Effect of post-flowering water stress on yield and physiological characters of grain sorghum genotypes

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Abstract

Drought is one of the most important factors limiting crop production in arid and semi arid regions, such as Iran. In order to study drought stress in four grain sorghum varieties (Kimia, Sepideh, KGS15 and KGS23), an experiment was laid in randomized complete block design with three replications in a split plot arrangement. Water treatments were considered the main plot at three levels: irrigation after 60 mm evaporation as well-watered, normal irrigation till flowering and then irrigation after 120 mm evaporation (mild water stress), and water withholding after flowering (severe water stress). There were significant ($P \leq 0.05$) decrease in grain yield, seed index, SPAD number and stomatal conductivity in post-flowering water stress, particularly in severe stress. Sepideh cultivar had the highest yield reduction of 73%, and KGS23 genotype had the least yield reduction of 29%, but still it was a good genotype if well-watered and the best in moisture stress conditions. Sepideh and KGS15 had a greatly significant reduction in stomatal conductivity of flag leaves in severe water stress and displayed premature leaf and stalk senescence. KGS23 as tolerant genotype with more elevated stomatal conductance under water stress probably had a more efficient water uptake by roots in comparison with the other genotypes.

Keywords: Terminal drought; sorghum; grain yield; stomatal conductivity; SPAD number

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Introduction

Drought is one of the most important abiotic stresses limiting cereal productivity throughout the world (Okiyo, 2008), particularly when the stress occurs during reproductive growth (Prasad et al., 2008; Kebede et al., 2001). Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most tolerant drought crops in arid and semi-arid regions (Ejeta and Knoll, 2007). Water shortage and increased food demand worldwide require development of more water efficient crops (Balota et al., 2008).

In the present study on four sorghum genotypes, we first evaluated the genotypic variation for drought tolerance during the

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reproductive stage based on the grain yield and its components under water stress condition. we also investigated possible physiological traits that could be used later on as screening criteria.

Materials and Methods

Field trail was performed at Seed and Plant Improvement institute of Iran – Karaj (SPII). The experiment was laid in randomized complete block design (RCBD) with three replications in a split plot arrangement. Water treatments were considered the main plot at three levels: irrigation after 60 mm evaporation from class A evaporation pan as control (well-watered), normal irrigation till 50% flowering and then irrigation after 120 mm evaporation (mild water stress), and water withholding after flowering (severe water stress). For flag leaves, the stomatal conductivity of flag leaves (using AP4 Prometer AP4, Decagon Devices Inc.), leaf area index (LAI) (using AccuPAR model LP-80, Decagon Devices Inc.) and their SPAD number (Minolta, Japan) were measured 21 days after flowering. At maturity, panicle were harvested in each plot, dried, threshed and grain yields and seed index were determined. Weight of 1000 seeds in g was recorded as seed index. In a sample of three plants per plot, seed number per panicle was measured.

Results

The effects of water treatments on the grain yield, seed index, SPAD number and stomatal conductivity were significant ($P \leq 0.01$), but LAI and seed number per panicle were not different for water treatments. Highly significant ($P \leq 0.01$) differences were observed for all traits among genotypes. There were significant ($P \leq 0.05$) interactions between genotypes and treatment for grain yield, seed index and

Table 1
Analysis of variance for agronomic and physiological traits of four grain sorghum genotypes subjected to different water treatments.

	df	Leaf Area Index	SPAD No.	Stomatal conductance	Seed Index	Seed No/Panicle	Grain Yield
Replication	2	0.22	34.61	117.44	38.91	18887	2112809
Stress	2	0.31	2059.4**	29427**	856.95**	9377431	69981271**
Error	4	0.079	35.22	402.27	20.39	3645.2	509808
Genotypes	3	0.01	239.12**	5960.1**	84.14*	473532	9263845**
Stress*Genotypes	6	0.04	54.96	905.97*	74.5*	1053047	3171449*
Error	18	0.09	30.19	241.04	30.13	13289	896429
CV%		5.00	13.97	14.96	23.21	15.1	14.22

** and * significant at ($P \leq 0.01$) and ($P \leq 0.05$) respectively

Table 2
Effect of water stress on agronomic and physiological traits of four grain sorghum genotypes

Water treatments	Leaf Area Index	Stomatal Conductance ($mmol/m^2s$)	SPAD No.	Seed No. /Panicle	Seed Index (g)	Grain Yield (Kg/ha)
Well watered	3.732 a	222 a	52.32 a	3125 a	32.01 a	9287.5 a
Mild stress (S1)	3.494 a	130 b	39.56 b	2050 b	23.92 b	6155.3 b
Severe stress (S2)	3.413 a	73.5 c	26.12 c	1372 c	15.11 c	4537.5 c

Treatments means followed by the same letters are not significantly different using Duncan's Multiple Range test.

Table 3
The Pierson's correlation index among different agronomic and physiological traits of four grain sorghum genotypes subjected different water treatments.

Traits	Leaf Area Index	Stomatal conductance	SPAD No.	Seed No./Panicle	Seed Index	Grain yield
Leaf Area Index	1					
Stomatal conductance	0.66*	1				
SPAD No.	0.81**	0.83**	1			
Seed No./Panicle	0.80**	0.70**	0.65*	1		
Seed Index	0.74**	0.77**	0.77**	0.83**	1	
Grain yield	0.87**	0.81**	0.88**	0.79**	0.87**	1

** and * significant at (P≤0.01) and (P≤0.05) respectively.

stomatal conductivity (Table 1). Furthermore, there were significant (P≤0.05) decrease in grain yield, seed index, SPAD number and stomatal conductivity in post-flowering water stress, particularly in severe stress (Table 2).

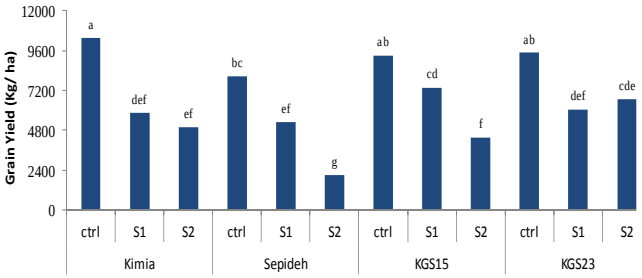

Fig. I. Effects of water stress on grain yield of four grain sorghum genotypes subjected different water treatments.

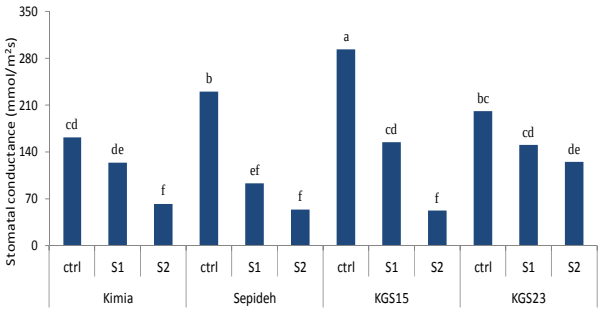

Fig. II. Effects of water stress on stomatal conductivity of four grain sorghum genotypes subjected to different water treatments

Sepideh cultivar had the highest yield reduction of 73%, and KGS23 genotype had the least yield reduction of 29%, but still it was a good genotype if well-watered (9472.2Kg/ha) and the best in moisture stress conditions (6061.1 and 6655.5Kg/ha at mild and severe stress, respectively) (Fig. I). Moreover, Sepideh cultivar and KGS15 had a great significant reduction in stomatal conductivity of flag leaves in severe water stress, and KGS23 had no significant reduction (Fig. II).

Relationships among agronomic and physiological traits were also analyzed using the Pierson's correlation test. Grain yield correlated significantly (P≤0.01) with LAI, stomatal conductance, SPAD number and grain yield components (Table 3).

Discussion

Grain yield or relative grain yield is one of the most important traits in screening drought-tolerant cultivars. In fact, selecting for other drought traits without considering yield will not be useful (Schaffert et al., 2010). Under post-flowering water stress, Sepideh and KGS15 as the susceptible sorghum genotypes had more closed stomata (Fig II), displayed premature leaf and stalk senescence (data not shown), and more reduced grain yield than the other genotypes (Fig I). Tolerance to moisture stress in Sorghum is manifested by a stay-green phenotype and normal grain filling (Xu et al., 2000). Nevertheless, the drought avoidance mechanisms in plants include deep rooting and conservative use of available water to complete grain filling and lifecycle. The stomatal conductance level may provide indirect indicators of water uptake by roots (Hosseini Salekdeh et al., 2009). Here, KGS23 as tolerant genotype with more elevated stomatal conductance under water stress probably had a more efficient water uptake by roots in comparison with the other genotypes.

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