Pak. J. Bot., 40(4): 1555-1560, 2008.

EFFECT OF DEFICIT IRRIGATION ON YIELD, WUE AND SOME MORPHOLOGICAL AND PHENOLOGICAL TRAITS OF THREE MILLET SPECIES

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Abstract

Selection of drought adapted genotypes and efficient use of water are among the most important goals in the breeding programs. In order to study drought tolerance of three important species of millets, Proso millet (*Panicum miliaseum*), Foxtail millet (*Setaria italica*) and Pearl millet (*Pennisetum americanum*) were planted in a split-plot design with two irrigation treatments (well watered and 50% of irrigation requirement) and four replications in Birjand Agricultural Research Station, Iran. Deficit irrigation declined yield by reduction of seed number per ear and ear number per plant. This reduction was greater in Proso millet than the other two species. In addition, although, drought stress caused a reduction in WUE of Proso millet, it increased WUE in the other ones. Harvest index also reduced in the presence of drought stress due to of both seed per ear and per plant reduction. Tillering started earlier in Proso millet than the other millets. Although, stem elongation started earlier in foxtail millet than the other millets, but its ear was emerged very late. Water stress caused reduction in the number of tiller and ear, peduncle and ear length and plant height. On the whole, foxtail millet showed the greatest yield in both stress and non-stress conditions.

Introduction

Water shortage is one of the most important restricting factors in crop production in the world (Umar,2006). Drought stress imposes many effects on plants. Firstly, water shortage declines plant growth and production (Yadav *et al*., 1999). In water shortage conditions, water had to use at critical growth stages (Stewart *et al*., 1975). In addition one of the main goals in breeding program is selection of genotypes with high yield in drought stress conditions (Richards *et al*., 2002).

Millet species need relatively less water than the other crops, because they have short growth season (Baltensperger, 2002). Golombek & Al-Ramamneh (2002) indicated that drought reduces CO_2 assimilation area through reducing of leaf number and area. Similarly, Singh & Singh (1995) in the study of agronomic and physiological responses of sorghum, maize and pearl millet to irrigation show that net assimilation rate reduced when drought stress increased. In addition, drought stress had significant effect on biomass yield. Yadav *et al*. (1999) demonstrated that water stress after pollination in pearl millet reduces seed yield through reduction of number of tiller per m^2, number of seed per ear and seed weight. Similarly, Yadav & Bhatnagar (2001) observed positive correlation between seed yield and day number to flowering in non stress conditions, but in stress conditions this correlation was negative.

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Crop WUE is an important trait in breeding programs. In almost all crops, the greater WUE for grain is not due to an improvement in biomass acummulation, but, rather surprisingly, it is due to almost entirely to an improved in HI (Richards *et al*., 1993). Thus, it is important to study the relationship between seed yield, WUE and HI. Hence, this experiment was conducted to compare yield and yield components and some morphological and phonological traits in three millet species under deficit irrigation conditions.

Materials and Methods

This experiment was conducted in 2003 summer at Birjand Agricultural Research Station, Iran. Longitude, latitude and altitude of Birjand are 59°13´, 32°53´, and 1480m, respectively. The climate of Birjand is dry and warm, because it is at the vicinity of Loot desert. Maximum and minimum temperature averages in Birjand are 27.5 and 4.6 degrees centigrade. Average annual rainfall is 170 mm. Maximum and minimum average humidity are 59.6% and 23.5%, respectively. Electrical conductivity of irrigations water was 5.4 dS/m.

Soil texture in experiment location was sandy-loam and soil pH was 8.4. Applied fertilizers consisted of 90 kg/ha P_2O_5 as Ammonium phosphate and 69 kg/ha Nitrogen as Urea (23 kg/ha pre-plant, 23 kg/ha 30 days after sowing and 23 kg/ha 60 days after sowing). Experimental design was split-plot based on randomized complete block with four replications. Each replication had two main plots as irrigation treatments (control and deficit irrigation). In deficit irrigation treatment the rate of irrigation was 50% crop water requirement. FAO method used to determine water requirement. Each main plot consisted of three sub-plots as millet species: Proso millet (k-c-m.9), Pearl millet (local genotypes) and foxtail millet (k-f-m.7). Each sub-plot had four planting rows. Sowing was conducted on the two sides of ridge. The distance between ridges was 70 cm, therefore the planting interval rows were 35 cm. the length of ridges was 5 m. Distance between plants on the rows was 4 cm. Final density was 714286 plants per hectare. Planting dates was on 18 may.. Seed yield and its components, WUE, HI and some morphological and phonological traits were measured in this experiment. SPSS and MStatc softwares used to analyze data.

Table 1- Depth of water application in different treatments (mm)

deficit irrigation			control		
Foxtail millet	**Pearl millet**	**Proso millet**	**Foxtail millet**	**Pearl millet**	**Proso millet**
459.9	454.3	412.3	919.8	908.6	824.5

Results and Discussion

Deficit irrigation reduced seed yield and its components (except weight of 1000 seeds), significantly (Table 2). Maqsood & Azam Ali (2007), Kumari (1988) and Mahalakshmi & Bidinger (1985) also reported that water stress in millet reduced seed yield and number of seed per ear. Seed weight is one of the most stable yield components. Although, deficit irrigation reduced assimilates production, seed weight didn’t reduce (Table 2), because when seed number reduced seed competition declined.

Table 2- Effect of irrigation levels on yield, yield components, WUE and HI of millet

Irrigation levels	Seed yield (t/ha)	Ear number per m^2	Seed number per ear	1000 seed weight (g)	WUE (g seed/ lit)	HI
Control	1.711 a	188.8 a	563.8 a	2.07 a	0.192 a	16.39 a
Deficit irrigation	1.016 b	134.7 b	483.4 b	1.96 a	0.227 a	13.73 b

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

Table 3- Comparison of yield, yield components, WUE, and HI in three millet species

Millet species	Seed yield (t/ha)	Ear number per m^2	Seed number per ear	1000 seed weight (g)	WUE (g seed/ lit)	HI
Proso millet	1.043 b	213.2 a	163.4 c	2.88 a	0.167 b	16.28 b
Pearl millet	0.865 b	136.1 b	408.5 b	1.54 b	0.131 b	10.78 c
Foxtail millet	2.183 a	135.9 b	998.9 a	1.60 b	0.332 a	18.14 a

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

Table 4- Effect of irrigation levels on some morphological traits of millet

Irrigation levels	Leaf number per main stem	Tiller number per plant	Ear number per plant	Ear length (cm)	Plant height (cm)
Control	12.4 a	3.7 a	2.6 a	25.0 a	96.5 a
Deficit irrigation	12.3 a	2.4 b	1.8 b	21.2 b	75.8 b

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

Table 5- Comparison of some morphological traits in three millet species

Millet species	Leaf number per main stem	Tiller number per plant	Ear number per plant	Ear length (cm)	Plant height (cm)
Proso millet	9.8 c	5.5 a	3.1 a	25.4 a	70.9 c
Pearl millet	12.1 b	1.8 b	1.8 b	17.9 b	90.7 b
Foxtail millet	15.1 a	1.8 b	1.8 b	26.0 a	96.9 a

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

Table 6- Effect of irrigation levels on some phonological traits in millet (GDD after sowing)

Irrigation levels	Tillering	Stem elongation	Ear emergence	Ripening
Control	419.1 a	715.2 b	1200.1 b	1824.5 a
Deficit irrigation	443.0 a	809.7 a	1325.4 a	1779.0 b

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

Table 7- Comparison of some phonological traits in three millet species

Millet species	Tillering	Stem elongation	Ear emergence	Ripening
Proso millet	287.0 b	797.0 a	1186.5 c	1661.2 c
Pearl millet	527.2 a	776.6 a	1265.1 b	1787.1 b
Foxtail millet	480.9 a	713.7 b	1336.6 a	1957.0 a

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

However, Prasad *et al*. (1988) in their experiment showed that irrigation increased 1000 seeds weight of Proso millet.

Foxtail millet produced the highest seed yield in this experiment (Table 3). The study of seed yield components showed that foxtail millet has the highest number of seed per ear, but its seed weight and ear number per m^2 were the lowest. More seed number in this millet could relate to longer duration between stem elongation to ear emergence and floret formation. Water stress didn't have significant effect on WUE (Table 2). However, Ibrahim *et al*. (1995) reported that water stress reduce WUE of millet. The lack of significant changes in WUE under water stress conditions shows that reducing seed yield had been proportional to to reduction of water consumption.

Deficit irrigation reduced HI significantly (Table 2). Powell & Fussell (1993) also reported that drought created by low rain, reduced HI. Thus water stress had more effects on reproductive structures than vegetative one. Foxtail millet had the highest WUE and HI (Table 3). Pearl millet genotype planted in this experiment that is local and non breeded, had the lowest HI. Although leaf number per plant was not affected by water stress, the number of tillers and ear per plant declined under water deficit conditions (Table 4). Similar results have already been reported in a number of studies that have shown reduction of tiller number caused by drought stress (Ludlow & Muchow, 1990; Mahalakshmi & Bidinger, 1985). The reduction in number of tillers is an adaptive mechanism that has been induced in response to water stress. This reduction reduces the transpiration area and hence help the plant to withstand against water stress. Similarly, the reduction in number of ear can be a regulative mechanism. It regulates physiological sinks to assimilate production. Ear length reduction with water stress was affected by floret number reduction. Water stress declined plant height, significantly (Table 4). Conover & Soonick (1989) and Madakadze (1999) also reported that drought stress reduces plant height. Since leaf number was not affected by water stress, the reduction in plant height can be a result of reduction in internodes and ear length.

In this study, Proso millet had the lowest and foxtail millet had the highest leaf number in main stem. More leaf number in foxtail millet can be a reason for producing more biomass. However, number of tillers and ear in foxtail and Pearl millets were not significantly different. On the other hand, Proso millet had the highest ear and tiller number per plant. The comparison of tiller number with ear number per plant showed that tiller fertilizing (percent) was less in Proso millet. This cause's seed yield potential in this millet to be less, because amounts assimilate has been spent to tiller production, but these tillers will not be produced any seed (Doust & Kellogg, 2006). It was observed that stem elongation started in foxtail millet earlier than the other ones, but that's ear was emerged later. Thus, there was more time for floret formation. As a result more seed per ear has been produced in this millet. In addition, the time of ripening in foxtail millet was later than the others (Li & Yang, 2008).

Pearl millet with the lowest seed yield had the lowest ear length. Foxtail millet had the highest plant height. Water stress did not impose significantly effect on the start of tillering but, it delayed stem elongation and ear emergence and accelerated ripening. Totally, seed filling period reduced in water stress conditions. Proso millet started its tillering earlier than the other millets. This could be caused more tillers produced in Proso millet (van Oosterom *et al*., 2001).

On the whole, foxtail millet had the greatest yield in both stress and non-stress conditions. This millet had the highest number of seed per ear as a result of longer interval between stem elongation to ear emergence. In addition this millet had the greatest WUE and HI. Thus, this millet genotypes is well adapted to drought stress.

References

Baltensperger, D.D. 2002. Progress with proso, Pearl and other millets. In: Janick J. and A. Whipkey (Eds.), *Trends in New Crops and New Uses.* ASHS press, Alexanderia, USA. Pp: 100-103.

Conover, D.G. and S.A. Soonick. 1989. Influence of water deficits on the water relations and growth of *Echinochloa turneriana*, *Echinochloa crus-gali*, and *Pennisetum americanum*. *Aust. J. Plant Physiol.*, 16: 221-228.

Doust, A. N. and E. A. Kellogg. 2006. Effect of genotype and environment on branching in weedy green millet (*Setaria viridis*) and domesticated foxtail millet (*Setaria italica*) (Poaceae). *Mol. Ecol.*, 15: 1335-1349.

Golombek , S. and E.A.D. Al- Ramamneh. 2002. *Drought Tolerance Mechanisms of Pearl Millet*. University of Kassel, Institute of Crop Sci, Germany.

Ibrahim Y.M., V. Marcarian and A.K. Dobrenz. 1995. Pearl millet response to different irrigation water levels: II. Porometer parameters, photosynthesis, and water use efficiency. *Emirates J. Agric. Sci.*, 7: 20-38

Kumari, S. 1988. The effects of soil moisture stress on the development and yield of millet. *Agron. J.*, 57: 480- 487.

Li, Hai-Yan and Yun-Fei Yang. 2008. Phenotypic plasticity of life history characteristics: Quantitative analysis of delayed reproduction of green foxtail (*Setaria viridis*) in the Songnen plain of China. *J. Integ. Plant Biol.*, 50(6): 641-647.

Ludlow, M.M. and R.C. Muchow. 1990. A critical evaluations of traits for improving crop yields in water- limited environments. *Adv. Agron.*, 43: 107-153.

Madakadze, I.C. 1999. Switchgrass biomass and chemical composition for biofuel in Eastern Canada. *Agron. J*., 97: 696-701.

Mahalakshmi, V. and F.R. Bidinger. 1985. Flowering response of Pearl millet to water stress during panicle development. *Ann. Appl. Biol.*, 106: 571-578.

Maqsood, M. and S. N. Azam Ali. 2007. Effects of environmental stress on growth, radiation use efficiency and yield of finger millet (*Eleucine coracona*). *Pak. J. Bot.*, 39(2): 463-474.

Powell, J.M. and L. Fussell. 1993. Nutrient and structural carbohydrate partitioning in Pearl millet. *Agron. J.*, 85: 862-866.

Prasad, U.K., R.D. Pandey, P.K. Gupta and N.N. Sharma. 1986. Effect of irrigation on growth, water requirement, water-use efficiency and yield of summer proso-millet. *Indian J. Agron*., 31: 280-284.

Richards, R.A., C. Lopez- Castaneda, H. Gomez- Macpherson and A.G. Condon. 1993. Improving the efficiency of water use by plant breeding and molecular biology. *Irrig. Sci*., 14: 93-104.

Richards, R.A., G.J. Rebetzke, A.G. Condon and A. F. van Herwaarden. 2002. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. *Crop Sci*., 42: 111- 121.

Singh, B.R. and D.P. Singh. 1995. Agronomic and physiological responses of sorghum, maize and Pearl millet to irrigation. *Field Crops Res.*, 42: 57- 67.

Stewart, J.I., R.D. Misra, W.O. Pruitt and R.M. Hagan. 1975. Irrigation corn and grain sorghum with a deficient water supply. Trans ASAE. 18: 270-280.

Umar, S. 2006. Alleviating adverse effects of water stress on yield of sorghum, mustard and groundnut by potassium application. *Pak. J. Bot.*, 38(5): 1373-1380.

van Oosterom, E. J., P. S. Carberry, J. N. G. Hargreaves and G. T. O'leary. 2001. Simulating growth, development and yield of tillering pearl millet. II. Simulation of canopy development. *Field Crop Res*., 72: 67-91.

Yadav, O.P. and S.K. Bhatnagar. 2001. Evaluation of indices for identification of Pearl millet cultivars adapted to stress and non- stress conditions. *Field Crops Res.*, 70: 201-208.

Yadav, R. S., C. Tom Hash, F. R. Bidinger, M. S. Dhanoa and C. J. Howarth. 1999. Identification and utilization of quantitative trait loci to improve terminal drought tolerance in pearl millet (Pennisetum glaucum (L.) R. Br.). In: J. M. Ribaut and D. Poland, Editors, *Proceedings of the Workshop on Molecular Approaches for the Genetic Improvement of Cereals for Stable Production in Water-Limited Environments*, CIMMYT, Mexico (1999), pp.108-114

(Received for publication 21 April, 2008)