water used

The data was subjected to analyze statistically for analysis of variance (ANOVA) and duncan's Multiple Range Test (DMRT), using Mstat-C computer programme (Anonymous, 1991)

RESULTS

Growth Performance

Growth performance of wheat genotypes grown under water stress conditions are presented in table 1.There was decrease in plant height under water stress. Under water stress condition the mean decrease was 26 %. Maximum plant height was observed in genotype DH-13, showing 19.6 % relative decrease. On the other hand the relative decrease in genotype DH- 20 was comparatively high (i.e. 30%). Effect of water stress was also significant on biomass production, showed average decrease of 67.5 %. Minimum decrease was observed in DH-18 followed by DH-13, showing 63 and 64 % decrease, respectively. The tillering capacity in wheat genotypes was also decreased under water stress conditions. The average decrease was 36 % under water stress environments. The genotype DH-18 showed minimum decrease (i.e. 25%). However, the differences among the individual genotypes were statistically at par. It was also observed that all the three DH lines comparatively had less decrease than drought tolerant check i.e. Chakwal-86. Trend in case of spike length was also similar to other growth parameters. The average decrease was only 14% under water stress condition. The mean spike lengths under normal and water stress conditions were 9.6 and 8.22 cm, respectively. Among the individual genotypes, the genotype Chakwal-86 (drought tolerant check) showed maximum spike length (i.e. 8.7cm) followed by DH-18 (8.5 cm) and DH-13 (8.2cm).

There was almost 50% decrease in grain numbers under water stress. The mean values for number of grains in two environments (normal and water stress), was 50, and 25 grain/ plant, respectively. All the DH lines are showing less than 50% decrease, with only 37% reduction in grain numbers in DH-18 followed by DH-13 and DH-20, having 47 and 48% relative reduction, respectively. The low availability of water also resulted in lower grain wt/ plant of all the wheat genotypes tested. Under drought stress all the genotype showed > 50 % reduction in grain weight having mean reduction of 57%. Among the individual genotypes, maximum grain weight/ plant under water stress was observed in genotypes DH-18 and DH-20 having grain weight (i.e. 0.9 g each).

Low availability of water in the growing medium, also resulted in decrease seed index (100 grain wt.), values in wheat genotypes. The relative decrease among the wheat genotypes was ranged between 9 to 23 %, with LU-26s having only 9 % decrease in seed index. However all the genotypes had < 50% decrease under water stress. The relative decrease due to water stress in drought tolerant check Chakwal -86 was only 2%, showing least reduction than the other tested genotypes.

b) Water use efficiency (WUE) in wheat genotypes

Wheat genotypes were evaluated for their water use efficiencies (WUE) under water stress condition. To observe the WUE, control pots were irrigated regularly to maintain the moisture at 100% field capacity, whereas water stress treatment was given by maintaining irrigation at 30% field capacity. Wheat genotypes responded varyingly under stress conditions. Under control conditions the average water consumed by wheat genotypes throughout the growing season was about 293 mm/ m^2 and the average biomass produced was 724 g/ m^2, showing an overall WUE of about 2.48 $g/m^{2/}mm$. Under water stress conditions there was

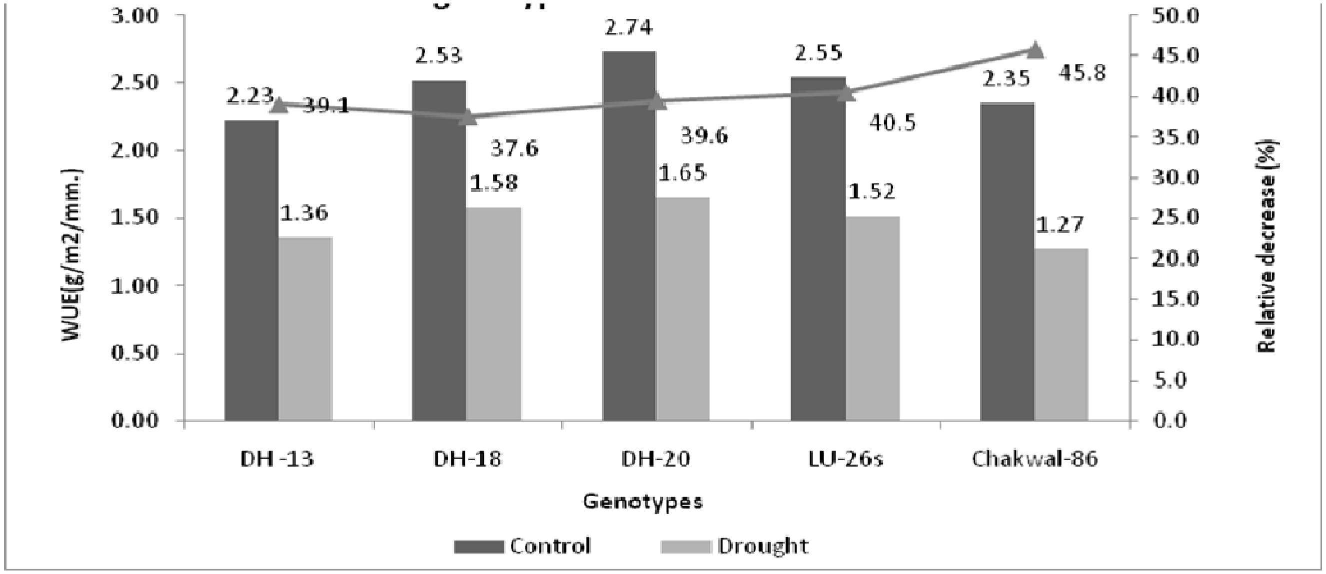

Figure 1: water use efficiency (g/m^2/mm.) by different genotypes under water stress

Table 1. Growth performance of some wheat genotypes under water stress

Genotypes	Plant height (cm)		Plant Biomass (g)		Productive Tillers		Spike length (cm)		No of grains/ spike		Grain weight/ plant (g)		Seed Index (100 grain wt.) (g)	
	Cont.	Drought	Cont.	Drought	Cont.	Drought	Cont.	Drought	Cont.	Drought	Cont.	Drought	Cont.	Drought
DH-13	67.0	53.9 (19.6)	6.4	2.3 (64.3)	1.8	1.3 (29.6)	9.5	8.2 (14.3)	41.1	21.9 (46.7)	2.2	0.8 (63.6)	4.5	3.57 (20.7)
DH-18	71.1	50.6 (28.8)	6.9	2.6 (62.6)	1.3	1.0 (25.0)	9.4	8.5 (9.6)	47.3	29.8 (37.0)	1.8	0.9 (50.0)	3.7	2.86 (22.7)
DH-20	68.3	48.1 (29.6)	7.7	2.4 (69.1)	1.6	1.0 (37.5)	9.0	7.8 (13.2)	56.8	29.6 (47.9)	1.9	0.9 (52.6)	3.4	3.02 (11.2)
LU-26s	67.9	51.2 (27.4)	7.3	1.9 (67.2)	1.9	1.0 (43.3)	10.1	7.9 (11.6)	55.8	19.8 (57.3)	1.5	0.5 (66.7)	2.9	2.63 (9.3)
Chakwal-86	68.2	49.5 (24.6)	7.2	2.4 (74.5)	2.0	1.1 (46.4)	9.8	8.7 (21.2)	51.0.	21.8 (64.5)	2.2	0.9 (59.1)	4.3	4.21 (2.1)
Mean	68.5	50.7 (26.0)	7.1	2.3(64.3)	1.8	1.3 (29.6)	9.6	8.22 (14.0)	50.4	24.6 (50.7)	1.9	0.8 (57.9)	4.0	3.26 (18.5)
LSD (0.05)	6.225		1.291		0.3797		0.7398		16.28		0.3300		1.244	

Values in parenthesis are the relative decrease over control.

reduction in biomass in all the wheat genotypes. The average water consumption under water stress condition was 159 mm/ m^2 to produce average biomass of about 234 g/ m^2 with average WUE of 1.5 g/$m^{2/}$mm.

Water requirements and the water use efficiencies (WUE) of the individual wheat genotypes were also varied among the individual genotypes. Water use efficiency (WUE) of individual wheat genotypes estimated under water stress condition showed 37 to 46% decrease. All the DH lines showed higher WUE than the drought tolerant check (Chakwal-86) and LU-26s. Maximum WUE was observed in genotype DH-20 followed by DH-18 (i.e. 1.65 and 1.58 g/$m^{2/}$mm, respectively), however the relative decrease was bit less in genotype DH-18 (37.6%) as compared to DH-20 (39.6%). Minimum WUE was observed in Chakwal-86, showing 45% decrease. WUE of LU-26s was also high than the check variety (i.e.Chakwal-86) showing 40.5% decrease.

DISCUSSIONS

Better growth and yield performance of wheat crop mainly depend on better utilization of water by a particular genotype in a limited supply of water. Unavailability of sufficient water is the main hindrance for wheat production in Pakistan. In the present investigations, there was an overall decrease in growth performance in wheat genotypes under water stress. Decrease in growth components also resulted in decreased grain yield of all the wheat genotypes. According to Ping et al, (2011), grain yield is a product of several contributing factors and can be estimated on the basis of performance of various components. Wheat plant height is a reliable form of growth indicators to reflect plant drought resistance (Yan and Yan, 2013) and a major agronomic metric in wheat growth and development (Donald and Hamblin, 1976).

There was decrease in plant height under water stress, showing about 26% decrease in plant height. Maximum plant height was observed in genotype DH-13, with 19.6 % decrease. Decrease in plant height due to water stress was also observed by Mirbahar et al. (2009). Decreased plant height in response to water stress might be due to decrease in relative turgidity and dehydration of protoplasm, which is associated with a loss of turgor and reduced expansion of cell and cell division (Arnon, 1972; El-Kholy and Gaballah, 2005) water stress also suppressed dry matter accumulation (Yan and Yan, 2013). Decreased availability of water also affected on tillering capacity of wheat genotypes, showing almost 36% relative decreases in productive tillers. The genotype DH-18 showed minimum decrease (i.e. 25%) in number of tillers under water stress. It is assumed that the number of tillers per plant has direct contribution towards grain yield. It means decrease in number of productive tillers will simultaneously decrease the grain yield in wheat (Khan and Naqvi,2011). Mobilization of photosynthetic material from leaves to grain also effects on grain yield.

According to Bayoumi et al (2008) under drought conditions the availability of current assimilates for extending seed filling will often be severely reduced. In such circumstances, a genotype that can mobilize reserves of carbohydrates in the stem will be able to maintain better seed filling. On the other hand Karim et al. 2000., Baque et al. 2006 and Guinata et al. 1993, had the opinion that the decreased grain yield is associated with the reduction in spike length, number of spikelets and number of grains/ spike. Comparatively less decrease in spike length and number of grain were observed in genotypes DH-18. Maximum grain yield was observed in DH-18, which might be due to its less reduction in other yield contributing factor. i.e. spike length and number of grains/ spike. Saini and Aspinall 1981 reported that water deficit at anthesis affects yield by reducing the number of grains per ear rather than ear number or grain size. In the present studies, the stress was imposed throughout the growing season (i.e. @ 30% field capacity), therefore the reduction in grain yield might be the as a results of all the growth factor, indicating the severity of drought in all the growth stages. Similar were the opinion of (Khan and Naqvi, 2011). While Solomon et al. (2003) and Ozturk and Aydin (2004) reported about 79.7 and 65.5% reductions in grain yield, when water stress was imposed either at earlier stages of growth or at grain formation, respectively. They further reported that the reduction in grain yield under water stress was due to variability of yield component. According to Iqbal et al., (1999), the decrease in grain weight may be due to disturbed nutrient uptake efficiency and photosynthetic translocation within the plant (Iqbal et al., 1999) that produced shriveled kernels due to hastened maturity. The shortage of moistures, forces plant to complete its grain formation in relatively lesser time (Riaz and Chowdhrv, 2003).

Water use efficiency estimated under two water regimes showed comparatively higher values under control (@ 100% F.C) than under water stress (@ 30% F.C.) in all the wheat genotypes. Variation among the individual genotypes exists due to water stress. According to Blum (2005), the genotypic variation in WUE under limited water regimes is affected more by variation in water use (WU) rather than by variation in the biomass. Bierhuizen and Slatyer (1965) studied interrelations between growth, yield and transpiration characteristics of cotton leaves. They concluded that plant growth is directly proportional to transpirational water use. Regression analysis in the present studies showed significantly positive relations (Table 2.) between WUE, Plant biomass (R^2 = 0.927), No. of grains (R^2 = 0.798) and grain wt. (R^2 = 0.796). Positively significant correlation between grain yield and WUE were also reported earlier (Shamsi and Kobraee, 2013).

Table 2: Regression studies (R2) among different growth parameters and Water Use Efficiency

S.#	Parameters	WUE
1	Plant height	0.659
2	Plant Biomass	0.927
3	Productive Tillers	0.536
4	Spike length	0.428
5	No. of Grains	0.798
6	Grain wt	0.796

The genotype DH-20 had maximum values (1.65 $g/m^{2/}mm$) for WUE under water stress conditions followed by DH-18 (i.e. 1.58 $g/m^{2/}mm$). Similar were the observation of Alireza and Habibi, (2013), who also reported higher biomass in the genotypes having high WUE. The results, with respect to individual genotypes, are in agreement with the above findings in case of DH-18 and DH-20, where comparatively higher values for biomass/ plant were observed in both genotypes (i.e. 2.6 and 2.4 g) along with the higher values of WUE (i.e. 1.58 and 1.65 $g/m^{2/}mm$), respectively). While the hypothesis did not follow the above findings in Chakwal-86, where in spite of having high values for biomass and grain yield, the genotype comparatively had minimum WUE under water stress condition (1.27 $g/m^{2/}mm$). Reduced WUE might be due to reduced transpiration or reduced evapo-transpiration as reported by Kobata et al. (1996), in rice and in sorghum (Tolk and Howell, 2003). On the other hand Alireza and Habibi, (2013) have the opinion that this genetic differences among cultivars could be due to differences in transpiration system performance or assimilation performance of these genotypes.

Minimum reduction in biomass, number of tillers, spike length, number of grains, grain yield and high WUE in DH-18 in response to drought may be ranked it best among the tested wheat genotypes. Better response of DH-18 under drought is encouraging for its recommendation in drought prone areas of Pakistan.

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