Genetic Variations for Key Adaptive Physiological Traits Associated with Drought Tolerance in Post Rainy Sorghum

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Evolution of IIMR

PIRCOMM

IARI Regional Station

AICRP-Sorghum

National Research Centre for Sorghum

Directorate of Sorghum Research

Indian Institute of Millets Research

1958 - Intensification of research on millets & other crops

1966 - Regional research centre for crop research

1970 - Coordination unit for Sorghum

1987- National Research Centre for Sorghum

1991 - Centre for Rabi Sorghum, Solapur

1995 - Off-season Nursery, Warangal

2009 - Upgradation to Directorate

2015 - Research on all millets under one umbrella

- Upgradation of status
The area planted to sorghum worldwide has increased by 66 percent over the past 50 years, while yield has increased by 244 percent.
Post Rainy Sorghum Area and Productivity Dynamics

Productivity increased by ~107%
Area reduced by ~44%
Challenges and strategies

- Predominantly cultivated with residual soil moisture - 3.69 m ha
- Post-flowering drought - a regular feature
- Restricted cultivar choice + shallow or medium soils
- CC Prediction: Increasing trend in Temp & decreasing in RF.
- Superior genetic resources and identification of traits associated with postflowering DT are required.
Today's Talk

1. Identification of sources with improved drought tolerance.
2. Traits associated with postflowering drought.
3. Physiological basis of drought tolerance
Field experimentation
identification of DT sources

Material:
✓ Land races
✓ Germplasm
✓ Breeding lines

Experiment:
• Split plot design
• 2 Treat (WW & WS)
• 3 Replications
Crop sown in two sets side by side
Both sets well watered till 45 DAS

Traits:
✓ Soil moisture monitoring
✓ Phenology, growth parameters
✓ Physiological traits (GLAR, RWC, SPAD)
✓ Yield components (Grain yield, panicle weight, stover weight)
Soil Moisture

Hyderabad

Solapur

Days after Sowing (DAS)

Days after Sowing (DAS)

Soil Moisture (%)

Well watered (WW)

Water stressed (WS)
Identification of DT Sources

(i) 350 genotypes evaluated during last 5 years under post-flowering drought conditions at three locations (Well watered (WW) and water-stressed (WS))

(ii) \[ DSI = \frac{(1 - Y_{ws}/Y_{ww})}{D} \]
\[ Y_{ws} = \text{yield under WS}, \quad Y_{ww} = \text{yield under WW}, \quad D = \text{(Environment Susceptible Index)} = (1 - \frac{Y_{wsMean}}{Y_{wwMean}}) \]

<table>
<thead>
<tr>
<th>Location</th>
<th>Treat</th>
<th>Range</th>
<th>Mean</th>
<th>Top genotypes on based on DSI, GLAR &amp; yield components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GY (gm⁻²)</td>
<td>TDM (gm⁻²)</td>
<td>GLAR (%)</td>
</tr>
<tr>
<td>Hyderabad</td>
<td>WW</td>
<td>171-348</td>
<td>875-1623</td>
<td>37-68</td>
</tr>
<tr>
<td></td>
<td>WS</td>
<td>87-244</td>
<td>639-1302</td>
<td>20-56</td>
</tr>
<tr>
<td>Solapur</td>
<td>WW</td>
<td>107-317</td>
<td>525-1290</td>
<td>50-85</td>
</tr>
<tr>
<td></td>
<td>WS</td>
<td>72-172</td>
<td>338-676</td>
<td>18-42</td>
</tr>
<tr>
<td>Rahuri</td>
<td>WW</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>WS</td>
<td>37-150</td>
<td>1050-2103</td>
<td>25-55</td>
</tr>
</tbody>
</table>
Variations in DSI for grain yield

DSI = (1 - Yws/Yww)/D - Yws = yield under WS, Yww = yield under WW,
D (Environment Susceptible Index) = (1 - YwsMean/YwwMean)

DSI : 0.20 to 1.67

Least susceptible
CRS 1
IC343586
CRS 20
CRS 7
IC392140 (SLV 44)
Variations in DSI for total biomass

DSI = (1 - Yws/Yww)/D - Yws = yield under WS, Yww = yield under WW,
D (Environment Susceptible Index) = (1 - YwsMean/YwwMean)

DSI : 0.61-1.44
Least Susceptible
IC 343586
CRS 20
EP 93
SLV 44 (IC 392140)
Bio-plot between GY & Biomass under WS

<table>
<thead>
<tr>
<th>Genotype</th>
<th>GY</th>
<th>BIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC 392140</td>
<td>588</td>
<td>1950</td>
</tr>
<tr>
<td>IC 343586</td>
<td>541</td>
<td>1947</td>
</tr>
<tr>
<td>CRS 20</td>
<td>561</td>
<td>1512</td>
</tr>
<tr>
<td>IC 305920</td>
<td>484</td>
<td>1630</td>
</tr>
<tr>
<td>Parb. Moti</td>
<td>455</td>
<td>1532</td>
</tr>
<tr>
<td>CRS 7</td>
<td>568</td>
<td>1434</td>
</tr>
<tr>
<td>PAxBRJ62</td>
<td>495</td>
<td>1415</td>
</tr>
</tbody>
</table>

$R^2 = 0.3206$
Negative relationship between DSI & Biomass under WS
Selection criteria need both DSI and Biomass potential
Bi-plot between DSI and Grain yield under WS

**Low DSI, High GY**

<table>
<thead>
<tr>
<th>Geno</th>
<th>GY</th>
<th>DSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC343583</td>
<td>588</td>
<td>0.17</td>
</tr>
<tr>
<td>CRS 20</td>
<td>561</td>
<td>0.17</td>
</tr>
<tr>
<td>IC 392140</td>
<td>537</td>
<td>0.04</td>
</tr>
<tr>
<td>IC 343586</td>
<td>541</td>
<td>0.20</td>
</tr>
<tr>
<td>CSV 22</td>
<td>516</td>
<td>0.14</td>
</tr>
<tr>
<td>BRJ62xRS585</td>
<td>476</td>
<td>0.22</td>
</tr>
<tr>
<td>Phule Suchitra</td>
<td>521</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Negative relationship between DSI & GY under WS
Selection criteria need both DSI and GY potential
**Bi-plot between DSI and Grain yield under WW**

*High GY + Low DSI*

**Grain yield (g m\(^{-2}\)) under WW**

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>GY (g m(^{-2}))</th>
<th>DSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC392140</td>
<td>606</td>
<td>0.17</td>
</tr>
<tr>
<td>CRS 20</td>
<td>577</td>
<td>0.17</td>
</tr>
<tr>
<td>IC343586</td>
<td>559</td>
<td>0.20</td>
</tr>
<tr>
<td>Phule Suchitra</td>
<td>564</td>
<td>0.47</td>
</tr>
<tr>
<td>SPV 2030</td>
<td>578</td>
<td>0.88</td>
</tr>
<tr>
<td>CRS 4</td>
<td>583</td>
<td>0.97</td>
</tr>
</tbody>
</table>

No relation between DSI & GY under WW

Selection criteria need both DSI and GY potential
(ii) Traits associated with postflowering drought in postrainy Sorghum

- Staygreen
- SLW
- SLN
- CSI
- RWC
- Deep-root

Stay-green has been a target of sorghum breeders for more than 35 years in India.

Stay-green plants maintain green leaves and stems when water is limiting during the grain-filling period resulting in:

- higher grain yield
- larger grain size
- increased lodging resistance.
STAY GREEN IS USEFUL TRAIT

But........

a. Need measurements of leaf area frequently- (tedious)

b. Depends upon visual scoring- which may involve some human error.

c. Very complicated- consist of group of QTLs Stg 1, 2, 3, 4, a, b..... Need to identify key QTL

Stay-green Senescent
Biomass accumulation under rainfed (g m\(^{-2}\))

**CSV 22**  
2483.3

**Parbhani Jyoti**  
2800.9

**SG06003**  
3018.5

**SG06014**  
2607.4

**SG06016**  
2675.5

**B 35**  
2575.9

**S 35**  
2193.5

**SG07003**  
1810.2

Mean of 56 lines  
2486.1
Most appropriate growth stage to screen for post-flowering drought tolerance on the basis of GLAR is around 30 DAF at both Solapur and Hyderabad

<table>
<thead>
<tr>
<th>Yield Component</th>
<th>Water Regime</th>
<th>Green leaf area retention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flowering</td>
<td>27 DAF</td>
</tr>
<tr>
<td>Biomass</td>
<td>No stress</td>
<td>0.53**</td>
</tr>
<tr>
<td>Biomass</td>
<td>Stress</td>
<td>0.46*</td>
</tr>
<tr>
<td>GY</td>
<td>No stress</td>
<td>0.40</td>
</tr>
<tr>
<td>GY</td>
<td>Stress</td>
<td>0.49**</td>
</tr>
</tbody>
</table>

Talwar et al 2010
Indian Journal Agricultural sciences
**Correlations between SPAD chlorophyll meter reading (SCMR) and growth and yield components**

<table>
<thead>
<tr>
<th>Trait</th>
<th>SCMR</th>
<th>50% FL</th>
<th>PH (cm)</th>
<th>TDM (g m$^{-2}$)</th>
<th>PWT (g m$^{-2}$)</th>
<th>GY (g m$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCMR</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% FL</td>
<td>0.069</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PH (cm)</td>
<td>0.591**</td>
<td>0.311*</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDM</td>
<td>0.831**</td>
<td>0.273*</td>
<td>0.698**</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PWT</td>
<td>0.720**</td>
<td>0.154</td>
<td>0.559**</td>
<td>0.775**</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>GY</td>
<td>0.650**</td>
<td>0.108</td>
<td>0.407*</td>
<td>0.664**</td>
<td>0.915**</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Use of SPAD Chlorophyll meter in postflowering drought screening

Significant & positive relationships of SCMR with TDM ($R^2 = 0.69$) and grain yield ($R^2 = 0.42$) suggests that selection using SCMR will have 42-69% probability in selecting superior genotypes.

Talwar et al. 2014
Indian J. Agri. sciences 79(1): 432-37
Increase in SLW during post-flowering growth period under stress is a potential selection criteria in Rabi Sorghum?

<table>
<thead>
<tr>
<th>Genotype</th>
<th>% Biomass accumulation during postflowering growth period</th>
<th>Specific leaf weight (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No-stress</td>
<td>stress</td>
</tr>
<tr>
<td>CSV 216 R</td>
<td>109</td>
<td>48</td>
</tr>
<tr>
<td>CSV 18</td>
<td>97</td>
<td>73</td>
</tr>
<tr>
<td>M 35-1</td>
<td>158</td>
<td>124</td>
</tr>
<tr>
<td>SPV 1626</td>
<td>102</td>
<td>85</td>
</tr>
<tr>
<td>296 B</td>
<td>184</td>
<td>111</td>
</tr>
<tr>
<td>C 43</td>
<td>126</td>
<td>97</td>
</tr>
<tr>
<td>Mean</td>
<td>129.8</td>
<td>93.3</td>
</tr>
<tr>
<td>SEm±</td>
<td>32.3</td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td>28.2</td>
<td></td>
</tr>
</tbody>
</table>

Specific leaf weight (SLW) increases under postflowering water stress

Talwar et al. 2015
Indian Journal Agricultural sciences
Conclusion

Relationships between increase in SLW under stress conditions & yield components indicate that increase in leaf thickness is an adaptive trait to moisture stress during the postflowering growth period.

Talwar et al 2014
Indian Journal Agricultural sciences
Physiological basis of Drought tolerance

Lysimetry facility at IIMR – capacity 360 cylindrical pots

1. Pattern of water use
2. Water extraction ability
3. Transpiration efficiency
4. Root traits

Weighing facility

Well-watered

Water-stressed
Pattern of water Use

$$y = -1.073x + 14493$$
$$R^2 = 0.583^{**}$$

Water extracted during pre-anthesis (g)

Water extracted during post-anthesis (g)

$$y = -0.743x + 16928$$
$$R^2 = 0.767^{**}$$

Water extracted during pre-anthesis (g)

Water extracted during post-anthesis (g)
Pattern of Water Use

Water extraction in pre-anthesis period is negatively correlated to the water extracted in the post anthesis period.
Evaluation of germplasm and elite/advanced lines for water extraction
Water extraction ability- among races

Average water extracted by group of lines of different races, Bicolor n=5, Caudatum n=5, Dura n=5, Kafir n=2, Guinea n=3, C-B n=3, D-C n=3
Water extraction under well watered (WW) & water stress (WS)

Water Extraction range (kg)

WW: 18.9 – 20.0
WS: 11.6 --14.6

Under WS genotypes has wider range in WE ability

Genotypes extract highest quantity of water under WS may extract lower quantity under WW & vice versa

Stable genotypes:
IC 392140, CRS 20, IC 343586
Evaluation for Transpiration Efficiency (TE)
Transpiration efficiency (TE)-among races

Average TE of group of lines of different races, Bicolor n=5, Caudatum n=5, Dura n=5, Kafir n=2, Guinea n=3, C-B n=3, D-C n=3
Variations in TE-Rabi verities, promising germplasm & Advanced Breeding lines

- More than two-fold TE variations under WS
- Phule chitra, CRS 20, IC 343586, Phule maulee, Phule Suchtra, & IC 343586 produces more per unit water used
Physiological basis of water extraction (Roots??)
Root traits study- Construction of Root chambers

Water stressed

Well watered

Fibrous Partition

Permanent wall

Temporary wall

Root sub-chamber

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Sorghum in the 21st century

April 9 - 12, 2018
Root traits study- Excavation of Roots from Root chambers.

HS Talwar
Sorghum in the 21st century
April 9 - 12, 2018
Genetic Variations in Root System
IC 392140, IC 343586 & CRS 20 has Deep and Prolific Root System
Root Traits

IC 392140, IC 343586 & CRS 20 has highest root mass

Exception: CRS 20 has lower diameter ???

HS Talwar Sorghum in the 21st century April 9 – 12, 2018
IC 392140, IC 343586 & CRS 20 has more root volume & surface area
Poor relation of DSI with root depth and strong with root length indicates that prolific (dense) root system is more important than deeper root system.
Root traits

DSI >> Root density & Root diameter

Root density has fairly strong relationship with drought susceptibility index

\[ R^2 = 0.493 \]

\[ R^2 = 0.2201 \]
In sum

- Staygreen (GLAR) is the most useful trait associated with GY & Biomass

- 30 DAF is the best stage to select genotypes on the basis of GLAR.

- Genotypes should not be selected on the basis GY or Biomass only, DSI should also be taken into account.

- Pattern of water use is critical for drought adaptation

- Water extraction ability & TE differs across sorghum lines. CRS 20, IC 343586, IC 392140 maintains higher WE and TE

- Dura is best adaptive race to postrainy season due its higher WE ability and TE.

- Root length & root density are the key root traits.
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Vema
Dev Kumar

Jai Kishan
Shiwesh kumar

Staygreen Project
NICRA Project
Institute project

Thanks for the attention!