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Yield Potential of Small Millets under Drought Condition

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An experiment was conducted to study the yield traits under reproductive stage drought in selected small millets *viz.,* finger millet (CO 15), little millet (CO 4) and barnyard millet (CO 2). The crops were imposed with drought during their flowering stage by withholding irrigation till the soil moisture reaches below 20 per cent. Barnyard millet performed better under drought at reproductive stage over other small millets, such as finger millet and little millet, in terms of more number productive tillers (11.16 plant^{-1}), ear heads (12.99 plant^{-1}), lesser reduction in ear head length (13.35 %), ear head weight (21.66 %) and 1000 grain weight (14.93 %) compared to well watered control plants. Little millet recorded the highest reduction in ear head length (19.01 %), ear head weight (39.64 %) and 1000 grain weight (23.26 %) whereas finger millet recorded the lowest number of productive tillers (9.41 plant^{-1}) and ear heads (9.71 plant^{-1}) under drought over control. Regarding the grain and straw yields of small millets subjected to water stress, it was evident from the results that the impact of water deficit at reproductive stage was prominent in little millet compared to barnyard millet and finger millet. Barnyard millet recorded the highest grain yield (18.94 g plant^{-1}) and straw yield (42.12 g plant^{-1}) followed by finger millet (14.48 and 33.14 g plant^{-1}). Little millet recorded the lowest grain yield (11.31 g plant^{-1}) and straw yield (26.01g plant^{-1}) under drought condition.

Key words: Small millets, Yield parameters, Drought

Small millets are a group of annual grasses found mainly in the arid and semi-arid areas and are nutrient-rich food sources traditionally grown and consumed by subsistence farmers in Asia and Africa. They are also unique due to their short growing season and can develop from planted seeds to mature, ready to harvest plants in 65 -120 days. Hence, they can be very well fitted into multiple cropping systems both under irrigated as well as dry farming conditions (Stanly and Shanmugam, 2013). Of the total area of 23 million ha under millets in India, small millets account for only about 3.5 million ha (Padulosi *et al*., 2015). Small millets have high production potential under optimum conditions and millets have diverse adaptation mechanisms to grow and survive under relatively marginal environments. Currently, drought is one of the most important limiting factors for crop production and becoming an increasingly severe problem in many regions of the world (Aslam *et al.,* 2006). To advance crop productivity in such drought prone areas, it is necessary to understand the mechanism of plant responses with the ultimate goal of improving crop performance. Understanding of the physiological, biochemical and molecular mechanisms of drought stress perception, manifestation and tolerance is still a major challenge in biology. Attempts to measure the degree of tolerance with single parameter have limited value because of the multiplicity of the factors and their interactions contributing to drought tolerance. Different workers used different criteria/traits to evaluate genetic differences in drought tolerance. Hence, in the present study, three small millets *viz.,* finger millet, barnyard millet and little millet have been selected to assess the various traits contributing to drought tolerance during reproductive stage of the crop.

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Material and Methods

A pot culture experiment was conducted in the Rainout shelter located at Field No. 75 of Eastern block, Department of Farm Management, Tamil Nadu Agricultural University, Coimbatore during *Rabi*, 2015. The location is in North Western Agro-Climatic Zone of Tamil Nadu at 11°N latitude and 77°E longitude and at an altitude of 426.7 m above MSL. During the cropping period in 2015-16 the average maximum and the minimum temperature were 30°C and 21°C, respectively. The total rainfall 3.1 mm was received during the cropping season (*Rabi*, 2015). The relative humidity ranged from 55.9 to 88.9 per cent. The mean evaporation rate ranged from 2.9 to 4 mm day^{-1}. The average bright sunshine hours were 5.8 hours day^{-1} and mean wind velocity was 4.7 km hr^{-1} during the cropping period. The experiment was conducted with seven replications in three small millets *viz*., finger millet (CO 15), little millet (CO 4), barnyard millet (CO 2).

All plants, in both the control and treatment groups, were watered regularly up to the flowering stage of small millets and then the irrigation was withheld to create drought at reproductive stage. Since, the selected small millets have different maturity duration, the flowering stage was not synchronized and hence, the drought was imposed after flowering of individual millets. Soil moisture content was measured using moisture meter (Delta-T Soil moisture kit - Model: SM150, Delta-T Devices, Cambridge) periodically and rewatering was done, when the soil moisture reached below 20 percent and 1/3rd of leaves started drying.

Red sandy soil was used for pot culture experiment. Pot mixture was prepared by using red soil, sand and vermicompost in the ratio of 3:1:1 and the pots (D26 ×H30 cm size) were filled with 14 kg of soil. The seeds were directly sown in the pot since minor millets used for the study are direct seeded one. After the establishment of seedlings, thinning was done to maintain three seedlings per pot uniformly across the replications. Crop was applied with recommended dose of fertilizers. Fertilizer dosage for pot culture was calculated using per hectare recommendations of small millets and other cultivation operations including plant protection measures were carried out as per recommended package of practices of Tamil Nadu Agricultural University, Coimbatore.

Since the crops tested were having different maturity duration, they were harvested in different dates. The fully matured ear heads from randomly tagged five plants were harvested separately, dried and threshed.

Results and Discussion

In the present study, significant reduction in number of productive tillers per plant was observed among the small millets for under drought condition. Comparatively less reduction in number of productive tillers was recorded in finger millet (15.0 %) over its control than the little millet (23.06 %) and barnyard millet (18.63 %).

Table 1a. Effect of reproductive stage drought on yield parameters of small millets

Crop	Number of productive tillers			Time to 50 percent flowering (days)			Number of ear heads per plant		
	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean
Finger millet	10.17	8.64	9.41	74	68	71	11.02	9.71	10.37
Little millet	13.66	10.51	12.09	53	49	51	15.13	11.29	13.21
Barnyard millet	14.33	11.16	12.75	56	51	54	14.27	12.99	13.63
Mean	12.72	10.10	11.41	61	56	59	13.47	11.33	12.40
	G	T	G x T	G	T	G x T	G	T	G x T
SEd	0.62	0.71	0.68	0.25	0.21	0.36	0.49	0.57	0.43
CD (0.05)	1.17	1.54	1.24	0.52	0.42	NS	1.08	1.15	0.94

Similar observation for number of productive tillers under drought stress was reported by (Anjum *et al*., 2011) in small millets. Yadav *et al*. (1999) demonstrated that, water stress after pollination in pearl millet reduces seed yield through reduction in number of tiller per square meter. Wietgrefe (1989) reported that water stress before panicle development reduces plant height, number of tillers and length of panicle in proso millet. This was in accordance with the results of the present study in finger millet, barnyard millet and little millet. Number of ear heads per plant decreased significantly in the small millets due to drought imposed during reproductive stage and the mean reduction accounts for about 26.94 percent due to drought. Water deficit around anthesis may lead to a loss in yield by reducing spike and spikelet number and the fertility of surviving spikelets (Royo *et al*., 1999). In present study barnyard millet showed greater recovery after rewatering with lesser reduction in number of ear heads per plant (8.96 %) over its control when compared to the finger millet (11.88 %) and little millet (25.38 %). Also, the reduction in ear head length was prominent in barnyard millet (15.87 cm) and little millet (14.49 cm) over their respective control (18.32 and 17.89 cm). Similar results were reported in prosomillet by Wietgrefe (1989).

Table 1b. Effect of reproductive stage drought on yield parameters of small millets

Crop	Ear head length (cm)			Single ear head weight (g)			1000 grains weight (g)		
	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean
Finger millet	7.86	6.58	7.22	2.89	1.99	2.44	2.58	2.04	2.31
Little millet	17.89	14.49	16.19	1.69	1.02	1.36	2.45	1.88	2.17
Barnyard millet	18.32	15.87	17.10	6.14	4.81	5.48	3.28	2.79	3.04
Mean	14.69	12.31	13.50	3.57	2.61	3.09	2.77	2.24	2.50
	G	T	G x T	G	T	G x T	G	T	G x T
SEd	0.10	0.08	0.14	0.10	0.08	0.14	0.10	0.08	0.14
CD (0.05)	0.20	0.16	0.28	0.20	0.16	0.28	0.27	0.22	0.37

The results showed that the reduction in ear head weight due to water stress at reproductive stage over the control was the highest in little millet (39.64 %) followed by finger millet (31.14 %) and barnyard millet recorded the least reduction (21.66 %) in ear head weight. (Table 1b). Mahalakshmi and Bidinger (1985) and Kumari (1988) also reported that drought stress in millets caused reduction of ear head weight.

1000 grain weight of small millets showed mean reduction of 14.8 percent under drought condition at reproductive stage (Table 1b). Similar observations were given by Sangakkara (1998) in cowpea. The reduced seed weight might be attributed to restricted mobilization of metabolites to the reproductive sinks. In *Pannisetum americanum* water deficit during grain filling stage showed reduced 1000 grain weight

(Arnon, 1972). In the present study, among the small millets, little millet recorded the highest reduction in 1000 grain weight (15.10 g) followed by finger millet (14.73 g)

In the present study, drought imposed during reproductive stage of the crop significantly reduced the grain yield in all the small millets taken for this study. Results showed that barnyard millet recorded higher grain yield of 27.24 g plant^{-1}and 18.94 g plant^{-1} under control and water stress conditions compared to finger millet (22.23, 14.48 g plant^{-1}) and little millet (19.12, 11.31 g plant^{-1}). Among the small millets, barnyard millet recorded the lowest reduction (30.46 %) in yield due to water stress over the control followed by finger millet (34.86 %) and the highest yield reduction of 40.84 per cent was observed in little millet (Table. 1c).

Table 1c. Effect of reproductive stage drought on yield parameters of small millets

Crop	Grain yield (g plant^{-1})			Straw yield (g plant^{-1})			Harvest index		
	Control	Stress	Mean	Control	Stress	Mean	Control	Stress	Mean
Finger millet	22.23	14.48	18.36	38.18	33.14	35.66	0.37	0.30	0.34
Little millet	19.12	11.31	15.22	32.03	26.01	29.02	0.37	0.30	0.34
Barnyard millet	27.24	18.94	23.09	48.85	42.12	45.49	0.36	0.31	0.34
Mean	22.86	14.91	18.89	39.69	33.76	36.72	0.37	0.30	0.34
	G	T	G x T	G	T	G x T	G	T	G x T
SEd	0.15	0.12	0.21	0.27	0.22	0.38	0.14	0.12	0.20
CD(0.05)	0.30	0.25	0.43	0.55	0.45	0.78	NS	0.24	NS

Similar result was reported in proso millet genotypes at ear emergence stage, the drought stress increased the floret death and loss of seed size which resulted in the reduction in harvest index of both ear and seed per plant (Seghatoleslami *et al*., 2008). Effects of drought stress on grain yield of *Pannisetum americanum* was evaluated and it was concluded that water deficit during grain filling stage reduced the grain yield significantly (Arnon, 1972). Ibrahim *et al*. (1995) reported that water stress reduces WUE of millet. Mahalakshmi and Bidinger (1985) reported that drought stress at seed filling stage reduced seed yield up to 50%. The measurement of seed yield components in the present study showed that, the decline in seed yield was mainly due to 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 due to condition less endosperm cells is produced in seeds (Bradford, 1994).

The yield component *viz.,* number of productive tillers, ear heads plant^{-1}, weight of ear head, length of ear head and 1000 grain weight showed significant reduction due to water stress which ultimately reflected on yield and HI of small millets. Barnyard millet performed better in terms of better yield compared to finger millet and little millet. Hence, the traits which are conferring better yield in barnyard millet may be studied further to unravel the actual mechanisms responsible for drought tolerance and to exploit these traits for genetic improvement in other millets and cereals.

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