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EFFECT OF DROUGHT STRESS AT DIFFERENT GROWTH STAGES ON YIELD AND WATER USE EFFICIENCY OF FIVE PROSO MILLET (*PANICUM MILIACEUM* L.) GENOTYPES

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Abstract

In order to examine the responses of proso millet (*Panicum miliaceum*) to drought stress in different growth stages, four breeded genotypes and a local one of proso millet were selected and planted in a split-plot design with five irrigation treatments and three replications. This experiment was conducted in two locations, Birjand and Sarbisheh, east of Iran. Irrigation treatments included well- watered, drought stress at vegetative stage, ear emergence stage, seed filling stage and vegetative and seed filling stages were considered as main- plots. The first five mentioned genotypes were considered as sub-plots. Drought stress caused a great reduction in grain yield and WUE at ear emergence stage. This reduction represented itself in the number of seed per ear and the weight of seeds, but it didn't have any effects on the number of ear per plant. At ear emergence stage, the drought stress increased the floret death and loss of seed size which resulted in the reduction in the harvest index of both ear and seed per plant. Comparison of genotypes indicated that K-C-M.4 had a greater number of ears and K-C-M.9 had heavier seeds that had higher grain yield. These two genotypes had the highest WUE and their harvest indices were relatively higher. Due to the salinity of water and infertility of soil in Birjand, the grain yield was lower compared with Sarbisheh. Based on these results, genotype K-C-M.4 proved to be more suitable for both areas.

Introduction

Water deficit is one of the most common environmental stresses that affects growth and development of plants (Shaw, 1988; Sadras & Milroy, 1996; Aslam et al., 2006). Drought continues to be a challenge to agricultural scientists in general and to plant breeders in particular, despite many decades of research. Drought, or more generally, limited water availability is the main factor limiting crop production. Drought is a permanent constraint to agricultural production in many developing countries, and an occasional cause of losses of agricultural production in developed ones (Ceccarelli & Grando, 1996).

In shortage water conditions, water had been to use at critical growth stages. Thus, it is important to recognize these critical growth stages for any crops. In addition, one of the main goals in breeding program is selection of genotypes that had been high yield in drought stress conditions (Richards *et al*., 1993; Richards *et al*., 2002).

Direct selection for yield is generally the simplest, most effective way to improve yield and hence WUE in all crops and the major share of the available resources for crop improvement should be devoted to direct selection for yield (Richards *et al*., 1993).

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Generally, water use efficiency in plants tends to be high as an adaptation under stress conditions (Umar, 2006).

Replacement of drought adopted crops with high water demanding ones is an efficient strategy in water shortage conditions. Millets can be successfully grown in a wide range of environmental conditions, being better adopted than most crops to hot, dry regions. Millet is a general term for a wide range of small seeded cereals. They are of potential value particularly in semiarid regions because of their short growing season. They can either tolerate drought and intense heat or avoid these conditions by growing to maturity very quickly (Baltensperger, 2002).

However, different characteristic of millet could be influenced by water stress. Maman *et al.* (2003) in a comparison between sorghum and pearl millet with respect to drought resistance show pear millet seed yield had less stability.

Yadav *et al.* (1999) indicated that drought after flowering of pear millet decreased seed yield through reduction of number of ear per m^2 and seed per ear and seed weight. Further researchers also show seed yield reduction of millet under water stress is as a result of reduction in these yield components (Mahalakshmi & Bidinger, 1985; Prasad *et al.* 1986). Seed weight decline could be through reduction of seed growth rate as well as seed filling period.

Effect of water stress on WUE depends on plant species and phenological stage of water stress imposition and severity. Kumari (1988) indicated that WUE for biomass yield increased under drought stress. In almost all crops the greater WUE for grain isn't due to an improvement in biomass, but, rather surprisingly, it is due to almost entirely to an improved HI. Yadav *et al* (1999) in an experiment under drought stress show a part of (50%) seed yield reduction was related to HI decline. Hence, this experiment was conducted to determine the effect of water stress at different growth stages on proso millet genotypes in south Khorasan, Iran.

Materials and Methods

This experiment was conducted in 2003 at two locations, Birjand and Sarbisheh in south Khorasan. Longitude and altitude of these locations are 59˚13΄ east- 32˚53΄north and 59˚42΄ east- 32˚15΄north, respectively. In total, the climate of south Khorasan is dry and warm, because it is at the vicinity of Loot desert, however, the water evaporation and air temperature in Sarbisheh are less than Birjand. Soil texture was sandy- loam at two locations. Soil pH was 8.41 and 8.71 in Birjand and Sarbisheh, respectively. Electrical conductivity of irrigation water was 5.4 and 2.6 dS/m in these locations, respectively. Experimental design was split- plot based on randomized complete block with 3 replications. Irrigation treatments included well- watered (N), drought stress at vegetative stage (V), ear emergence stage (E), seed filling stage (F) and vegetative and seed filling stages (V+F) were considered as main plots. Five proso millet genotypes (local, K-C-M.2, K-C-M.4, K-C-M.6 and K-C-M.9) were considered as sub- plots. FAO method used to determine water requirement in each locations (Table 1).

Applied fertilizers consisted of 90 kg/ha P_2O_5 as ammonium phosphate and 69 kg/ha nitrogen as urea (23 kg/ha/plant, 23 kg/ha 30 days after sowing and 23 kg/ha 60 days after sowing).

Sowing dates were 30 May and 4 Jun in Birjand and Sarbisheh, respectively. Sowing was conducted on the two sides of ridges. The distance between ridges was 70 cm, therefore the planting interval rows were 35 cm. plant distances on the row was 4 cm (final density was 714286 plants ha^{-1}). Seed yield and its components, WUE (seed yield/ irrigation water quantity), harvest index of ear (seed yield of ear/ total ear weight), and harvest index (plant seed yield/ total plant biomass) were determined. Analysis of variance was conducted using Mstatc software.

Table 1: Depth of water application at different treatments (mm)

Place	Control	Stress at vegetative stage	Stress at ear emergence stage	Stress at seed filling stage	Stress at vegetative and seed filling stages
Birjand	874	830.8	764.2	798.8	755.6
Sarbisheh	719.5	682.1	626.5	646.8	609.4

Results and Discussion

Seed yield and its component: Drought stress reduced seed yield and its component, significantly (Table 2). Stress at ear emergence stage caused the greatest reduction in seed yield (because of pollination susceptibility to water stress) (Table 1). The percent of seed yield reduction in this treatment were 40.7 and 43.3 respectively, in Birjand and Sarbisheh. Yadav and Bhatnagar (2001) in a study on pearl millet indicated that seed yield in stressful and non-stress environments were 828-1136 $kg.ha^{-1}$ and 3123-3942 $kg.ha^{-1}$, respectively. Mahalakshmi & Bidinger (1985) reported that drought stress at seed filling stage reduced seed yield up to 50%. The measurement of seed yield components showed that seed yield decline was mainly due to reduction of seed number per ear and seed weight (Table 2). There weren't significant differences between ear numbers per plant in drought stress treatments. Mahalakshmi and Bidinger (1985) and Kumari (1988) also reported that drought stress in millet decreased seed yield through reduction of seed number per ear and seed weight. Seed number reduction could be as a result of stress effect on pollination and floret abortion (Bradford, 1994). Seed weight reduction under drought stress might be a result of cytokinin reduction. In this condition less endosperm cells is produced in seeds (Bradford, 1994). The amount of seed yield reduction in treatments F and V+F were lower than treatment E. Mastrorilli *et al*. (1995) also reported that seed filling stage is less susceptible to drought than ear emergence stage. Comparison of genotypes indicated that K-C-M.4 and K-C-M.9 had the highest and local had the lowest seed yield (Table 3). K-C-M.4 had the greatest number of ear per m^2 and K-C-M.9 had heavy seeds. Due to the salinity of water and infertility of soil in Birjand, the grain yield was lower compared with Sarbisheh (Table 4).

Table 2: Effect of drought stress on proso millet seed yield and its components

Stress	Seed yield (t/ha)		No. ear/m^2		No. seed/ear		1000 seed weight (g)	
	B	S	B	S	B	S	B	S
N	1.556 a	1.977 a	252.9 a	254.6 a	221.6 a	278.2 a	2.83 a	2.87 a
V	1.462 a	1.926 a	239.8 ab	257.1 a	221.5 a	278.5 a	2.83 a	2.86 a
E	0.923 c	1.120 c	244.4 a	269.4 a	166.7 b	174.3 c	2.35 c	2.40 c
F	1.167 b	1.537 b	227.3 b	253.7 a	208.5 a	244.9 ab	2.49 b	2.51 bc
V+F	1.290 b	1.552 b	249.9 a	272.5 a	206.4 a	221.7 b	2.50 b	2.63 b

-Well- watered (N), drought stress at vegetative stage (V), ear emergence stage (E), seed filling stage (F) and vegetative and seed filling stages (V+F)
-B: Birjand , S: Sarbisheh
-Means followed by the same letters in each column, are not significantly different at the 5% level.

Table 3: Effect of proso millet genotypes on seed yield and its components

Genotypes	Seed yield (t/ha)		No. ear/m^2		No. seed/ear		1000 seed weight (g)	
	B	S	B	S	B	S	B	S
Local	1.150 c	1.454 c	236.6 c	259.1 b	199.7 b	222.0 bc	2.46 b	2.54 b
K-C-M.2	1.251 bc	1.625 ab	186.5 d	212.6 c	241.7 a	279.7 a	2.77 a	2.78 a
K-C-M.4	1.424 a	1.740 a	288.6 a	327.1 a	194.3 b	206.0 c	2.55 b	2.59 b
K-C-M.6	1.249 bc	1.562 bc	243.9 bc	250.8 b	201.9 b	247.6 b	2.54 b	2.57 b
K-C-M.9	1.324 ab	1.731 a	258.8 b	257.7 b	187.0 b	242.4 b	2.71 a	2.79 a

-B: Birjand , S: Sarbisheh

- Means followed by the same letters in each column, are not significantly different at the 5% level.

Table 4: Comparison of proso millet seed yield and its components in Birjand and Sarbisheh

Region	Seed yield (t/ha)	No. ear/m^2	No. seed/ear	1000 seed weight (g)
Birjand	1.280 b	242.9 b	204.9 b	2.60 a
Sarbisheh	1.618 a	261.4 a	239.6 a	2.65 a

- Means followed by the same letters in each column, are not significantly different at the 5% level.

Table 5: Effect of drought stress on proso millet WUE and HI

Stress	WUE (g.seed/l)		HI of ear per plant		HI of seed per ear		HI of seed per plant	
	B	S	B	S	B	S	B	S
N	0.181 a	0.275 a	36.2 a	36.9 a	51.0 a	53.3 a	18.5 a	19.8 a
V	0.179 a	0.282 a	36.1 a	36.7 a	49.3 a	51.1 a	17.8 a	18.7 ab
E	0.123 c	0.175 c	30.4 c	31.0 b	36.9 c	40.4 c	11.2 d	12.5 d
F	0.149 bc	0.238 b	33.0 b	35.8 a	42.6 b	46.5 b	14.1 c	16.7 c
V+F	0.174 ab	0.259 ab	35.7 a	36.6 a	43.3 b	47.1 b	15.5 b	17.2 bc

-well- watered (N), drought stress at vegetative stage (V), ear emergence stage (E), seed filling stage (F) and vegetative and seed filling stages (V+F); -B: Birjand , S: Sarbisheh

- Means followed by the same letters in each column are not significantly different at the 5% level.

Table 6: Effect of proso millet genotypes on WUE and HI

Genotypes	WUE (g.seed/l)		HI of ear per plant		HI of seed per ear		HI of seed per plant	
	B	S	B	S	B	S	B	S
Local	0.142 c	0.217 c	33.2 b	34.9 a	41.7 b	44.3 c	13.9 b	15.5 b
K-C-M.2	0.155 b	0.250 ab	34.4 ab	35.2 a	44.2 ab	47.5 b	15.4 a	17.0 a
K-C-M.4	0.176 a	0.264 a	35.2 a	36.2 a	45.9 a	49.7 a	16.3 a	18.1 a
K-C-M.6	0.155 b	0.236 bc	34.2 ab	35.5 a	46.4 a	47.6 b	16.0 a	17.0 a
K-C-M.9	0.178 a	0.262 a	34.4 ab	35.0 a	45.0 a	49.4 ab	15.6 a	17.4 a

-B: Birjand , S: Sarbisheh

- Means followed by the same letters in each column are not significantly different at the 5% level.

Table 7-Comparison of proso millet WUE and HI in Birjand and Sarbisheh

Region	WUE (g.seed/l)	HI of ear per plant	HI of seed per ear	HI of seed per plant
Birjand	0.161 b	34.3 a	44.6 b	15.4 b
Sarbisheh	0.245 a	35.2 a	47.7 a	17.0 a

- Means followed by the same letters in each column are not significantly different at the 5% level.

Water use efficiency (WUE): WUE was significantly reduced by water stress (Table 5). Kumari (1988) and Ibrahim *et al*. (1995) also reported that drought stress reduced WUE of millet. Water stress at ear emergence stage caused the greatest reduction in WUE (Table 5). The percents of reduction in this treatment were 32.0 and 36.4, respectively in Birjand and Sarbisheh. Reca *et al*. (2001) also show water shortage at flowering declined seed yield more than stress at other stages. Water stress at vegetative and seed filling stage (V+F) hadn't significantly effect on WUE (Table 6). This is because of irrigation water quantity in this treatment was lower than other stress treatments (Table 1). Genotype comparison indicates K-C-M.4 and K-C-M.9 with the greatest seed yield had the highest WUE (Table 6). Local genotype that produced the least seed yield had the lowest WUE. WUE in Sarbisheh was more than Birjand (Table 7), because seed yield in Sarbisheh was more than Birjand and evaporation and total volume of irrigation water was lower in Sarbisheh

Harvest index (HI): Water stress had significant negative effect on harvest index (Table 5). Control had the highest and water stress at ear emergence stage had the lowest HI (Table 5). At ear emergence stage, the drought stress increased the floret death and loss of weight of seeds which resulted in the reduction in the harvest index of both ear per plant and seed per plant. However, stress at this stage reduced HI of seed per ear more than HI of ear per plant. This means that assimilate transition within the ear to floret was more affected by stress than its transfer within the plant to ear. Genotype effect on the harvest index was significant (Table 6). In total, K-C-M.4 had the highest and local had the lowest harvest index. The local genotype is non breeded, thus it's HI is low. In summery, it can be said that genotype K-C-M.4 proved to be more suitable for both areas. In addition, irrigation omission in early growth stages could increase WUE of proso millet.

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