# Sorghum improvement for abiotic stress adaptation and climate change resilience in dryland conditions

**Poster** · December 2015

DOI: 10.13140/RG.2.1.2893.5767



S.S. Rao
Indian Institute of Millets Research


Harvinder Talwar
Indian Institute of Millets Research


Prabhakar Bhat
Indian Institute of Millets Research


P. V. Vara Prasad
Kansas State University

# Sorghum improvement for abiotic stress adaptation and climate change resilience in dryland conditions

S.S. Rao[a]*, H.S.Talwar[a], B S Rayudu[a], N .Kanna Babu[a]. C. Aruna[a], TGN Rao[a], Prabhakar[a], P.V.V. Prasad[b] , and J.S. Mishra[a]

a ICAR-Indian Institute of Millets Research, Rajendranagar, Hyderabad- 500030, TS, India;
b Agronomy Dep.,Throckmorton Hall, Kansas State University, Manhattan KS 66506, USA.
*ssrao@millets.res.in

## Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the important nutritional cereal grown for food, feed, fodder and bioenergy in India and around the world. Drought and heat stress are major environmental constraints limiting productivity. In India, sorghum is grown over 7.00 m ha both in rainy (3.00 m ha) and postrainy (4.05 m ha) seasons. Average yields are ≤1.0 t ha$^{-1}$ due to negative impacts of abiotic and biotic stresses.

Sorghum productivity is reduced due to the occurrence of drought and heat stresses during pre- and post-flowering stages. There is a need to improve yield and climate change resilience (drought and heat stress tolerance) of dryland sorghum due to the projected climate change and its variability.

The objectives of this research were to 1) quantifying the impact of drought (D), high temperature (HT) and combined stress (D*HT) on sorghum physiological traits and 2) assessing the climate effects on bioenergy sorghum yield and sugar quality traits.

## Materials and Methods

Two experiments were conducted i,e. one in controlled environment (growth chambers) and other is in field.

Expt. 1: Growth chamber experiment: The treatments include 1) control [Irrig. + optimum temp. (OT) (32/22° C day and night time, resp.]; 2) drought stress [drought for 20 days + OT (32/22°C)]; 3) HT stress [Irrigation+ HT (38/28°C)]; and 4) combined stress [drought + HT (38/28°C)]. Sorghum hybrid DKS-29-28. Location: Manhattan, Kansas State University, KS , USA . Growth chamber Model: Conviron CMP3244.

Expt. 2. Field experiments: Two field trials (1. rainy (June- Sept.) and 2. postrainy (Nov –Jan ) seasons).

Design: Split-plot (Main plots: Planting dates; Subplots: Genotypes).
Planting dates: 1. Rainy –five [1 June, 16 June, 1 July, 16 July, & 1 August ); 2. Postrainy- five [9 Nov, 25 Nov, 14 Dec, 31 Dec. &15 Jan]
Genotypes: 1. Rainy- four (SSV84, SSV74, CSV19SS & CSH22SS ; 2. Postrainy- four (SSV84, CSV19SS, CSH22SS & PAC 52093)
Location: Hyderabad, India (17°27' N, 78°28' E, and 524.6 m MSL).
Soil particulars: Medium black clay loam; depth ≥1.0 m; clay 50%; silt 29%; coarse sand 6%; organic carbon 0.51%; pH 7.5; FC 36%; WP 18%; BD1.28 g cc$^{-1}$; EC 0.138 d Sm$^{-1}$; soil available N, P and K 159,16, and 672 kg ha$^{-1}$, res.
Plot size, spacing: 18.0 m$^2$; 45 cm between rows and 15 cm between plants (14 plants m$^{-2}$).
Crop husbandry: Fertilizer @ 80–40–40 kgN–$P_2O_5$–$K_2O$ ha$^{-1}$ in the form of urea, single superphosphate, muriate of potash, res.) with half the N and all P & K as basal; the rest of the N was side-dressed at 10 leaf stage i.e., panicle initiation.

Image 1. Data collection on leaf temperature, SPAD, photosynthesis rate etc. in the growth chambers.

Data collection: Crop phenology, yield components, grain & stalk yields and juice sugar quality traits were collected. Data were analyzed according to the Fisher's method of analysis variance (ANOVA).

## Results

### Experiment 1:

- Leaf area decreased by 25% in D *HT stress over OT. (Fig.1).
- Average leaf temperature increased by 8.0, 5.0, 2.5% resp., in combined, HT and D over OT (Fig. 2).
- Root length and root-shoot ratio significantly increased by 11.0% in combined stress over OT.
- Leaf water content decreased by 16.1% and 35.0% respectively, in D and D*HT over OT (Fig.1).

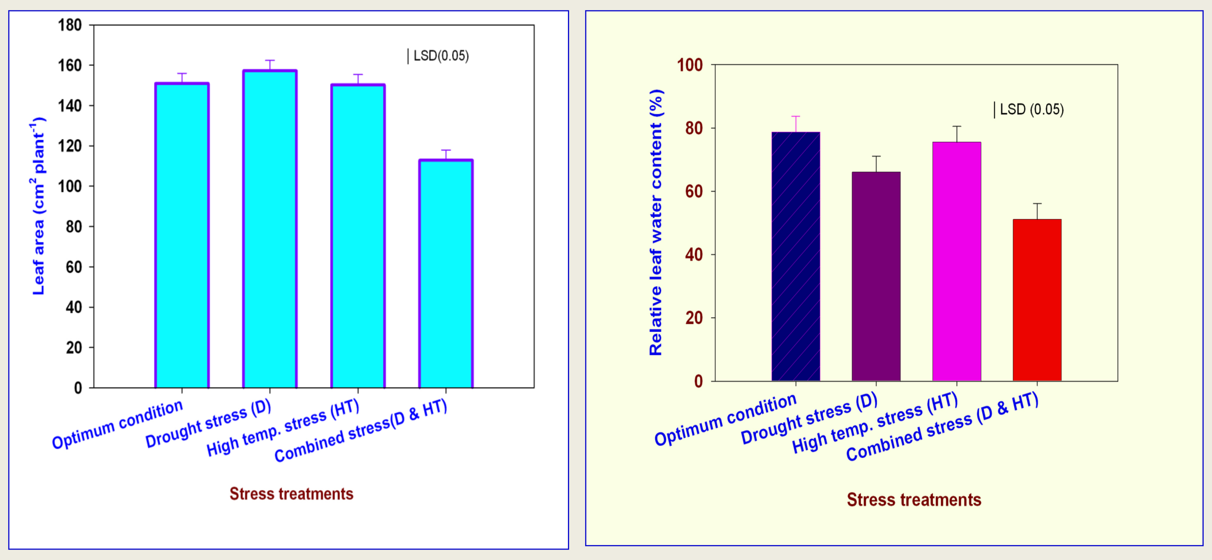


Figure1: Effect of drought and combined stress on leaf area (left panel) and crop water status (right panel) during pre-flowering stage of sorghum.

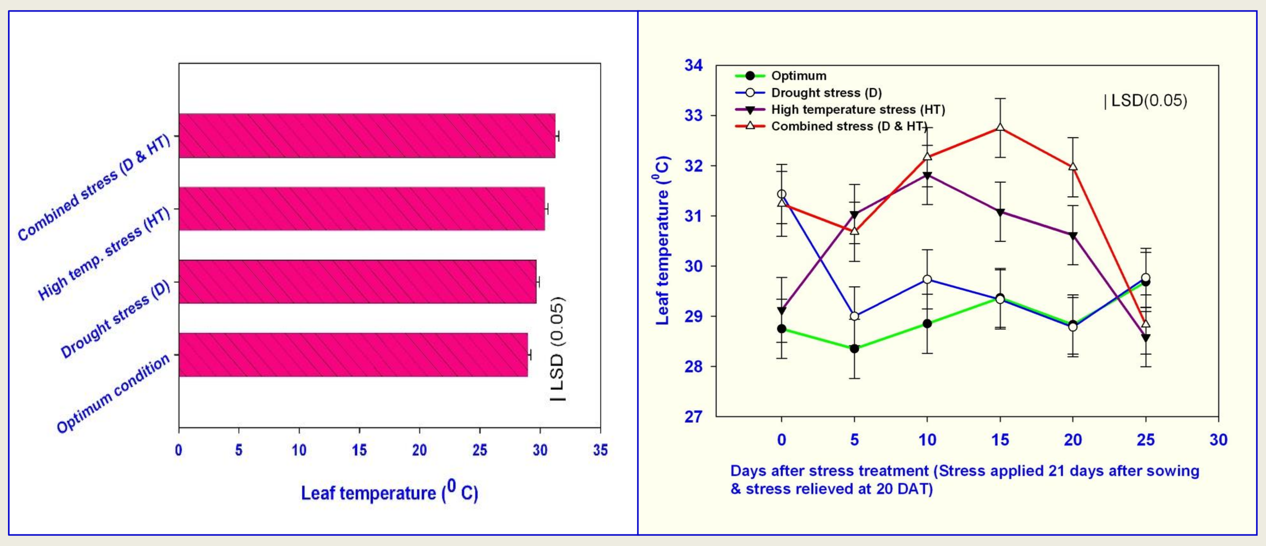


Figure 2 Effect of heat (HT) and combined (D *HT) stress leaf tissue temperature during pre-flowering stage of sorghum.

### Experiment 2:

- In rainy season, June first week planting gave highest fresh stalk yield (58.1 tha-1) across genotypes and years (Fig. 3).
- Across plantings, sweet sorghum hybrid CSH22SS produced 29.0% more bioethanol yields than SSV84, while SSV74 too yielded 16.6% more than SSV84.
- Hybrid CSH22SS produced significantly ($P \leq 0.05$) fresh stalk, grain, sugar and ethanol yields over inbred genotypes SSV84 or SSV74.
- Based on biomass and sugar quality traits, cv.CSH 22SS and SSV74 were more stable across planting dates (climates) and resilient to climate change in rainy season.

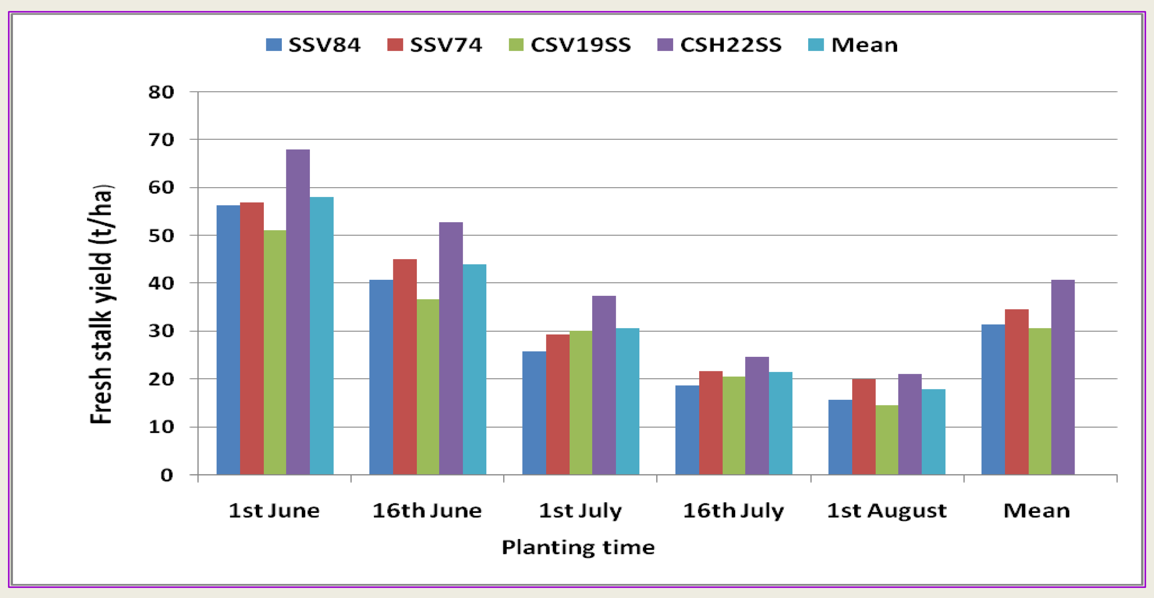


Figure 3 Sweet sorghum planting effects on stalk yield in rainy season showing decrease in yield when planting delayed.

Image 2. Sweet sorghum cultivar expression when staggered planted ( left panel) and superior hybrid (CSH22SS) across the plantings ( right panel)..

- In postrainy season, crop phenology shortened as planting delayed from November to December and CSV19SS was the earliest and stable across the plantings.
- Mean leaf area index (LAI) at flowering ranged from 1.9 (31Dec.) to 3.7 (9Nov.) across plantings.
- Sweet sorghum stalk yield (17.1 to 25.1 t ha$^{-1}$) decreased by 26-36% in December planting over November (Fig.4). Cv. PAC 52093 (25.1 tha$^{-1}$) recorded 10 % more stalk yield than CSH22SS (22.5 t ha$^{-1}$).
- Mean brix across plantings ranged from 14.8 to 16.3%. Total soluble sugars ranged from 11.1 to 16.1% across plantings and cv.CSV19SS was superior (16-33%) to others.
- Based on stalk and sugar yields, cvs. PAC52093 & CSV19SS were stable in postrainy season across staggered plantings and are climate resilient.

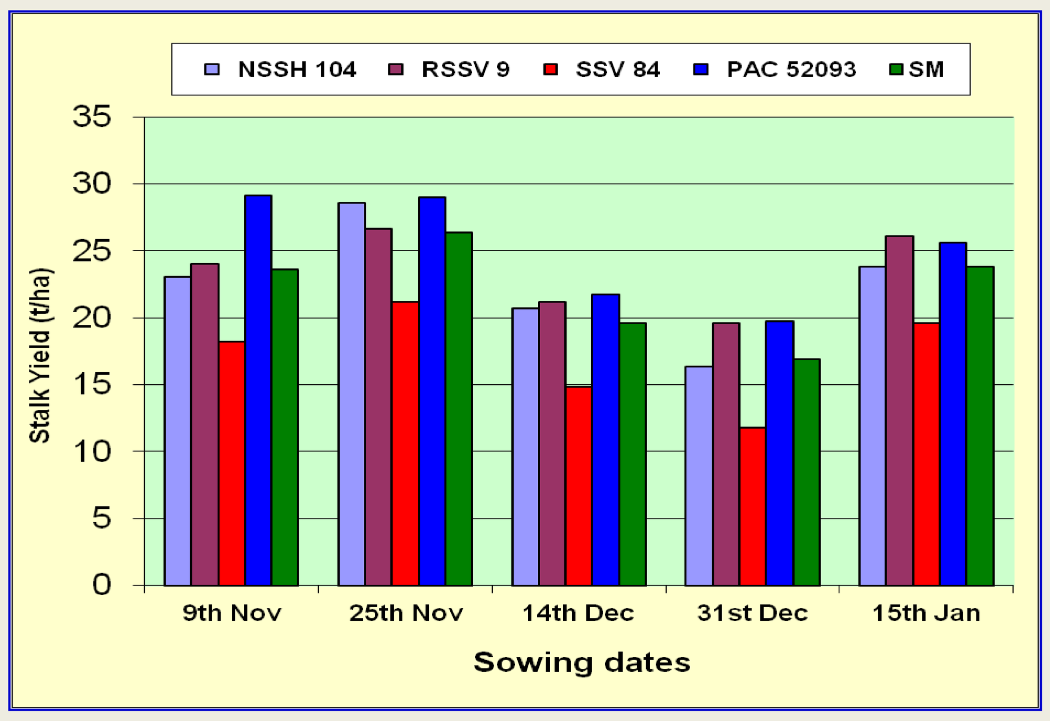


Figure 4. Sweet sorghum fresh stalk yield as influenced by fortnightly staggered planting in postrainy season

Image 3. Growth of sweet sorghum cultivars at fortnightly planting in postrainy season showing better expression at early (9Nov- extreme left panel) to late planting ( 31 Dec. extreme right panel).

## Conclusions

- This research suggests that there are opportunities to select and improve sorghum drought and heat tolerance in combination than either.
- In both rainy and postrainy seasons, crop phenology shortened, while leaf area index, and biomass too decreased as plantings delayed.
- Cultivars CSH 22SS & SSV74 in rainy season, and PAC52093 & CSV19SS in postrainy were more stable across plantings for biomass and sugar quality traits, and possessed climate resilience in dryland condition.

## Path-forward

- Promising genotypes identified from this study will be tested at multi-environments under drought and heat stress conditions in both rainy and postrainy seasons.
- Collaborate molecular breeders to detect QTLs that could help understand the underlying genes associated with plant traits governing drought & heat stresses and bioenergy traits, and could be used for development of molecular markers for MAS.

## Acknowledgements

We thank Indian Council of Agricultural Research and National Agricultural Innovative Project (funded through World Bank grant) and Agronomy Deptt., Kansas State University, Manhattan USA for award of fellowship to senior author under sabbatical leave .