AICSIP Sorghum Physiology Progress report, Rabi 2012-13
SS Rao co-ordinating with scientists at SAUs

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Executive summary

Trial 1R: Preliminary evaluation of diverse germplasm for rabi adaptation: Forty-eight durra landraces rabi sorghum germplasm along with three checks were evaluated at Parbhani, Tandur, Bijapur, Solapur and Rahuri. Entries Honawad, Pathari local, RSV-1458 and Bidar local had shown high SPAD values (54.6-59.3) than check Phule Chitra. Entry Halyal local maintained high photosynthesis combining high canopy temperature depression indicating its water conservation efficiency in stored soil moisture stress condition. RWC had shown significant positive relationship with stomatal conductance at flowering (r=0.290; P≤0.05). High biomass yields were recorded by Pathari local, Mundewadi local, Khadkat local, and Kavalagudda mungaru. Biomass has shown significant positive relationship with 1000- seed weight (r=0.382; P≤0.05). Landraces germplasm which gave higher yield across locations include Patoda local (27%), Kavalagudda local (24%), RSV 1426 (21%) Tikota (19%) and Nimbodi local (16% more) than best check CSV22R.

Trial 2(M) & 3(S): Evaluation of advanced rabi sorghum entries for drought adaptation in medium in medium and shallow soils: Sixteen advanced rabi-adapted sorghum entries along with three checks were phenotyped in both medium (≤75 cm soil depth) and shallow soils (≤45 cm soil depth) at Bijapur, Parbhani, Rahuri, Solapur and Tandur. Entries BJV 116 (0. 351), RSV 1420 (0.464) and CRS 19 (0.554) showed less drought susceptibility index (DSI) means more plant height stability under drought than checks. The relationship of days to flowering with plant height was significantly positive (r=0.537, 0.582; P≤0.05 in medium and shallow soil, res.) in both the soil depths. Higher biomass at physiological maturity showed positive correlation (r=0.598; P≤0.05) with grain yield in shallow soil stress conditions.

Entries CRS 20, BJV 114, and BJV 116 recorded high crop water status than checks especially in shallow soil stress condition. The mean SPAD units varied from 48.3 to 55.6 in medium and 40.0 to 46.7 in shallow soil. Higher SPAD units (more leaf staygreen) resulted in realization of higher 1000-seed weight as could be seen from significant positive relationship between the two (r=-0.549; and 0.523; P≤0.05, in medium and shallow soil res.). Entries BJV116, BJV 103 and Phule Anuradha showed higher Photosynthesis (Pn) rate in shallow stress than medium. Pn rate had shown significant positive correlation with stomatal conductance (r=0.503; P≤0.05 in medium soil). Superior entries for stover yields are BJV 83 in medium soil and RSV 1098 in shallow soil. In Entries stable for stover yield across soil depths in terms of DSI include BJV 103, RSV1420 and RSV 1098.
Mean grain yield ranged from 1818 to 2230 kg ha\(^{-1}\) and 1219 to 1706 kg ha\(^{-1}\) in medium and shallow soil, respectively. In medium soils, none was significantly superior to check Phlue Chitra, while RSV 1098 and MSV 71 were on par with check. On the contrary, none was superior to check M35-1 in shallow soils. Mean grain yield reduced by 26.2% in shallow soils over medium with a range observed was between 4.2 and 43.9%. In terms of DSI for grain yields, check M35-1 itself was stable (DSI=0.162). Interestingly, entries recorded low DSI for both grain and stover yields than means more stable were BJV 103 and RSV1420.

**Trial 4 R and 4 Irrg: Evaluation of sorghum plant types for root characteristics:** Thirteen advanced rabi sorghum genotypes including checks were characterized for root and shoot traits that contribute survival under flowering and postflowering drought and heat stress. Mean plant height, decreased by 15.0% in rainfed than irrigated. Mean RWC, SPAD and Pn rate declined by 4.5, 11.3 and 12.5% due moisture stress than control. CRS19 and RSV1410 have showed no reduction in above traits due to stress and were more stable than check.

Mean root length at physiological maturity under rainfed condition varied from 64 to 108 cm/plant. CSV22R and RSV 1429 were stable in stress condition. Root number per plant at maturity varied in 22 to 46 and 43 to 78, respectively in rainfed and irrigated conditions. Interestingly, RSV1410 recorded higher root number in rainfed conditions than check. Root mass declined by 61.0% (range: 25-71 g/plant) due to moisture stress than irrigated. BJV83 alone recorded significantly superior (P\(\leq\)0.05) root mass in drought stress conditions.

**Detailed report**

Sorghum (Sorghum bicolor (L.) Moench) is one of the important cereal crops grown for food, feed, fodder and bioenergy production around the world. In India, it is grown over 7.65 m ha both in kharif (3.00 m ha) and Rabi (4.65 m ha) seasons. Drought and temperature stresses (low and high) occurring during pre-and postflowering stages are major environmental constraints limiting sorghum productivity, apart from biotic stress conditions. Average yields are \(\leq\)1.0 t ha\(^{-1}\) due to negative impacts of abiotic and biotic stresses. Further, climate change especially short episodes of heat stress (above optimum) are projected to impact the sorghum yields considerably.

In coordinated rabi physiology program six trials were conducted at six locations Bijapur, Parbhani, Rahuri, Phaltan, Tandur and Hyderabad. The broad objectives of the rabi physiology program were to 1) preliminary evaluation of landrace germplasm (primarily *durra* types) for traits related to drought adaptation, 2) to characterize key crop physiological traits in advanced genotypes that determine higher biomass, grain productivity, combining drought and temperature stress (low and high) tolerance under stored soil moisture stress situation and 3) identify potential and durable sources for genetic enhancement of rabi sorghum. Identification of stress tolerance genotypes has greater importance in view of current climate change and variability. This ultimate goal of the program is to identifying contrasting sources/traits for tolerance/susceptibility that determine broad adaptation to climate change (drought, temperature stress & combined) that facilitate mapping population (RILs)/cultivar development, and QTL identification/analyses.

**Soils and planting:** The soils where trials were planted varied from medium deep black (vertisols) to shallow vertisols. Planting was mainly done between mid-September and first or second week of week of October.

**Environmental conditions at different test locations**

**Bijapur:** At Bijapur, the total rainfall received during kharif and rabi seasons was 453.4 mm which amounts to a deficit of 23.0% than long term normal (590 mm). The rainfall distribution revealed the kharif season cropping period received very low rainfall July and August (Fig. 1). The Rainfall distribution is unimodel with peak rainfall occurring in October first week. The rainfall received in September was far less than the normal. The rainfall occurred in early October was adequate to plant the rabi sorghum. Subsequently, the rainfall ceased by the end of October which might be coincided with panicle initiation stage (end of GS1). Following this, the crop experienced severe dry conditions in during reproductive (GS2) and ripening phases (GS3). Temperature data showed that the diurnal variation in maximum and minimum was wide in rabi cropping season than kharif (Fig 1). Immediately after sowing of rabi crop, the minimum temperatures dropped continuously reaching a low of about 12.5°C which...
coincided with flowering and subsequent grain filling. The accumulated thermal time recorded was 2282 and 1910 °Cd, respectively for kharif and rabi cropping periods. Thus, the lower availability (16.3 % less than kharif) of accumulated growing degree days (GDD) for the rabi cropping period is one of the reasons for lower productivity of rabi sorghum, besides occurrence of drought stress during pre-(GS2) and post-flowering (GS 3) stages (Fig 1). Weekly mean minimum and maximum temperatures recorded were from 12.6 to 23.0°C and 29.0 to 35.3°C, respectively. The weekly mean open pan evaporation too ranged from 3.0 to 8.2 mm during kharif and rabi cropping period. The evaporation values were much lower in the rabi cropping period than kharif (Fig 1).

Solapur: The rainfall received at Solapur during kharif and rabi cropping period and was 489 mm which was 22.0% less than normal (629 mm). The rainfall distribution and temperature variability were almost similar to Bijapur excepting prevalence of relatively higher minimum temperatures during GS3 stage (Fig 2). The rainfall occurred during first week of October was adequate for sowing of rabi crop. The crop was exposed to pre-and post-flowering drought stress from October onwards until maturity (Fig 2). This erratic distribution of rainfall at Solapur resulted in poor performance of the crop especially in shallow soils. Weekly mean minimum and maximum temperatures recorded were from 13.4 to 24.3°C and 31.0 to 37.4°C, respectively (Fig 2).

Rahuri: The total rainfall received during kharif and rabi seasons (standard week 24 to 5) was 415.4 mm which amounts to a deficit of 30.0% than long term normal (595 mm). The rainfall distribution revealed the kharif season cropping period received very low rainfall in July and August (Fig 3). The rainfall distribution is unimodal with peak rainfall (123.4 mm) occurring in October first week. The rainfall received in September was far less than the normal. The rainfall occurred in early October was adequate to plant the rabi sorghum. Subsequently, the rainfall ceased from mid-October onwards which coincided with panicle initiation stage (end of GS1). Following this, the crop experienced severe atmospheric and soil drought conditions during reproductive (GS2) and ripening phases (GS3). Temperature data showed that the diurnal variation in maximum and minimum was rather very wide in rabi cropping season than kharif (Fig 3). Immediately after sowing of rabi crop, the minimum temperatures dropped continuously reaching a low of about 9.3°C which coincided with flowering to soft dough stage. The accumulated thermal time recorded was 2366 and 1814 °Cd, respectively for kharif and rabi cropping periods. Thus, the lower availability (23.0% less than kharif) of accumulated GDD for the rabi cropping period is one of the reasons for lower productivity of rabi sorghum, besides occurrence of drought stress during pre- (GS2) and post-flowering (GS3) stages (Fig 3). Weekly mean minimum and maximum temperatures recorded were ranged from 9.0 to 26.6°C and 28.0 to 38.6°C, respectively (Fig 2).

Parbhani: At Parbhani, the total rainfall received was 674.0 mm which is close to normal for kharif season. The rainfall received in kharif cropping season was more or less uniformly distributed with peaks in mid-August and early Sept. (Fig 4). The rainfall occurred in early to September to early-October was just adequate to plant the rabi sorghum. Hence, the crop experienced both pre-and post-anthesis drought and heat stresses as could be seen from the rainfall data. The accumulated thermal time was 2407 and 1901 °Cd, respectively for kharif and rabi cropping periods. Thus, the lower availability (21.0% less than kharif) of accumulated GDD for the rabi cropping period is one of the reasons for lower productivity of rabi sorghum, besides occurrence of drought stress during pre- (GS2) and post-flowering (GS3) stages (Fig 4). Weekly mean minimum and maximum temperatures recorded were ranged from 9.0 to 26.6°C and 28.0 to 38.6°C, respectively. The weekly mean open-pan evaporation too ranged between 3.0 to 11.2 mm during kharif and rabi cropping period.

Hyderabad: Total rainfall received was 722.1 mm which is close to normal (669.1mm) during kharif and rabi seasons. The rainfall received in kharif cropping season was more or less uniformly distributed single peak of 186.2 mm in mid-July (Fig 5). The rainfall occurred during the late September and October was just adequate to raise the rabi sorghum. Furthermore, the crop experienced both pre-and post-anthesis drought stress as no rainfall occurred from November onwards. The accumulated thermal time was 2293 and 1858 °Cd, respectively for kharif and rabi cropping periods. There was 19.0% less GDD available for rabi than kharif cropping season that might be one of the reasons for lower productivity of rabi sorghum, besides occurrence of drought stress during pre- (GS2) and post-flowering (GS 3) stages (Fig 5). Weekly mean minimum and maximum temperatures were ranged from 11.0 to 25.6°C and 27.5 to 36.0°C, respectively. The weekly mean open-pan evaporation too ranged between 2.6 to 5.6 mm, respectively during kharif and rabi cropping period.
**Phaltan:** The rainfall received at Phaltan during kharif cropping period and was 198 mm which was 55.0% lower than normal (459.0 mm) for the corresponding period. Severe drought conditions prevailing during GS1 and GS2 as very low rainfall received excepting single peak in early October (Fig.6). The rainfall occurred during first week of October was adequate for sowing of rabi crop. Weekly mean minimum and maximum temperatures recorded were ranged from 18.8 to 23.7°C and 31.1 to 36.1°C, respectively (Fig.6)

The total amount of rainfall received during rabi crop period (standard week 38 (mid-Sept) to 5 (Jan. end)) was 211,183, 232, 138 and 159 mm, respectively at Rahuri, Solapur, Bijapur, Parbhani, and Hyderabad.
Forty-eight landraces rabi sorghum germplasm along with three checks were evaluated at Parbhani, Tandur, Bijapur, Solapur and Rahuri with an objective of identifying potential donors for rabi adaptation traits such as phenology, physiological traits components of biomass, and grain yield. These landrace germplasm were collected from different rabi sorghum growing areas of Karnataka and Maharashtra. All the accession belong to the biological race *durra*. The crops were grown on medium vertisols under dryland conditions. The data are presented in tables 1R.1.1 – 1R.1.7.

**Phenology and plant height:** Mean days to flowering and days to physiological maturity differed significantly (P≤0.05) and were ranged from 70 - 76 d and 117-123 d, respectively. In general, time taken for flowering was longer at Solapur (78) followed by Parbhani (75). Least time to flowering was recorded at Tandur (69 d). In general, none was earlier to best check *Phule Chitra* for days to flowering, but entries showed on par with check include SSRG 206, RSV 1425, Honawad-2, and SSRG 147. The trend in days to physiological maturity was similar to flowering. Days to flowering had shown positive correlation with (0.353; P≤0.05) biological yields, and 1000-seed weight (0.262; ns). Plant height differed significantly (P≤0.05) at different locations and ranged from 155 to 201 cm with an average of 181 cm. Entries RSV 1468, *Honsal local*, RSV1460 and *Bairodagi* grew taller than check.

**Physiological traits:** Leaf area index (LAI) at flowering varied significantly (P≤0.05) at different locations and ranged from 2.68 to 4.71 with a mean of 3.49. Entries *Mundewadi local*, RSV-1449, *Honawad, Halyal local* were superior to check in LAI. Relative chlorophyll content (SPAD units) at flowering differed significantly (P≤0.05) and varied from 44.5 to 59.1 with an average of 50.0. Entries *Honawad, Pathari local*, RSV-1458 and *Bidar local* had shown high SPAD values (54.6-59.3) than check *Phule Chitra* .

Photosynthesis rate (Pn), transpiration rate (Tp), stomatal conductance (rc) and leaf temperature depression differential (LTD) recorded at flowering varied significantly (P≤0.05). Pn ranged from 22.8 to 35.0 μ mol CO₂ m⁻² S⁻¹ and none was superior to check *Phule Chitra*, while, entries were on par with check include *Halyal local*, *Gondavale local*, and *Tillehal local*. SPAD values has no relationship with component of Pn. Interestingly, entry *Halyal local* maintained high Pn combining high canopy temperature depression indicating its water conservation efficiency in stored soil moisture stress condition. Relative water content (RWC) differed significantly ((P≤0.05),...
but none was superior to check *Phule Chitra*, while entries on par with check include RSV1478, Gondavale local and Katarakhata local. The RWC had shown significant positive relationship with stomatal conductance at flowering \( r=0.290; P \leq 0.05 \).

**Biomass components and fodder yields:** Leaf dry weight, stem dry weight, total biomass differed significantly \( P \leq 0.05 \). None was superior to check CSV22R for total biomass at maturity and ranged from 550 to 1247 g m\(^{-2}\). High biomass yields were recorded by *Pathari local, Mundewadi local, Khadkat local, and Kavalagudda mungaru*. Biomass has shown significant positive relationship with 1000-seed weight \( r=0.382; P \leq 0.05 \).

**Grain yield components:** Grain yield, HI and 1000-seed weight differed significantly \( P \leq 0.05 \) at all locations. Mean 1000-seed weight ranged from 28.3 to 40.2 g. None was superior to check *Phule Chitra*. High mean grain yields were obtained at Parbhani followed by Bijapur. The grain yield recorded at Solapur was very low due to planting the crop in shallow soil. Average mean grain yield recorded was 529, 67, 265, and 255 g m\(^{-2}\), respectively at Parbhani, Solapur, Bijapur and Tandur. Landraces germplasm which gave higher yield across locations include *Patoda local* (27%), *Kavalagudda local* (24%), RSV 1426 (21%) *Tikota* (19%) and *Nimbodi local* (16%) more than best check CSV22R. Mean HI ranged from 5.7 to 36.8 % with an average of 12.8 %. Entries SSRG 170, SSRG 206, *Tilchal local* and RSV 1426 were superior for HI.

**Trial 2(M) & 3(S): Evaluation of advanced rabi sorghum entries for drought adaptation in medium in medium and shallow soils**

*(Tables 2M 2.1-2M2.4 and 3S 2.1- 3S.3.3).*

Sixteen advanced rabi-adapted sorghum genotypes including three checks were phenotyped in both medium (\( \leq 75 \) cm soil depth) and shallow soils (\( \leq 45 \) cm soil depth) at Bijapur, Parbhani, Rahuri, Solapur and Tandur. Plant Breeders from different sorghum centres contributed these test materials which are in advanced stage of development (stabilized at F\(_6\)-F\(_7\)). These materials were contributed based on their superior performance in the station and state MET trials. The test materials are belongs to biological landrace *durra* which had specific adaptation to rabi season and possessing traits such as shoot fly tolerance, pearly white and bold grain, relatively tolerance to low temperature at flowering. The broad objectives of this trial were to evaluate advance rabi sorghum entries for key traits associated with drought adaptation and productivity across the soil depth (medium and shallow soils) and identify potential donors or contrasting parents for further crop improvement work. Testing was done in medium and shallow soils where development of flowering and post-flowering drought stress is rapid than deep soil. The testing hypothesis of genotypes across the soil depths is based on the farmers’ practice of growing rabi sorghum with stored soil moisture in both soils in the target production area. Since the same set of entries were grown in both soils, the entries compared for their performance across the soil depths to identify the stable performing genotypes.

Data on important morpho-phonological, physiological traits, biomass, yield and its components were recorded as per standard procedures. Drought susceptibility index (DSI): DSI for plant height, biomass, stover and grain yield was calculated according to the Fischer and Maurer (1978) and the same is described below. DSI = \( 1 – YYp)/D; \) where Y is the mean grain yield or biomass of a genotype in drought stress condition (shallow soil); Yp is the mean grain yield or biomass of same genotype in nonstress condition (medium soil) and D is the stress intensity D=1–X/Xp; where X is the mean Y of all genotypes; Xp is the mean Yp of all genotypes. DSI is used to characterize the relative drought tolerance of various genotypes (DSI\(<0.50 \) highly stress tolerant, DSI >0.50 to \( \leq 1.00 \) moderately stress tolerant, and DSI>1.00 susceptible).

**Soil moisture status:** Soil moisture content recorded at flowering stage was about 58% of available moisture indicating the prevalence of drought conditions. The moisture content decreased further decreased at maturity. The details of the soil moisture are presented in table 1. As discussed previously, the rainfall received in GS 1 and G2 was almost nil at all rabi centres indicating the occurrence of pre –and post-flowering drought conditions.
Table 1. Soil moisture particulars for advanced drought adaptation germplasm trial - Rabi 2012-13, Rahuri

<table>
<thead>
<tr>
<th>S.No</th>
<th>Particulars</th>
<th>Medium</th>
<th>Shallow soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-15</td>
<td>15-30 cm</td>
</tr>
<tr>
<td>I</td>
<td>Soil moisture content (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>At planting</td>
<td>29.1</td>
<td>39.3</td>
</tr>
<tr>
<td>b.</td>
<td>At Panicle initiation</td>
<td>29.2</td>
<td>38.7</td>
</tr>
<tr>
<td>c.</td>
<td>At 50% flowering</td>
<td>20.3</td>
<td>26.1</td>
</tr>
<tr>
<td>d.</td>
<td>At maturity</td>
<td>18.4</td>
<td>22.1</td>
</tr>
<tr>
<td>II</td>
<td>Available soil moisture content (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a.</td>
<td>At planting</td>
<td>83</td>
<td>168</td>
</tr>
<tr>
<td>b.</td>
<td>At Panicle initiation</td>
<td>83</td>
<td>109</td>
</tr>
<tr>
<td>c.</td>
<td>At 50% flowering</td>
<td>9</td>
<td>58</td>
</tr>
<tr>
<td>d.</td>
<td>At maturity</td>
<td>-7</td>
<td>24</td>
</tr>
<tr>
<td>III</td>
<td>Field capacity (%)</td>
<td>31.2</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Wilting point (%)</td>
<td>19.2</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Bulk density (g/cc)</td>
<td>1.28</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>Rainfall during crop period (mm) (standard week 38th - 5th)</td>
<td>211 mm</td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td>Date of sowing</td>
<td>Medium:25/9/12 ;</td>
<td></td>
</tr>
</tbody>
</table>

Crop phenology and plant height: Days to flowering and days to physiological maturity differed significantly (P≤0.05). Mean days to flowering did not differ between the soils depths. None was earlier to early check Phule Anuradha in both the soils. Similar trend was observed for days to maturity also. Significant difference (P≤0.05) was observed in plant height in both the soil depths at all the locations. Plant height ranged from 183 to 221 cm in medium and 163 to 199 cm in shallow soils. Average plant height decreased by 10.8 % in shallow soil over medium. As regards DSI, entries BJV 116 (0.351), RSV 1420 (0.464) and CRS 19 (0.554) showed less DSI means more plant height stability under drought than checks. Plant height and days to flowering showed negative correlations with 1000-seed mass in both medium and shallow soils. The relationship of days to flowering with plant height was significantly positive (r=0.537, 0.582; P≤0.05 in medium and shallow soil, res.) in both the soil depths

Physiological traits: Leaf area index (LAI) varied significantly (P≤0.05) in both the soil depths. LAI values did not differ much across soil depths. CRS19 and SRS 20 were stable across the soil depths as both entries maintain almost similar LAI in both soils. Leaf mass, stem mass, biomass differed significantly at flowering and maturity (P≤0.05). Average biomass production at flowering between the soil depths was almost similar although there is some decrease in biomass in shallow soils over medium in some entries. At physiological maturity, genotypes RSV1415, CRS 15, BJV 116 and BJV 103 produced significantly higher biomass (15.0 to 22.0% more) than best check M35-1 in medium soils. Interestingly, none was superior to check M35-1 in shallow soils. Higher biomass at physiological maturity showed positive correlation (r=0.598; P≤0.05) with grain yield in shallow soil stress conditions.

Relative leaf water content (RLWC) recorded at flowering varied at different locations. It declined by 3.0 % in shallow over medium soils. Entries CRS 20, BJV 114, and BJV 116 recorded high crop water status than checks especially in shallow soil stress condition. Stomatal frequency varied significantly at Rahuri. Significantly higher stomata were recorded on the lower leaf surface than upper in both soil types. Relative chlorophyll content (SPAD units) at flowering differed significantly (P≤0.05) at Bijapur and Rahuri locations. The mean SPAD units varied from 48.3 to 55.6 in medium and 40.0 to 46.7 in shallow soil. None was superior check Phule Anuradha in medium soil and MSV 71 was superior in shallow soil. SPAD values showed significant negative relationship with transpiration rate (r=-0.446 ns; and -0.747; P≤0.05 in medium and shallow res.). Interestingly, higher SPAD units (more leaf staygreen) resulted in realization of higher 1000-seed weight as could be seen from significant positive relationship between the two (r=0.549; and 0.523; P≤0.05, in medium and shallow soil res.). Photosynthesis rate (Pn), transpiration rate (Tp), stomatal conductance (rc) and leaf temperature differential (LTD) recorded at flowering varied significantly (P≤0.05) among the entries. Pn ranged in 20.9-30.4 and 21.1- 33.9 µmol CO₂ m⁻¹ S⁻¹ in
medium and shallow soils, respectively. Mean Pn did not differ between the soil depths. Entries BJV116, BJV 103 and Phule Anuradha showed higher Pn rates in shallow stress than medium. Pn rate had shown significant positive correlation with stomatal conductance (r=0.503; P≤0.05 in medium soil), while Pn rate negatively (r= -0.508; P≤0.05) related to Tp in shallow soil conditions where development of drought stress is more rapid than medium. Stover yield at maturity differed significantly in both soil depths. Average stover yield recorded was 4.8 and 3.8 t ha⁻¹ in medium and shallow soils, respectively. The stover yield declined by 21.0% in shallow soil over medium. Superior entries for stover yields include BJV 83 in medium soil and RSV 1098 in shallow soil. In Entries stable for stover yield across soil depths in terms of DSI include BJV 103, RSV1420 and RSV 1098 (Fig. 1). These entries possessed lower DSI values means more stable performance under pre-and post-flowering drought conditions.

**Grain yield and its components:** Grain yield, HI and 1000-seed weight differed significantly (P≤0.05) at all locations. Grain yield varied significantly at all locations in both soil depths. Mean grain yield ranged from 1818 to 2230 kg ha⁻¹ and 1219 to 1706 kg ha⁻¹ in medium and shallow soil, respectively. High mean grain yield was realized at Rahuri in medium soils and Bijapur in shallow soils. Significant difference was observed for grain yield at all locations in both soils. In medium soils, none was significantly superior to check Phlue Chitra, while RSV 1098 and MSV 71 were on par with check. On the contrary, none was superior to check M35-1 in shallow soils. Mean grain yield reduced by 26.2 % in shallow soils over medium with a range between 4.2 and 43.9%. In terms of DSI for grain yields, check M35-1 itself was stable (DSI=0.162). In terms of grain yield stability, under severe terminal drought and heat stress conditions, any cultivar that give reasonably stable yields is desirable. The comparison between grain and stover yields revealed (Fig. 1), entries recorded low DSI for both grain and stover yields were BJV 103 and RSV1420. The entries are more stable and terminal drought and heat stress tolerance types.

![Fig. 1](image-url) **Fig. 1** Drought susceptibility index (DSI) for grain and stover yield in 16 rabi sorghum entries. The values are mean of three locations. DSI is calculated according to the Fischer and Maurer (1978). (DSI≤0.50 highly stress tolerant, >0.50 to ≤1.00 moderately stress tolerant, and >1.00 susceptible).
**Trial 4 R and 4 Irrg.: Evaluation of sorghum plant types for root characteristics.**

(Tables 4.1-4.2 R).

Thirteen advanced rabi sorghum genotypes including checks were characterized for root and shoot traits that contribute survival under flowering and postflowering drought and heat stress. Genotypes were evaluated in the specially constructed root structure facility at Rahuri. The root screening facility was specially created above the ground with required soil depth (1.0 m) and compaction as applicable to natural field conditions. This root screening facility was filled with vertisol and irrigated up to saturation prior to the sowing of. Entries were planted in split-plot design with two replications. Two water regimes namely i) rainfed and 2) limited irrigated (control) were assigned main-plots, while genotypes were allotted to sub-plots. The irrigated control treatment received 4-irrigations. At each irrigation, the soil was brought back to near field capacity.

Significant differences were observed for main effects and interactions for various root and shoot related traits ($P \leq 0.05$) at Rahuri. There was significant decrease in root and shoot related traits under rainfed than in irrigated. Mean plant height, decreased by 15.0 % in rainfed than irrigated. Check M35-1 maintained stable plant height in both moisture regimes followed by RSV1410. Mean RWC, SPAD and Pn rate declined by 4.5, 11.3 and 12.5% due moisture stress than control. CRS19 and RSV1410 have showed no reduction in above traits due to stress and were more stable than check.

The mean root length, root volume, and root numbers declined by 23.0, 38.0% and 40.0 % in rainfed condition than in irrigated. Mean root length at physiological maturity under rainfed condition varied from 64 to 108 cm/plant. CSV22R and RSV 1429 were stable in stress condition. In root volume, CSV 19 SS was more stable than others. Root number per plant at maturity varied in 22 to 46 and 43 to 78, respectively in rainfed and irrigated conditions. Interestingly, RSV1410 recorded higher root number in rainfed conditions than check. Data on root mass indicated that there was a 61.0 % decrease (range: 25-71 g/plant) due to moisture stress than irrigated. BJV83 alone recorded significantly superior ($P \leq 0.05$) root mass than checks in drought stress conditions. Entries MSV 71 and RSV 1429 did not show panicle exsertion due to severe moisture stress and grain yield data could not be obtained and hence no data reported.

**List of Collaborators**

DSR, Hyderabad
SS Rao, PI; JV Patil , JS Mishra, HS Talwar & OV Ramana

MAU, Parbhani:
RR Dhutmal, RM Kokate, SP Mehtre, AW More, BM Kadam & RL Aundhekar

MPKV, Rahuri:
SV Nirmal, SR Gadakh, US Dalvi, UD Chavan & MS Shinde

CRS, Solapur
Prabhakar, Nimbose

RRS, UAS, Bijapur
VH Ashvatham & BD Biradar

ARS, ANGRAU, Tandur
D Shivani

NARI Phaltan
N Nimbkar, A Siddique & V Singh,