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The Effect of Deficit Water Irrigation on the Performance of Promising Lines of Grain Sorghum †

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Abstract: The current research aimed to perceive the effect of water deficit irrigation and plant density on yield and yield components of promising lines of grain sorghum. The experiment was conducted in the form of split-plot factorial design with three replications at the Seed and Plant Improvement Institute (SPII) for two years (2015–2016). Irrigation was considered as the main factor (60, 120 and 180 mm evaporation from pan class A) and plant spacing on the row (8, 12 and 15 cm) and lines (KGS23, KGS32 and KGS36) were considered factorial. The combined analysis of variance indicated that there was a significant difference between the lines in terms of grain yield ($p \leq 0.01$). The lines KGS23 and KGS36 exhibited the highest grain yield with 5333 and 4645 kg ha^{-1}, respectively, while line KGS32 produced the lowest grain yield of 4011 kg ha^{-1}. The results indicated different reaction of the grain sorghum lines to irrigation. Under water deficit irrigation, the line KGS23 had a significant advantage in comparison to the other two lines in terms of high yield, morphological characteristics, and adaptation to drought stress conditions. Grain yield was positively correlated with panicle weight, biological yield, and 1000-grain weight. Additionally, line KGS36 performed better than KGS32 in terms of grain yield and drought tolerance. The highest grain yield (7964 kg ha^{-1}) was observed for line KGS23 under normal irrigation and plant space on the row of 12 cm in the second year. Moreover, the effect of plant density on grain yield was not significant ($p \leq 0.05$).

Keywords: drought; density; sorghum morphology; correlation

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1. Introduction

Drought is the most significant environmental stress that greatly reduces crop production in areas where the annual rainfall is reduced and the distribution is uneven [1]. Iran is considered an arid (65%) to semi-arid (25%) region (25° to 38° N latitude) with an area of about 1.5 million km^2, which is equivalent to 3% of the area of arid and semi-arid regions of the world [2]. Sorghum has been introduced as a drought-tolerant crop due to its unique morphological and physiological characteristics and less water requirement compared to maize [3]. Onken et al. [4] reported an increase in water use efficiency in sorghum during long irrigation cycles.

Determining the density, planting date, and suitable cultivars of grain sorghum in each region are important factors for optimal crop production. Hum and Kebda [5] showed that increasing plant density from 75,000 to 450,000 plants ha^{-1} grain yield increased linearly. The effect of plant density on the grain yield of three sorghum cultivars different in terms of maturity reported that early cultivars needed higher plant density than late cultivars for maximum yield [6]. Despite its complexity, grain yield is an indicator of plant response to environmental stresses. The selection of drought-tolerant genotypes is generally performed under both stress and non-stress conditions to select genotypes adapted to both conditions [7].

This study was conducted to determine the effect of drought stress and plant density on the yield and phenotypic traits of promising lines of grain sorghum.

2. Materials and Methods

This experiment was carried out in the research farm of Seed and Plant Improvement Research Institute, Karaj (35°59′ N, 50°75′ E). The soil texture of the experimental field was clay-sand with a pH = 7.5 in a depth of 0–30 cm. Split plot-factorial was implemented in a randomized complete block design with three replications during 2015–2016.

Irrigation was applied as the main factor (A) at three levels (60, 120, and 180 mm evaporation from the Class A Evaporation Pan). Plant spacing on row (B) at three levels (8, 12, and 15 cm) and lines (C) at three levels (KGS23, KGS32, and KGS36 (BC) were evaluated as factorial (BC). The experimental plots were 4 lines 5 m long with a row distance of 60 cm. Ammonium phosphate was distributed with tillage as 250 kg ha^{-1}, while urea was applied 100 kg ha^{-1} at planting time and 100 kg ha^{-1} in the 6–8 leaf stage, based on the soil test.

Phenotypic parameters including plant height, panicle length, stem diameter, panicle weight, forage weight, biological yield, 1000-grain weight, and grain yield were measured. Grain harvest was performed at the physiological maturity stage. For this purpose, the middle two rows were harvested by removing marginal effects. Panicles were removed from the plant and weighed. The seeds were counted by Seed Counter and then weighed. The plant height was calculated from the soil surface until the panicle head. The stem diameter was calculated by measuring the first node by the caliper. Analysis of variance, comparison of means, and simple correlations were performed using SAS software. Means comparison was performed using the LSD test method ($p < 0.05$).

3. Results and Discussion

Combined analysis of variance showed that the effect of year was significant for plant height, panicle length, stem diameter, panicle weight, 1000-seed weight, and grain yield at $p < 0.01$ and for forage weight and biological yield at $p < 0.05$. The grain yield was influenced by the effect of the year. The results showed that the grain yield in the second year was superior compared to the first year (Table 1).

Significant differences between irrigation regimes were observed for all traits except stem diameter ($p < 0.01$). Comparison of means showed that the highest grain yield with an average of 6350 kg ha^{-1} was related to the well-watered condition and the lowest was obtained under severe water stress with an average yield of 3320 kg ha^{-1} (Table 1). Our results demonstrated that sorghum grain yield significantly decreases under water stress.

It seems that balanced water consumption (normal irrigation) during different development stages may lead to improved grain yield. The effect of water stress on sorghum and millet in the reproductive growth stage reduced grain yield up to 50%; however, the stress in the vegetative growth stage in millet decreased grain yield by 25% and in sorghum by 30% [8].

Irrigation in well-watered conditions led to an increase in biological yield (33.21 t ha^{-1}). Biological yield significantly decreased under mild and severe water stress conditions (23.98 t ha^{-1}) (Table 1).

There was a significant difference between the promising lines in terms of grain yield ($p < 0.01$) (Table 1). Comparison of mean showed that KGS23 and KGS36 produced the highest yield (5333 and 4645 kg ha^{-1}, respectively), and KGS32 (4011 kg ha^{-1}) had the lowest grain yield (Table 1).

The interaction of promising lines and irrigation levels was significant on grain yield ($p < 0.05$) (data not shown). KGS23 line had the highest grain yield in three irrigation levels with a grain yield of 7113 kg ha^{-1} at IR_1, 5053 kg ha^{-1} at IR_2, and 3832 kg ha^{-1} at IR_3 (Table 1).

Levels of density were significantly different in terms of forage weight ($p < 0.01$) and in terms of biological yield ($p < 0.05$). However, density did not affect grain yield. The highest forage and biological yield was related to the plant spacing of 8 cm on the row (Table 1).

Table 1. Mean of comparison some of morphological characteristics, biological yield and grain yield in promising grain sorghum lines.

Treatment	Plant Height (cm)	Panicle Weight (t ha^{-1})	Biological Yield (t ha^{-1})	Grain Yield (Kg ha^{-1})
Year(Y)				
Y1	100.5 ^{b}	6.8 ^{b}	26.4 ^{a}	3797.1 ^{b}
Y2	107.3 ^{a}	8.9 ^{a}	27.7 ^{a}	5529.1 ^{a}
Irrigation regime (IR)				
well-watered (IR_1 = 60 mm)	117.50 ^{a}	10.37 ^{a}	33.21 ^{a}	6350.0 ^{a}
mild water stress (IR_2 = 120 mm)	99.57 ^{b}	7.01 ^{b}	23.98 ^{b}	4318.70 ^{b}
severe water stress(IR_3 = 180 mm)	94.65 ^{c}	6.15 ^{b}	23.98 ^{b}	3320.20 ^{c}
Cultivars				
V1(KGS23)	90.82 ^{c}	8.95 ^{a}	28.31 ^{a}	5333.0 ^{a}
V2(KGS32)	121.0 ^{a}	6.87 ^{c}	26.65 ^{b}	4011.0 ^{c}
V3(KGS36)	99.91 ^{b}	7.70 ^{b}	26.25 ^{b}	4645.0 ^{b}
Density				
D1 = 8 Cm	103.0 ^{a}	7.99 ^{a}	28.31 ^{a}	4819.0 ^{a}
D2 = 12 Cm	104.4 ^{a}	7.56 ^{a}	26.65 ^{ab}	4451.0 ^{a}
D3 = 15 Cm	104.4 ^{a}	7.97 ^{a}	26.25 ^{b}	4719.0 ^{a}

Means with same letters in each column are not significantly different at 5% level.

Grain yield was positively correlated with panicle weight, biological yield, and 1000 seeds, while biological yield was positively correlated with plant height, panicle length, and panicle weight (Table 2).

Table 2. Correlations between morphological characteristics, biological yield and grain yield in promising grain sorghum lines.

Grain Yield (kg ha^{-1})	1000 Grain Weight (g)	Biological Yield (t ha^{-1})	Panicle Weight (t ha^{-1})	Stem Diameter (cm)	Panicle Length (cm)	Plant Height (cm)	Parameters
						1	Plant height (cm)
					1	0.76 **	Panicle length (cm)
				1	0.19 ^{ns}	−0.11 ^{ns}	Stem diameter (cm)
			1	−0.17 ^{ns}	0.10 ^{ns}	0.18 ^{ns}	Panicle weight (t ha^{-1})
		1	0.66 **	0.01 ^{ns}	0.28 *	0.43 **	Biological Yield (t ha^{-1})
	1	0.45 **	−0.21 ^{ns}	0.39 **	0.37 **	0.27 *	1000 grain weight (g)
1	0.29 **	0.57 **	0.92 **	−0.17 ^{ns}	0.10 ^{ns}	0.14 ^{ns}	Grain yield (kg ha^{-1})

** and *: significant at the 0.01 and 0.05 probability levels, respectively; ns: non-significant.

The results of this research support the idea that the reaction of grain sorghum lines can be different with irrigation treatment. Totally, under water stress conditions, line KGS23 showed a significant advantage in terms of most traits than the other two lines. KGS23 showed more tolerance to drought stress and exhibited superiority in terms of morphological traits and grain yield. Irrigation restriction in grain sorghum caused a reduction in most of the measured traits, which led to a significant reduction in yield.

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