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Leaf Temperature: A Screening Trait for Drought Tolerance in Finger Millet

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Abstract

One of the important traits that have direct relevance on plant water relations is the leaf temperature (LT). Hence, a study was conducted to evaluate 181 germplasm lines for moisture stress tolerance using leaf temperature as a trait. The results indicated that the mean LT under stress was 28.3 ºC as against 24.7 ºC in control conditions. The grain yield was 310.6 gm^{-2} in stress as against 442.4 gm^{-2} in control. In the large germplasm, the grain yield was not correlated with LT both in control and stress conditions. However, under controled condition lower LT (< 23ºC) reduced the grain yield, while under stress conditions the grain yield was gradually reduced with an increase in temperature. Based on these two parameters and in comparison to popular variety (GPU-28), genotypes have been selected for high seed yield both at low LT and high LT.

Keywords: Finger millet, moisture stress, leaf temperature, GPU-28

Finger millet is one of the important staple food crop mostly grown during *kharif* season in southern Karnataka. In the recent times, it is considered as nutraceuticular crop with good source of nutrients such as calcium (264-365 mg/100g), magnesium (66-130 mg/100g), iron (3.60-7.31 mg/ 100g), sodium (0.60-0.95 mg/100g) and potassium (294-1160 mg/ 100g) with lower quantities of anti-nutritional factors such as tannins and phytate (0.30 and 0.34 mg/100g, respectively) (Chethan and Malleshi, 2007). It is cultivated in an area of 6.3 lakh ha in Karnataka state with a productivity of 1759 kg ha^{-1} (Anon., 2013). Most of the cultivated area is occupied by the cv. GPU-28 and mostly cultivated as a rainfed crop. In the recent years, occurrence of frequent and uneven distribution of rainfall during monsoon season is a common feature (Rajegowda *et al*., 2013). Finger millet productivity under such moisture stress situations will be affected to the tune of 25 per cent (Anon., 2009). Some of the nutrients like iron and zinc are also found decreased, when crop was grown under stress conditions compared to the irrigated conditions (Unpublished). For moisture stress situation, selection of drought tolerant lines superior to popular variety, GPU-28 would be of immense useand the selected lines can also be used as parent material in breeding programmes. For screening of genotypes to drought tolerance, various techniques like leaf wilting, leaf rolling, drought susceptibility index (DSI) etc. have been used in different crops (Hirayama *et al*., 2006). It would be pertinent in finger millet as it is an un-exploited rainfed crop and no high-through put technique has been made use in screening of finger millet. Under rainfed/moisture stress conditions, the rate of water uptake from the soil may not meet the transpiration rates resulting in closure of stomata and increased leaf temperature. Hence maintenance of low leaf temperature by water mining or by reflecting radiation through epicuticular waxes would be an indicator of plant water status. In this direction, the technique of CCATD has been widely used in different crop plants (Kashiwagi *et al*., 2008). However, measurement of individual leaf temperature could be one of the easy and rapid physiological strategies to screen genotypes for moisture stress tolerance as the air temperature remain unaltered (Sajeevan *et al*., 2017). Hence, identification of germplasm lines using the leaf temperature as a screening technique has been attempted in the present study.

Material and Methods

The experiment was conducted during *kharif* 2016 in the experimental field of AICRP on small millets at the University of Agricultural Sciences, GKVK, Bengaluru. A set of selected one hundred and eightyone germplasm entries including popular varieties were used in the experiment. The experiment was laid out in factorial augmented design with two treatments (control and stress) in 6 blocks using three check varieties in each block (GPU-28, GPU-67 and PR-202) in one replication. The seeds were sown directly on 9th August 2016 in the spacing of 30 cm between rows and 10 cm between plants. Each block had 33 entries in rows of 2m length consisting of 30 entries and three check varieties. The recommended dose of manure and fertilizer, @7.5 t ha^{-1} and 50: 40: 25 kg of NPK ha^{-1}, respectively were applied. The full dose of farm yard manure was applied 15 days prior to sowing. On the day of sowing, half of the recommended dose of nitrogen and full dose of phosphorus and potassium were applied. The remaining half dose of nitrogen was applied on 40 days after sowing. Two hand weedings were taken up within 20 days after sowing and plots were maintained weed free. Thinning was carried out within 20 days after sowing to maintain the plant population of one seedling per hill. The moisture stress was imposed at the ear emergence stage (reproductive to grain filling) by withholding the irrigation for 30 days.

Observations were recorded on leaf temperature at 25days after stress imposition in comparison with control treatment. Leaf temperature (LT) was measured using infrared thermometer gun (Raytek-MINITEMP) on third leaf in three randomly selected plants. Measurements were made between 12.00 Noon to 1.00 pm (Suma, 2014). At crop maturity, grain yield was measured in continuous 1.8 meter row length leaving the border plants and the yield was expressed as gm^{-2}. The data was interpreted by frequency distribution analysis and association study by correlation-coefficient analysis.

Results and Discussion

From analysis of frequency distribution of genotypes against the leaf temperature (LT), in control condition, the LT ranged from 20.6 ºC to 29.9 ºC (Fig.1a) while, the range was wide under moisture stress, ranging from 22.9 ºCto 35.5 ºC (Fig.1b). Lower genotypic variation is expected under control conditions as

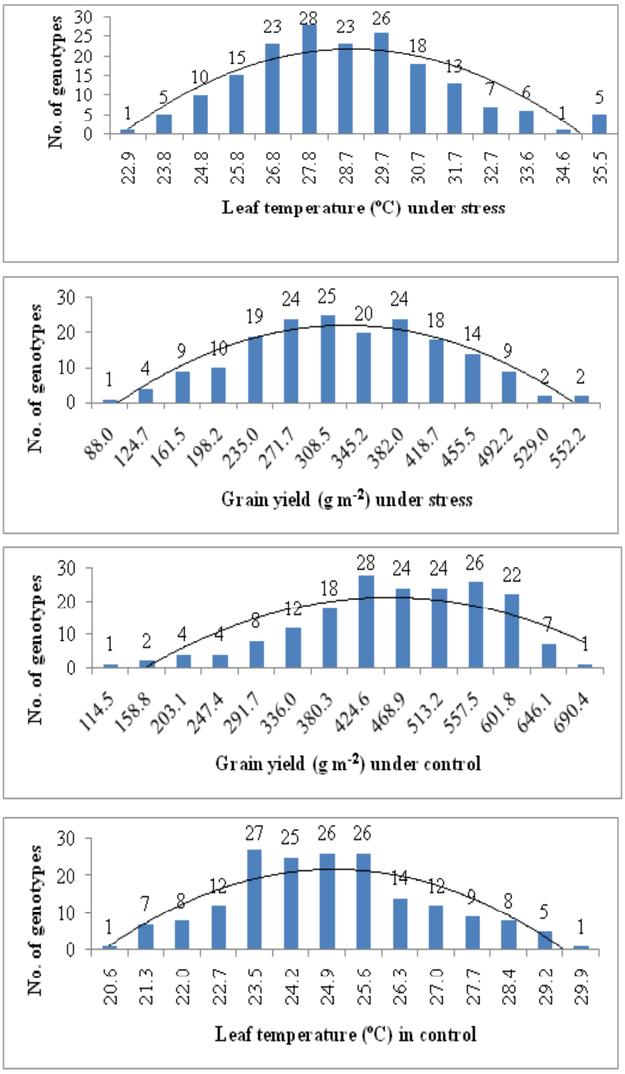

Fig.1: Frequency distribution of genotypes with respect to leaf temperature in control (a), leaf temperature in stress (b), grain yield under control (c) and grain yield under stress (d).

sufficient moisture is available for transpiration (Vinaykumar, 2015). Among 181 genotypes, the mean leaf temperature was 24.6 ºCand 28.3 ºC under control and stress condition respectively, which accounts to an increase in LT by 3.7 ºC. Similar increase of 4.0 ºC due to moisture stress was observed in sugarcane (Silva *et al.,* 2007). Out of 181 genotypes, a large number of genotypes (104 No.) showed the leaf temperature between 23.5 ºCand 25.6 ºC (Fig. 1a) while, 151 genotypes showed higher LT temperature (more than 25.8 ºC) under moisture stress conditions (Fig. 1b). Increase in LT has been observed in other crops also (Kashiwagi *et al*., 2008). Such higher LT under stress would be due to lower tissue water status and lower transpiration rates. Though there was a significant increase in leaf temperature, some of the genotypes maintained a cooler canopy under moisture stress conditions, indicating the existence of genetic variability in the present study for selection of this trait and is also evidenced by Tambussi *et al.* (2007) in other crops. The maintenance of low LT under stress condition indicates the tolerance of varieties to moisture stress and their suitability for rainfed cultivation.

The grain yield under control ranged from 114.5 gm^{-2} to 690.4 gm^{-2} (Fig. 1c) while under stress it ranged from 88 gm^{-2} to 552.2 gm^{-2} (Fig. 1d). The mean grain yield was 442.4 gm^{-2} under control and 310.6 gm^{-2} under stress condition, with a decrease of 29.7 per cent due to moisture stress for one month period. In comparison to the results, Silva *et al*. (2007) reported a decreased sugarcane yield by 20.85 per cent due to stress and also in chickpea (Kashiwagi *et al*., 2008). Higher LT under moisture stress condition lead to impaired metabolism, closure of stomata, reduced photosynthesis that result in reduced crop productivity (Hallajian, 2016). Further, the increased leaf temperature leads to disruption of PS-II machinery with reduced photosynthesis (Shahenshah and Isoda, 2010) and decreases pollination and fertilization due to pollen abortion under moisture stress condition (Sacks and Kucharik, 2011) resulting in overall reduction in grain yield.

To analyse the effect of leaf temperature on grain yield, correlation was drawn between LT and grain yield across 181 genotypes. The correlation coefficient was not significant both in control and stress conditions (Fig. 2a & 2b). Under control conditions, the maximum yield was observed at 28.1 ºC and in stress condition it was at 29.7 ºC (Fig. 1a & 1b). Under control conditions, the maximum LT was 31.1 ºC with not much reduction in yield (Fig. 1a). However, under stress conditions, the grain yield was decreased gradually after 29.7 ºC till the maximum LT of 36.9 ºC (Fig. 1b). The air temperature during the LT measurements was maximum with 30.8 ºC, while the

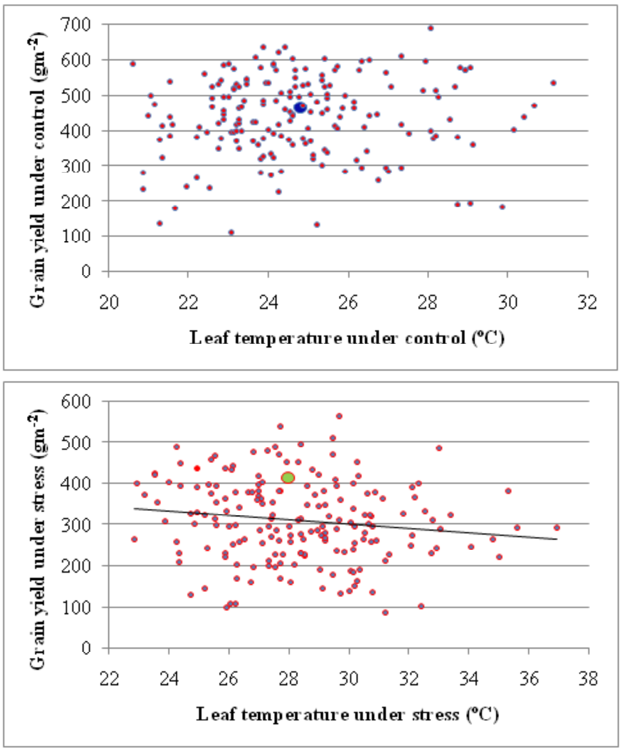

Fig 2 : Relationship between leaf temperature and grain yield under control and moisture stress conditions in finger millet genotypes (Mark filled with different colour refers to Cv. GPU-28).

soil temperature was 24.2 ºC and 33.3 ºC under control and stress treatments respectively (data not shown). The high LT under stress conditions would lead to higher respiration at the cost of food reserves and result in reduced grain yield under stress conditions. The correlations clearly indicates that more than the LT of more than 30 ºC, decreases the grain yield. Further, it also clearly indicates that finger millet will not be affected considerably upto 30 ºC and above which significantly decreases the grain yield. Interestingly, 82 genotypes performed better over the check variety GPU-28 under control conditions and 27 genotypes under stress conditions (Fig. 2a & b). This indicates the existence of better / superior varieties tolerant to drought as compared to GPU-28 (Fig. 1b). Similarly, varieties which can yield relatively better under high temperature conditions (summer season) have been reported (Opole, 2012; Yogeesh *et al*., 2016) and highlights the possibility of selection of drought tolerant genotypes better than popular variety GPU-28.

TABLE 1

Effect of leaf temperature on grain yield in finger millet genotypes under control and moisture stress conditions

Control (Non-stress)			Moisture Stress		
Leaf temperature	Grain yield (g m^{-2}) $\pm$ SE	N	Leaf temperature	Grain yield (g m^{-2}) $\pm$ SE	N
21.0	386.6 $\pm$ 61.7	7	23.0	346.3 $\pm$ 41.3	3
22.0	392.4 $\pm$ 25.6	18	24.0	359.7 $\pm$ 28.3	11
23.0	453.7 $\pm$ 22.6	22	25.0	303.7 $\pm$ 32.5	10
24.0	455.2 $\pm$ 14.1	52	26.0	307.9 $\pm$ 21.9	26
25.0	443.0 $\pm$ 21.7	24	27.0	325.2 $\pm$ 19.9	21
26.0	458.7 $\pm$ 17.6	32	28.0	305.8 $\pm$ 20.1	28
27.0	448.8 $\pm$ 65.2	5	29.0	328.8 $\pm$ 15.1	29
28.0	435.0 $\pm$ 30.9	21	30.0	291.9 $\pm$ 28.8	17
			30.9	262.4 $\pm$ 21.1	17
			32.2	297.5 $\pm$ 46.7	6
			32.9	335.3 $\pm$ 35.9	7
			34.4	256.1 $\pm$ 8.3	2
			35.5	297.9 $\pm$ 32.6	4
	r = 0.636 (Correlation between leaf temperature and grain yield under control)			r = -0.608* (Correlation between leaf temperature and grain yield under stress)	

This clearly indicates that, increase in LT beyond the threshold, will affects grain yield and such temperatures are expected under stress situations. Interestingly, under control conditions, genotypes with lower temperature up to 23 ºC had similar grain yields, below which the grain yield was decreased markedly showing a positive relationship between LT and grain yield (r= 0.636 NS, Table 1). However, under stress conditions, considerable decrease in grain yield was noticed with increased temperature above 24 ºC and showed a significant negative relationship (r = -0.608*). This indicates that under control conditions, temperature between 28 ºC and 30 ºC appears to be optimum, while under stress conditions, high temperature is undesirable. The study is evidenced by Shaibu *et al.* (2015) where they reported that canopy temperature had direct negative effect on grain yield (-0.365) and indirect effect through leaf temperature (-0.011) in maize when temperature ranged from 23 ºC to 35.5 ºC. Further, in rice plants, Hirayama (2006) reported that the leaf temperature under moisture stress had a significant negative correlation with transpiration (r= -0.733), photosynthetic rates (r=-0.494) and a significant negative correlation between LT and grain yield (r=-0.532). Hence, the present data suggests that the maintenance of low LT is an important trait in determining higher grain yields of finger millet under stress conditions.

Therefore, to identify superior genotypes, data was compared with leading variety GPU-28. The mean yield of GPU-28 was 465.4 gm^{-2} and 414.3 gm^{-2} in control and stress conditions respectively (Table 2). Among the genotypes selected, the genotypes which are having markedly lower leaf temperature than

TABLE 2
List of superior genotypes compared to GPU-28 based on differences in leaf temperature

Group	Sl.No	Genotypes	Leaf temperature in control (°C)	Leaf temperature in stress (°C)	Grain yield in control(g m^{-2})	Grain yield in stress(g m^{-2})
I	1	GPU-28	24.7	28.0	465.4	414.3
II	1	GE-388	26.7	27.0	447.1	419.6
	2	GE-524	22.9	23.5	445.9	422.9
	3	GE-449	22.9	23.5	431.2	426.2
	4	GPU-66	20.6	24.9	589.4	438.2
	5	GE-4596	23.8	25.9	578.1	438.7
	6	L-5	24.9	26.1	473.1	444.8
	7	GE-319	23.5	24.4	544.9	449.3
	8	GE-4730	26.3	27.9	598.8	454.5
	9	GE-4798	23.9	25.4	476.3	458.2
	10	GE-4929	22.6	25.5	494.5	470.0
	11	GE-144	26.1	26.8	484.0	470.6
	12	HR-911	22.6	26.8	525.9	476.9
	13	GE-145	25.3	26.4	556.3	481.1
	14	GE-156	27.1	27.5	525.4	489.8
	15	GE-294	22.9	24.3	497.5	490.8
	16	GE-6370	26.9	27.7	564.7	538.7
		Mean	**24.5**	**26.3**	**529.1**	**460.8**
III	1	GE-208	24.1	30.3	589.1	420.0
	2	GE-1074	28.8	29.0	578.8	421.7
	3	GE-1265-B	25.9	32.7	498.9	433.5
	4	GE-834	24.5	28.8	497.2	434.7
	5	GE-6336	25.1	30.3	502.5	452.5
	6	GE-1855	23.1	28.3	522.9	453.1
	7	GE-4568	24.9	29.5	527.4	471.3
	8	GE-1657	24.1	33.0	587.9	488.7
	9	GE-4969	24.6	28.4	605.2	495.2
	10	GE-1264-A	24.0	29.5	537.9	511.4
	11	GE-4597	24.4	29.7	637.2	565.7
		Mean	**24.8**	**29.7**	**558.6**	**471.4**

GPU-28 had a mean yield of 529.1gm^{-2} & 460.8 gm^{-2} in control and stress respectively. Whereas, under stress conditions, genotypes which had higher leaf temperature than that of GPU-28 also showed a higher mean yield of 558.6 gm^{-2} and 471.4 gm^{-2}, suggesting other mechanisms apart from LT which may be operating for higher productivity. The genotypes which are selected based on both lower LT and higher LT with higher grain yield as compared to the GPU-28 under stress condition can be further utilized in breeding programmes aimed at developing drought tolerant finger millet and also to study the mechanism of drought tolerance in finger millet.

From the present study, it is concluded that measurement of LT is a high through-put and effective trait to screen large number of finger millet genotypes easily and rapidly in identification of drought tolerant genotypes.

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