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Genotypic variability for increase in specific leaf weight and its relationship with yield components under post-flowering moisture stress in *rabi sorghum* (*Sorghum bicolor*)*

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Sorghum (*Sorghum bicolor* L.), an important cereal crop, is grown for food, feed, fodder and industrial purposes in India. Compared to other cereals, it is more tolerant to many stresses, including heat, drought, salinity and flooding. Sorghum productivity during post-rainy season is limited by post-flowering drought. Enhancing drought tolerance of winter *(rabi)* sorghum is a priority as post-flowering drought remains a major factor contributing to sorghum production instability. Severe drought stress during post-flowering stages coinciding with anthesis or post-anthesis stages in post-rainy sorghum resulted in loss of chlorophyll, cell electrolyte leakage, flag leaf yellowing and grain pre-maturation (Beltrano and Ronco 2008). Different morpho-physiological traits have been potentially utilized for screening genotypes of different crops under water stress conditions. These include seedling traits like shoot weight, root weight, root and shoot lengths, root : shoot ratio, specific leaf area, specific leaf weight, coleoptiles length at seedling stage and root morphology (Songsri *et al.* 2008, Amjad Ali *et al.* 2009). However, success of breeding under stress condition is low due to limited understanding of genetic basis of drought tolerance in crop, which is a pre-requisite for a geneticist to evolve superior genotype through either conventional breeding methodology or genetic engineering. Therefore, identification and analysis of plant traits with significant association in respect to drought tolerance and high productivity under moisture stress is necessary (Rauf and Sadaqat 2008). Specific leaf weight (SLW, the ratio of leaf weight to area) is reported to be related positively to drought tolerance in several crops and has been suggested as a selection criterion in several breeding programmes. The present study is aimed at examining the effect of moisture stress on SLW and its relationship with yield components under postflowering moisture stress conditions in sorghum.

The experiments were conducted at the Research Farm of Centre for Rabi Sorghum, Directorate of Sorghum Research, Solapur (17° 40'N, 75° 55'E, altitude 457 m). A set of six genotypes ('CSV 216R', 'CSV 18', 'M 35-1', 'SPV 1626', '296 B' and' C 43') were evaluated during 2007–08 and 2008–09 in post-rainy seasons. Seeds were sown in a split-plot design with three replications on 11 October in 2007 and 20 October in 2008. Each plot consisted of 4 long 10 rows with row-to-row spacing of 0.60 m. A basal dose of 20 kg/ha N and 20 kg/ha P_2O_5 as di-ammonium phosphate was broadcast before sowing. The seeds were hand sown and the field was irrigated to saturate the soil profile with water to ensure uniform germination. The crop was thinned to two plants/hill after 12 days of emergence and then to one plant/hill after 20 days of emergence to maintain plant-to-plant spacing of 0.15 m. Twenty days after emergence, an additional 20 kg/ha N as urea was side dressed, followed by irrigation. The crop was grown under intensive crop protections measurements to keep free from pests and diseases. Recommended packages of practices were followed. During both the seasons, there was no rainfall during crop growth period. Treatments of two water regimes (no-stress and stress) were created during post-flowering period. In 'stress' treatment the crop was kept free from water stress till initiation of flowering and thereafter irrigation was withheld during the remaining growth period. In 'no-stress' treatment crop was kept free from water stress till maturity by providing additional irrigations at 16, 37, 56 days after the beginning of stress treatment during post-flowering growth period. Soil moisture was monitored in both the treatments after three days of every irrigation during the post-flowering growth period by gravimetric method.

Plant growth analysis was performed at 18, 40 and 63

*Short note

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(physiological maturity stage) days after imposing the stress. Plant sample of 1.2 m^2 area was collected by cutting the plants from the ground level. Plant parts were separated into leaves, stem and panicles and were dried in oven at 80 °C for 48 hr to record the oven dry weight. Leaf area and plant height were recorded on five representative plants in the two middle rows of each plot. Leaf area was estimated by measuring the length and breadth of top six leaves and calculated by the formula, length × breadth × 0.71. Specific leaf weight was calculated as the ratio of leaf weight to leaf area. At maturity, plants were harvested from 10.8 m^2 (3m × 6 rows of 0.60 m row-to-row spacing) area. Crop was harvested on 28 February in 2008 and 11 March in 2009. The dry weights of vegetative parts and panicles were recorded after drying the samples in a hot air oven for 48 hr at 80°C. The panicles were threshed and grain yield was recorded. The data collected from the experiments were subjected to ANOVA using *Statistix* 8.1 software for assessing the genotypic interaction with post-flowering moisture stress.

Genotypic differences were highly significant for all the traits (fodder dry weight, panicle dry weight, grain yield, total dry mater and specific leaf weight (Table 1). All traits, except fodder dry weight, differed significantly under two water regimes during post-flowering growth period. Genotype × water interactions differed significantly for all observed traits except fodder dry weight and total dry matter. All yield components (fodder weight, panicle weight, grain yield and total dry matter) reduced significantly in all the six genotypes under moisture stress conditions imposed. Genotypic variations for the reduction in yield components under moisture stress conditions were reported (Talwar *et al.* 2009). The reduction in the leaf gas exchange under drought has been reported (Kholova *et al.* 2010), and this might have led to lower biomass accumulation and grain yield. Under stress conditions, fodder and total dry matter production were highest in CSV 18, followed by M 35-1 and was the lowest in 296 B and C 43. On the other hand, panicle weight and grain yield were highest in M 35-1 and lowest were in 296 B. Average reduction of 20.5, 36.9, 37.8 and 26.7 % was recorded in fodder weight, panicle weight, grain yield and total dry matter, respectively under stress conditions during postflowering period. The minimum reduction in fodder weight, panicle weight, grain yield, total dry matter under stress as compared to non-stress conditions were 6.9%, 3.9%, 7.6%, and 6.9%, respectively in 'M 35-1'. On the other hand, maximum reduction in panicle weight and grain yield under stress as compared to non-stress conditions were recorded as 64.1 and 64.4%, respectively in '296 B', while maximum reduction in fodder and total dry matter were 45.7 and 76.4 %, respectively in 'C 43'. This indicates that vegetative growth under water stress conditions was more affected in 'C 43' and reproductive growth was more affected in '296 B'.

Genotypic variations were clearly evident for green leaf area retention (GLAR) at physiological maturity as compared to flowering under both stress and non-stress conditions (Table 2). There was significant reduction in GLAR at physiological maturity under stress conditions as compared to non-stress conditions in all the genotypes (Talwar *et al.* 2009). A severe drought stress during post-flowering stages like anthesis or post anthesis causes loss of chlorophyll, cell electrolyte leakage, flag leaf yellowing and grain pre-maturation (Beltrano and Ronco 2008, Talwar *et al.* 2009). The maximum GLAR at physiological maturity under stress treatment was recorded in 296 B, followed by M 35-1 and minimum GLAR at physiological maturity was recorded in CSV 18 and CSV 216R. The increase in biomass accumulation during postflowering growth period indicates that it decreases in stress conditions as compared non-stress conditions in all the genotypes. Maximum and minimum accumulation of biomass under stress conditions was recorded in M 35-1 and CSV 216R, respectively.

Specific leaf weight (SLW), differs significantly among the genotypes under both water regimes. There was significant increase in SLW under stress conditions as compared to that non-stress conditions. SLW is reported to be related to drought tolerance in several crops and has been suggested as a selection

Table 1 Variation in yield components, fodder weight, panicle dry weight, grain yield and total dry matter in six genotypes grown under irrigated (IR) and un-irrigated (UNIR) conditions during post-flowering growth period

Genotype	Fodder dry weight (g/m^2)		Panicle dry weight (g/m^2)		Grain yield (g/m^2)		Total dry matter (g/m^2)	
	IR	UNIR	IR	UNIR	IR	UNIR	IR	UNIR
CSV 216 R	648.9	471.1	449.3	255.8	374.0	193.8	1 098.0	727.0
CSV 18	1040.0	853.0	319.6	249.8	250.0	198.2	1 359.3	1 103.0
M 35-1	782.2	728.0	384.0	369.0	316.0	292.0	1 166.3	1 097.0
SPV 1626	702.2	546.7	529.8	283.1	424.5	211.1	1 232.0	829.7
296 B	302.2	328.9	304.7	109.3	216.2	77.0	607.0	438.3
C 43	654.8	355.6	453.6	272.7	372.9	242.7	1 108.3	628.3
Mean	688.4	547.2	406.8	256.6	325.6	202.5	1 095.2	803.9
SEm±	51.4		11.2		42.4		69.0	
CV%	15.5		14.3		18.6		7.1	

Table 2 Variation in green leaf area retention (GLAR) at physiological maturity, biomass accumulation during post-flowering period and specific leaf weight in six genotypes grown under irrigated (IR) and un-irrigated (UNIR) conditions during post-flowering growth period

Genotype	Per cent GLAR at physiological maturity		Per cent biomass accumulation during post-flowering growth period		Specific leaf weight (g/m²)	
	IR	UNIR	IR	UNIR	IR	UNIR
CSV 216 R	37.0	6.3	109	48	11.63	19.67
CSV 18	44.2	5.7	97	73	8.52	12.63
M 35-1	57.0	30.2	158	144	7.66	17.88
SPV 1626	22.9	8.8	102	85	8.20	13.17
296 B	71.0	38.6	184	111	7.64	8.90
C 43	64.8	19.3	126	97	7.03	10.67
Mean	49.6	18.2	129.8	93.3	8.5	13.8
SEm±	5.2	32.3	1.65			
CV%	27.2	28.2	17.6			

criterion for breeding programmes targeting low rainfall areas. Genotypes with a high specific leaf weight have leaves with a small surface area to volume ratio, in other words, thick leaves, which is an advantage in using water efficiently. Significant genotypic variations were recorded in the per cent increase in SLW under stress conditions in six genotypes evaluated. Increase in leaf thickening (decrease in specific leaf area or increase in SLW) under drought conditions have been reported in pearlmillet (Kholova *et al.* 2010) and sugarbeet (Ober *et al*. 2005). The range of increase in SLW under stress conditions as compared to that under non-stress conditions was 48.2 to 133.4 %. The maximum increase in SLW was recorded in M 35-1 and minimum in CSV 18. Genotypic variations in the increase in leaf thickening under moisture stress conditions have been reported (Kholova *et al.* 2010) and it was more in tolerant than sensitive genotypes in pearlmillet. Positive relationships between increase in SLW under stress conditions with fodder weight (R^2=0.25), total dry matter (R^2=0.46), panicle weight (R^2=0.80) and grain yield (R^2=0.71) were recorded (Fig 1). Comparatively,

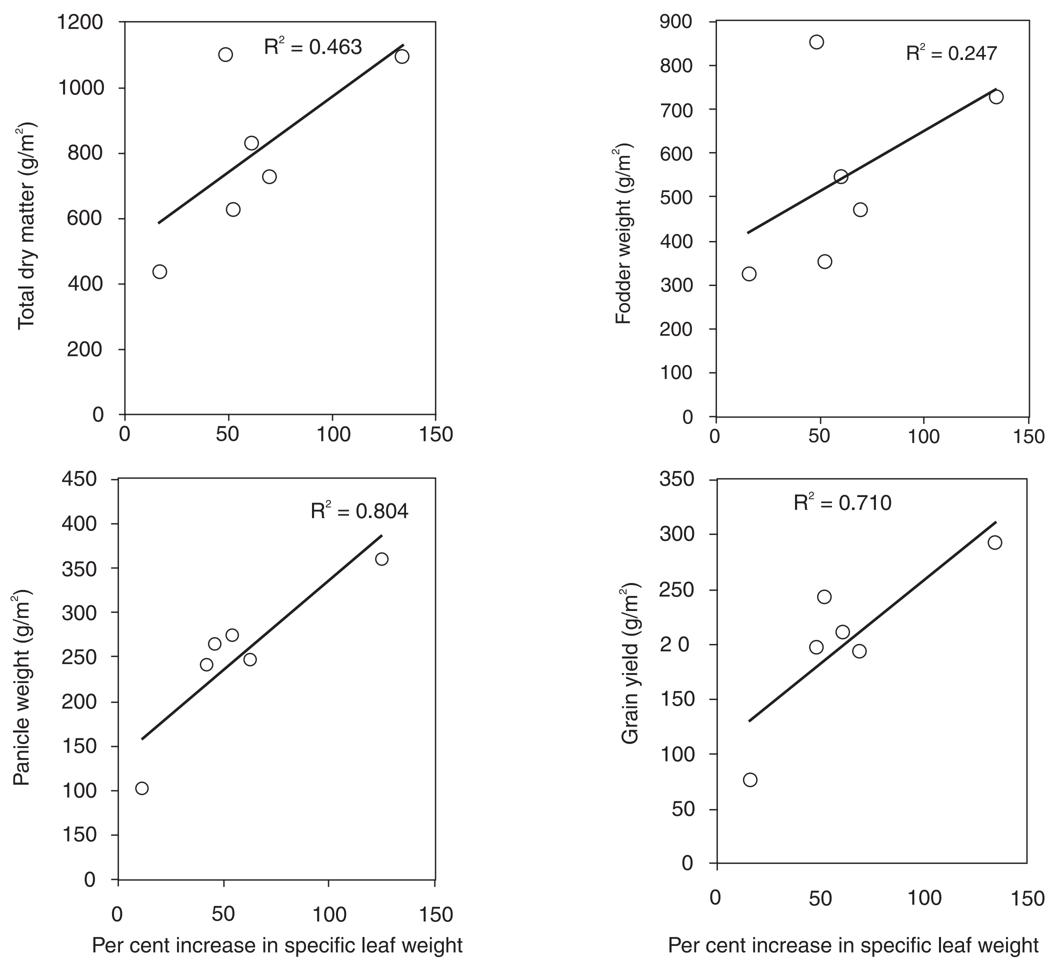

Fig 1 Relationship of per cent increase in specific leaf weight under moisture stress with yield components (total dry matter, fodder weight, panicle dry weight and grain yield) in six genotypes grown under irrigated (IR) and un-irrigated (UNIR) conditions during post-flowering growth period.

the relationship with fodder weight is weaker; this may be due to the low biomass partitioning to grain yield in 'CSV 18'. These relationships between increase in SLW under stress conditions and yield components indicate that increase in leaf thickness is an important adaptive trait to moisture stress during the postflowering growth period.

SUMMARY

The experiments were conducted during 2007–08 and 2008–09 in *rabi* seasons to evaluate six genotypes for postflowering moisture stress and examine the relationship of specific leaf weight with yield components. Two water regimes 'irrigated' and 'un-irrigated', were imposed during post-flowering period. Average reductions of 20.5, 26.7, 36.9, and 37.8% was recorded in fodder weight, total dry matter, panicle weight and grain yield, respectively under moisture stress conditions. Specific leaf weight (SLW) increased significantly under un-irrigated as compared to irrigated conditions in all the genotypes suggesting increase in leaf thickness under moisture stress conditions. The range of increase in SLW under stress conditions as compared to that under non-stress conditions was 48.2% to 133.4%. Significant genotypic variations were noticed in the increase in SLW under stress conditions. The maximum increase in SLW was recorded in M 35-1 and minimum in CSV 18. Positive relationships between per cent increase in SLW under stress conditions with total dry matter (R^2=0.46), panicle weight (R^2=0.80) and grain yield (R^2=0.71) were recorded. These relationships between increase in SLW under stress conditions and yield components indicate that increase in leaf thickness is an important adaptive trait to moisture stress during the postflowering growth period.

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