Original Article

Journal of Aridland Agriculture 2015, 1: 31-35
http://scienceflora.org/journals/index.php/jaa/
doi: 10.19071/jaa.2015.v1.2934

Screening *Triticum aestivum* L. genotypes for drought stress tolerance under arid land conditions

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Received: 27.12.2015
Accepted: 31.12.2015
Published: 31.12.2015

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ABSTRACT

Screening of drought tolerant genotypes for arid land cultivation is the best approach to avoid yield losses as breeding and selection are time taking techniques. A current experiment was planned to evaluate late sown wheat cultivars potential for drought tolerance and adaptability in Jeddah region, KSA. Four wheat cultivars (YocoroRojo [YR], Faisalabad-2008, F-10 and L-7096) were tested against drought stress applied as (75% and 50%) of total crop water requirement. A 100% water requirement was also applied as a control. Data regarding crop growth stages, growth, grain yield, and yield contributors were tested using MSTAT-C. Drought stress significantly decreased all growth and yield traits except harvest index, and the effect of water stress was the most severe where 50% of the total water requirement was applied. Both studied crop growth stages (days to complete tillering and days to complete 50% heading) were also affected to applied water stress and effect was a more pronounced for days to complete 50% heading. Studied cultivars responded variably for different growth and yield traits. Cultivar YR took minimum days to complete tillering and heading while L-7096 presented the highest plant height and dry biomass accumulation. Faisalabad-2008 reported maximum values for grain yield and yield contributors except spike length that was maximum in YR. Based on the field evaluation, it is concluded that Faisalabad-2008 produced significant results for growth and yield traits among studied cultivars and can be successfully grown in arid land conditions under limited water supplies.

KEY WORDS: Arid land, cultivars screening, drought stress, Jeddah, late planting

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a cereal grain, originally from the Levant region of the near East and Ethiopian Highlands, but now cultivated worldwide is one of the first plants cultivated by mankind. In 2012, world production of wheat was 651 million tons, making it the third most produced cereal after maize (*Zea mays* L.) and rice (*Oryza sativa* L.). It is currently second to rice as the main human food crop and ahead of maize (Chen *et al*., 2012). Wheat provides 19% of world's food energy and 21% of protein intake (FAO, 2011). An essential staple food, which fulfills the need of more than 1/3rd of world's population and known to be severely affected by drought stress (Chaves and Oliveira, 2004). China, India, Russia, USA, France, Canada, Germany, Pakistan, and Australia are the major wheat producing countries (FAO, 2011).

Currently, stress is affecting about 99 million hectares of wheat cultivation in developing countries and at least 60 million hectares in developed countries (Rajaram, 2001). A significant increase (an estimated 50%) in grain yield of major crop plants such as rice, wheat and maize is required to fulfill the food supply requirements for the projected population by 2050 (Godfray *et al*., 2010).

Environmental stresses are divided into two major groups: Biotic and abiotic. Biotic stresses include various pathogenic microorganisms, weeds, fungi, and other predators. Sources of abiotic stress include air pollutants, extreme temperatures (including freezing), drought, high light intensity, salinity, and mechanical damage (Vickers *et al*., 2009). Among the various abiotic stress conditions, water deficit is the most devastating factor (Vickers *et al*., 2009). Drought is a non-uniform phenomenon that influences plants differently depending on the development stage at the time of its occurrence adversely affects physiology, morphology, growth and yield traits of wheat (Hossain and Da Silva, 2012). Water stress significantly altered the internal water status by decreasing relative water content, water potential, and osmotic potential of wheat that consequently decreased the turgor potential, closure of stomata, and decrease in cell enlargement and growth (Jaleel *et al.*, 2008; Akram, 2011; Seghatoleslami *et al.*, 2008). Plant drought tolerance is a highly complex trait that involves multiple genetic, physiological, and biochemical mechanisms (Cushman and Bohnert, 2000; Erdei *et al.*, 2002; Mattana *et al.*, 2005).

Delay in planting wheat crop, due to harsh weather conditions in Jeddah region have also contributed in wheat yield decline. Evaluation of new cultivars for short duration, efficient water use, and drought resistance characteristics are needed for economic crop production. The current experiment was planned to evaluate late sown wheat genotypes growth and yield potential to different levels of drought stress under arid land conditions of Jeddah region.

MATERIALS AND METHODS

To evaluate the drought tolerance potential of late sown four wheat cultivars (YocoroRojo [YR], Faisalabad 2008, F-10 and L-7096) under arid land conditions, a field experiment was performed at Agronomic Research Station of King Abdulaziz University, KSA. Drought stress was applied as 75% and 50% of total water requirement. Full water requirement was applied as control. The experiment was laid out in randomized complete block design with split plot arrangement and three replications. Water requirement was applied in main plots while subplots were consisted of cultivars. Late plantation was executed at December 20th, 2013.

Crop Husbandry

About 1 month prior to planting, soil was cultivated twice with tractor mounted plough and kept free for next 2 weeks. After that soil was ploughed again followed by planking, drip irrigation system was installed to apply irrigation treatments. Crop water requirement was calculated and applied according to the 100%, 75% and 50% of the total. Wheat was planted with hand driven pore and line to line distance was maintained at 22 cm. fertilizers (N:P:K) were applied as 120:100:80 in the form of diammonium phosphate, urea and potassium chloride. Manual weeding was performed twice at 20 and 30 days after sowing. No pesticide was used for in insect or disease. Agro-climatic data of the experimental site is presented in Table 1.

Data Recording

Wheat growth and yield data were recorded to estimate cultivar response to applied levels of drought stress for late plantation under arid land conditions. Plant height was recorded with measuring scale, while days taken to complete tillering and 50% heading were counted to differentiate cultivar for their sensitivity to drought stress based on their vegetative and reproductive growth stages. Cultivar difference in term of leaf area index, dry matter accumulation and capacity for productive tillers were also estimated. Wheat yield and yield contributors (spike length, grains per spike, 1000 grain weight, and harvest index) were also recorded. Spike length was measured as plant height has recorded while grain weight and yield was recorded using electric balance. Forced dry air oven was used to get dry biomass accumulation.

Table 1: Agro-climatic data of the experimental site

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
December	32.06	12.54	94.5	20.8	0
January	31.48	11.09	99.8	25.13	15
February	33.2	12.02	98.34	16.35	0
March	35.76	11.86	96.75	9.82	0
April	40.9	14.08	79.5	12.55	0

Statistical Analysis

Data were analyzed using analysis of variance technique using MSTAT-C software. Two-way interactions were drawn for different growth and yield traits. Treatments differences were evaluated using least significant difference with *P* at 0.05 and 0.01 probability levels.

RESULTS

Wheat Growth

Statistical analysis of the obtained results described significant ($P \leq 0.05$) negative effect of drought stress on plant height, days to complete tillering and 50% heading, dry biomass accumulation, leaf area index and number of productive tillers (Figure 1). Effect of cultivars was a significant ($P \leq 0.05$) for plant height, productive tiller and dry biomass accumulation. Effect of drought stress × cultivars interaction was also significant ($P \leq 0.05$) for studied growth traits except for leaf area index and plant height. The highest plant height and maximum values for other growth traits were documented for unstressed plots. A significant reduction in these traits was assessed with increasing drought stress levels. The Highest reduction in plant growth and development was noted where half of the water requirement was applied irrespective of the cultivar background (sensitive or tolerant). Comparative effect of drought stress for 75% and 50% of water requirement was non-significant for plant height, days to 50% heading and dry biomass accumulation. Cultivars also behaved

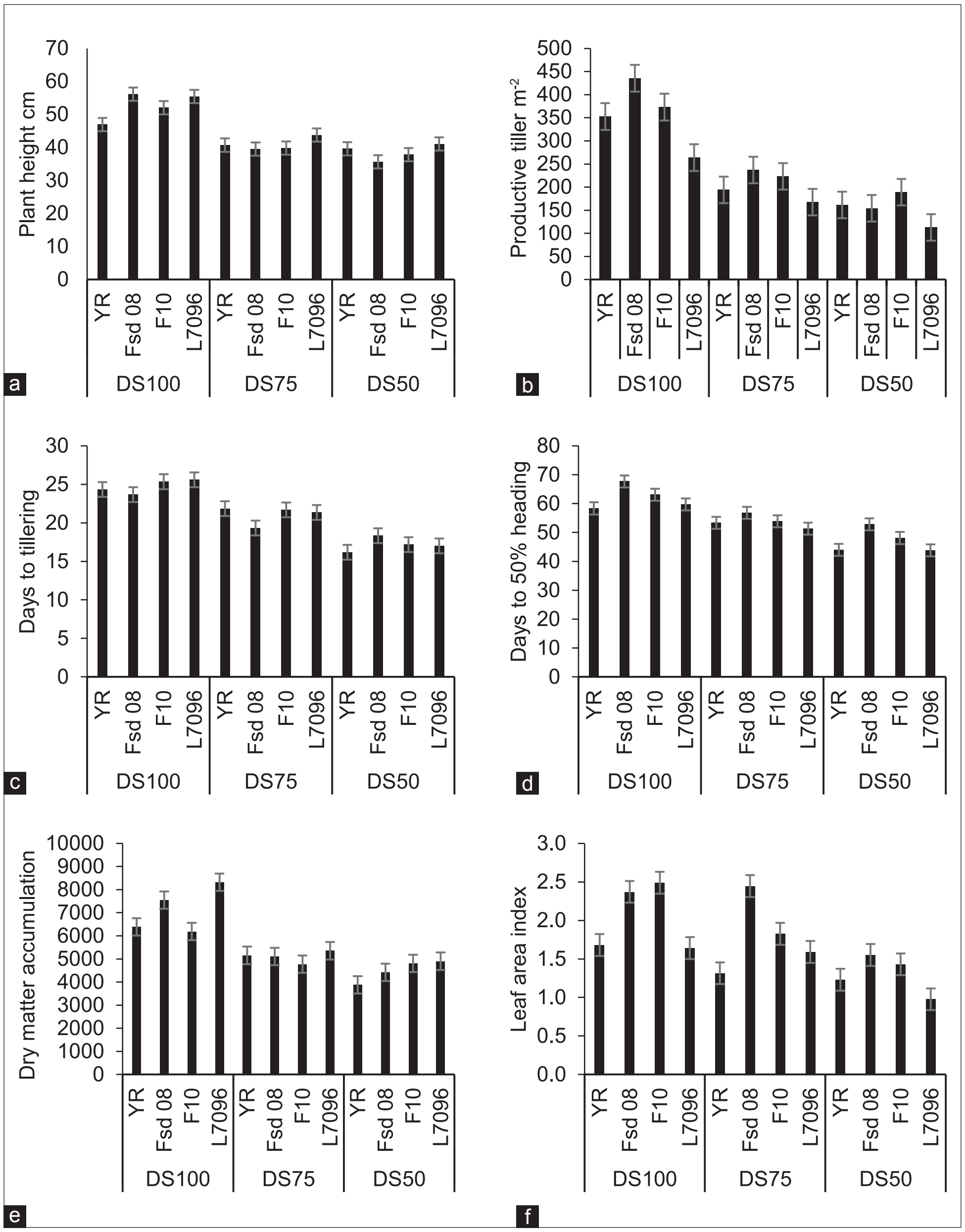

Figure 1: Response of different wheat cultivars to applied levels of water requirements for (a) plant height cm, (b) number of productive tiller m^{-2}, (c) days to complete tillering stage, (d) days to complete 50% heading, (e) dry matter accumulation kg/ha and (f) leaf area index. YR: Yocororojo, Fsd 08: Faisalabad 2008, DS 100: 100% water requirement, DS75: 75% of water requirement, DS50: 50% of water requirement

variably to applied drought stress for different growth traits. The cultivar L-7096 produced the highest plant height. The cultivar Faisalabad-2008 represented the highest number of productive tiller under non-stresses conditions while F-10 reported the highest number for severe drought stress (50%). The L-7096 took maximum days to complete tillering while Faisalabad-2008 was the last one to complete 50% heading. Dry matter accumulation was also the highest for L-7096 and F-10 reported maximum leaf area index for non-stressed plots while the Faisalabald-2008 documented highest leaf area index for drought-stressed plots.

Grain Yield and Yield Contributors

Effect of drought stress and cultivar was highly significant ($P \leq 0.01$) for spike length, grains per spike, 1000 grain weight, and grain yield and harvest index. Interaction of drought stress × cultivar was highly significant ($P \leq 0.01$) for grains per spike and harvest index, significant ($P \leq 0.05$) for 1000 grain weight and non-significant for spike length and grain yield (Table 2). By increasing the drought stress all yield contributing traits presented a decline while harvest index continue to increase with severity of applied drought stress. The highest negative

Table 2: Effect of water stress on yield and yield components of four wheat cultivar

Applied water	Genotype	Spike length (cm)	Grains/spike	1000 grain weight (g)	Grain yield (kg/ha)	Harvest index
100%	YR	10.31[a†]	48.16[ab]	40.16[ab]	2412[b]	27.44[de]
	Fsd	9.47[ab]	46.99[b]	39.66[ab]	2636[a]	25.90[f]
	F10	9.32[ab]	50.25[a]	41.58[a]	2515[ab]	28.92[c]
	L-7096	9.45[ab]	41.58[c]	34.58[de]	2162[cd]	20.71[h]
75%	YR	8.88[b]	42.20[c]	33.20[e]	1858[e]	26.48[ef]
	Fsd	8.64[bc]	40.62[b]	36.16[cd]	2231[c]	30.40[ab]
	F10	7.45[d]	41.86[c]	38.58[bc]	2104[d]	30.59[a]
	L-7096	7.70[cd]	34.82[ef]	33.66[de]	1831[ef]	25.47[f]
50%	YR	7.49[d]	32.72[f]	25.05[g]	1570[g]	28.80[cd]
	Fsd	6.85[d]	37.70[de]	29.37[f]	1819[ef]	29.14[bc]
	F10	7.09[d]	36.87[e]	25.83[g]	1723[f]	26.38[ef]
	L-7096	7.07[d]	33.87[f]	25.54[g]	1461[g]	22.97[g]
DS		**	**	**	*	*
Cv		*	**	**	**	**
DS×Cv		NS	**	*	NS	**
CV		7.19	7.21	10.82	5.12	8.58
LSD $P\leq 0.05$		1.02	2.94	2.64	123	1.43

[†]Value with different letters are significant, *Significant at $P\leq 0.05$, **Significant at $P\leq 0.01$, NS: Non-significant, DS: Drought stress, CV: Cultivar, Cv: Coefficient of variation, LSD: Least significant difference, YR: YocoroRojo, Fsd: Faisalabad

impression of drought stress was assessed on 1000 grain weight and grain yield. Cultivars also produced significant difference to drought stress for studied grain traits. Except spike length, all other Faisalabad-2008 produced highest values for the studied traits under drought stress. Spike length was the longest for YR. The Cultivar F-10 was the second best after Faisalabad-2008 and was most of the time non-significant with Faisalabad-2008 for the studied yield parameters.

DISCUSSION

Drought is the most devastating abiotic stress that hinders normal crop production. Effect of drought stress varies with the intensity, duration and crop growth stage. In wheat, flowering is most sensitive than vegetative growth stage. Alghabari *et al*. (2015) reported negative effect of drought stress on wheat growth and yield, and cultivars difference was present for drought tolerance depending on their background. Wheat growth traits are key indicator for cultivar potential against stress tolerance and adaptability (Sanghera and Thind, 2014). Cultivar L-7096 produced maximum plant height but grain yield was least as compared to rest of the cultivars. On contrary cultivar Faisalabad-2008 was short stature but produced the highest grain yield. Cultivar potential to delay in completing heading stages and maturity along with greater leaf area index also played vital role in drought tolerance (Dalirie *et al*., 2010). These traits favored Faisalabad-2008 to remain green for a longer period of time while greater leaf area index resulted in higher photosynthates production and assimilation to grain. The short stature of the Faisalabad-2008 and F-10 was due to their dwarfing nature owing to reduced height genes. Grain yield and yield contributors especially number of grains a spike and 1000 grain weight were also important in determining the cultivar potential for drought resistance (Denčić *et al*., 2000). As both of these traits are related to reproductive stage, and any decline in these traits can directly reduce final grain yield. Drought stress presented a significant reduction in these traits but cultivar Faisalabad-2008 and F-10 showed minimum reduction as compared to intolerant cultivars (YR and L-7096).

CONCLUSION

Development of drought-resistant cultivars using conventional breeding methods is laborious job and need sufficient capital and time. Screening of already cultivated verities for drought tolerance under arid land conditions looked instant solution of the problem. Among four tested cultivars, Faisalabad-2008 presented promising results for drought tolerance and adaptability in arid environment of the Jeddah region in term of growth and grain yield. Thus, this cultivar can be successfully incorporated and recommended for general cultivation. Moreover, genetic bases of this cultivar can be used in breeding and development of new drought-resistant cultivars.

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