Collection and Characterization of Indian Sorghum Landraces

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Landraces are the varieties nurtured and cultivated by the farmers through traditional method of selection over the decades. The "landrace" is a primitive cultivar grown by farmers and their successors since ancient times. We explored seven states and collected 674 accessions. Out of which, 138 are popular landraces. These collections have specific traits and traditional utilities. Moli jowar from MP fetches higher prices due to attractive grains. The irungu cholam from Tamil Nadu yields best quality porridge and mathappu cholam is for preparing a jelly like food called khali. The beed maldandi and bidri from Maharashtra produce best quality jowar roti or unleavened bread. Karnataka's kodumurugu jola and allin jola are used to make laddus and papads, respectively. The allur jola from Karnataka is for pops (allu). The pachcha jonna from Andhra Pradesh, barmuda local, deshi chari and gudli local from Rajasthan and bendri dagdi and khondya from Maharashtra are excellent fodder types. Valsangh maldandi local, Vadgaon dagdi maldandi, tongraligaon maldandi, tongraligaon dagdi, sultanpur local dagdi, sultanpur maldandi, harni jogdi (dagdi), harni jogdi, chungi maldandi, musti local (Maldandi), chungi kuch-kachi, baddi jowar, chakur maldandi from Maharashtra, and sai jonna from Andhra Pradesh are considered by the farmers as drought tolerant landraces. These landraces were characterized both for qualitative and quantitative traits. The correlation coefficients of the quantitative traits revealed highly positive correlations among many characters. These trait linkages can serve as best source information on these materials to breed high yielding sorghums targeting food traits and industrial utility.

Key Words: Characterization, Evaluation, Germplasm, Sorghum, Landraces

Introduction

Plant genetic resources represent the inter- and intra-specific reservoir of potentially useful genetic material. Landraces or farmer varieties constitute the basic material for developing any variety or hybrid. Landraces are the varieties nurtured and cultivated by the farmers through traditional method of selection over the decades. An autochthonous landrace is a variety with a high capacity to tolerate biotic and abiotic stress, resulting in high yield stability and an intermediate yield level under a low input agricultural system (Zeven, 1998). The Biodiversity Act (2002) describes "*landrace*" as primitive cultivar that was grown by ancient farmers and their successors.

Early domestication of sorghum occurred from Ethiopian borders extending west through Sudan and up to Lake Chad (Harlan, 1975). There is great prevalence of diversity in this area as apart from the presence of the primitive race *bicolor* (Harlan and de Wet, 1972). It is likely that this race arose from the domestication of *Aethiopicum verticilliflorum* complex some 3,000 to 5,000 years ago. The finding at Nabta Playa may cause some rethinking of dates; however, it is not clear if these 8,000 year old seeds were from plants that did not shatter grains, although altered chemical composition would indicate some selection. *Bicolor* sorghum has spread across much of the old sorghum growing world including India. It is the likely progenitor of the *kaoliongs* of China. The race *guinea* arose from *bicolor* with possible interaction with the wild race *arundinaceum* in the high rainfall areas of West Africa. The *guinea* is now the dominant sorghum of West Africa but has spread also around Tanzania and Malawi. The *guinea* race arose more than 2,000 years ago. The race *caudatum* also possibly evolved from *bicolor*. Today, the *caudatums* are most abundant from East Nigeria to eastern Sudan and southward into Uganda. The race *durra* was selected from early *bicolor* that had moved into India some 3,000 years ago. With Arab migration the *durra* moved into Ethiopia around 615 A.D., and is today the dominant race in India, Ethiopia, the Nile Valley of Sudan and Egypt. Race *kafir* was probably derived from *bicolor* but there is also evidence of association with the wild race *verticilliflorum*. The *kafir* is found primarily in eastern and southern Africa. Later sorghum found its way into the Americas after 1850.

Sorghum is of African origin (Kimber 2003) and Africa has largest diversity of cultivated and wild sorghum (Doggett 1988; deWet, 1977), in the Indian Subcontinent there is evidence for early cereal cultivation discovered at an archaeological site in western parts of Rojdi (Saurashtra) which dating back to about 4,500 before present (Damania, 2002) and India is considered to be secondary center of origin of sorghum (Vavilov, 1992).

The process of genetic resource management's greatest contribution for sorghum improvement has been the establishment of a world sorghum collection. This collection is an outgrowth of an effort which began in

1959 to collect the sorghums and also several of the millets in India, funded by the Rockefeller Foundation. The collection was assembled because of request from different sorghum growing countries. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) along with NARS partners was responsible for this collection, and the programme continues to till date. The collection has grown from about 10,000 accessions in 1972 to 36,774 accessions till date. The total collections encompass landraces (83%), breeding lines (16%) and wild races (1%). During 1999 – 2005, National Research Centre for Sorghum (NRCS) has collected 674 accessions from seven sorghum growing states. This paper discusses about the sorghum landraces collection and characterization at NRCS, under the Indian Council of Agricultural Research (ICAR).

Materials and Methods

National Research Centre for Sorghum under the Indian Council of Agricultural Research is one of the National Active Germplasm Sites (NAGS) with the mandate to collect, conserve, document and utilize the sorghum genetic resources and act as a "National Repository" for sorghum germplasm. In the last decade, we have explored seven states, undertook 15 collection missions and collected 674 accessions, out of which 138 are popular landraces traditionally cultivated by the farmers.

The preliminary characterization of 138 accessions of sorghum landraces was carried out at NRCS, Rajendranagar, Hyderabad during 2002-05. The centre is located at $17^0$19' N latitude and $78^0$24' E longitude and at an altitude of 538 m above MSL with temperature varying from 10^0C to a maximum of 30^0C during the cropping season. The accessions were raised in an augmented design in the sandy soil with check varieties (M35-1, Swati and CSV-15) in each block. The accessions were grown in 4 m rows with row spacing of 60 cm with plant to plant distance of 10 cm. Standard agronomic and plant protection practices were followed during the cropping season. The data on qualitative and quantitative descriptors were recorded using minimal descriptor developed by NBPGR (Mahajan *et al.,* 2000) and NRCS (Elangovan, *et al*., 2004). Five representative plants in each accession were tagged for recording the qualitative and quantitative characters. Brix percentage of each accession was estimated by refractometer. The quantitative data was analysed statistically.

Results and Discussion

There is great variability in sorghum, making selection possible for most traits of economic importance. Germplasm, in the form of breeding stock, collected accessions, and converted tropical cultivars, now moves readily world wide and has contributed significantly to the crop's improvement in terms of yield, resistances and utilization/quality traits (House, 1985). Seven states were explored under the NATP (MM – BD) and 674 accessions were colleted. In which, 138 accessions are popular landraces traditionally cultivated by the farmers. The state-wise list of sorghum landraces is presented in Table 1.

Table 1. State-wise sorghum landrace collections

State	No. of landraces
Andhra Pradesh	18
Karnataka	19
Madhya Pradesh	42
Maharashtra	44
Rajasthan	5
Tamil Nadu	6
Uttar Pradesh	4
Total	138

In these collections, the sorghum landraces are mostly named with the village name prefixed to the landrace (ex. *Tongraligaon maldandi*, *Sultanpur maldandi* etc), landraces are also named based on the grain colour (ex. *tella jonna, bili jola* etc.) and size (ex. *moti rabi jowar*), ear head compactness (ex. *mudda jola*), use of the stem or grain (ex. *dagdi, gundu, allur* etc.) for varieties utilities. A similar observation was made by Teshome *et al.,* (1997) because the midrib color, grain color, grain size, glume color, glume hairiness, and grain shape were the leading morphological characters used by the farmers naming the sorghum landraces. The list of 138 sorghum landraces collected is given in Table 2.

The landraces are being grown by farmers over the years for many reasons. The *moli jowar* grains are attractive and fetch higher price in the market compared to other released varieties in Madhya Pradesh. Some are used for specific food preparations. The *irungu cholam* flour is boiled with water to prepare food. The *mathappu cholam* is used to prepare a jelly like food known as *khali* in Tamil Nadu. The *beed maldandi* and *bidri* from Maharashtra are used to make quality jowar roti. Karnataka's *kodumurugu jola* and *allina jola* are used to make laddu's and pappads,

Table 2. List of sorghum landraces collections

S.No.	Collector number	Indigenous Collection number	Vernacular name	District	State
1	EP – 123	IC420938	Jowri	Nashik	Maharashtra
2	EP – 124	IC420939	Khondya	Ahmednagar	Maharashtra
3	EP – 127	IC420942	Mutka	Pune	Maharashtra
4	EP – 128	IC420943	Bidri	Pune	Maharashtra
5	EP – 132	IC420947	Dagdi maldandi	Pune	Maharashtra
6	EP – 138	IC420953	Bendri dagdi	Satara	Maharashtra
7	E – 101	IC415792	Sabet deshi	Kanpur Dehat	Uttar Pradesh
8	E – 106	IC415797	Jonnari	Unnao	Uttar Pradesh
9	E – 109	IC415800	Jonndi	Rae Bareli	Uttar Pradesh
10	E – 143	IC415834	Bani	Lucknow	Uttar Pradesh
11	E – 89	IC369120	Tella jonna	Mahaboobnagar	Andhra Pradesh
12	PEC – 2	IC392125	Jungala local	Lathur	Maharashtra
13	PEC – 5	IC392128	Baddi jowar	Lathur	Maharashtra
14	PEC – 7	IC392130	Chakur maldandi	Lathur	Maharashtra
15	PEC – 15	IC392138	Maldandi	Bidar	Karnataka
16	PEC – 22	IC392145	Sai Jonna	Medak	Andhra Pradesh
17	PEC – 26	IC392149	Tandur local	Ranga Reddy	Andhra Pradesh
18	EC – 1	IC345703	Tella jonna	Mahaboobnagar	Andhra Pradesh
19	EC – 11	IC345713	Mudda jonna	Kurnool	Andhra Pradesh
20	EC – 12	IC345714	Raichur jonna	Kurnool	Andhra Pradesh
21	EC – 20	IC345722	Oola jonna	Cuddapah	Andhra Pradesh
22	EC – 21	IC345723	Eduakula jonna	Cuddapah	Andhra Pradesh
23	EC – 33	IC345735	Palar jonna	Prakasam	Andhra Pradesh
24	EC – 34	IC345736	Mudda jonna	Prakasam	Andhra Pradesh
25	SEVS – 2	IC347568	Pachcha jonna	Khammam	Andhra Pradesh
26	SEVS – 3	IC347569	Nattu jonna	Khammam	Andhra Pradesh
27	SEVS – 7	IC347573	Tella jonna	Khammam	Andhra Pradesh
28	SEVS – 8	IC347574	Konda jonna	Khammam	Andhra Pradesh
29	SEVS – 17	IC347583	Konda	Khammam	Andhra Pradesh
30	SEVS – 18	IC347584	Kade jonna	Khammam	Andhra Pradesh
31	SEVS – 20	IC347586	Gompu jonna	Khammam	Andhra Pradesh
32	SEVS – 26	IC347592	Koda muddu jonna	Khammam	Andhra Pradesh
33	EP – 54	IC343553	Gorani maldandi	Osmanabad	Maharashtra
34	EP – 55	IC343554	R - 8	Osmanabad	Maharashtra
35	EP – 57	IC343556	Beedari	Beed	Maharashtra
36	EP – 59	IC343558	Beed maldandi	Beed	Maharashtra
37	EP – 64	IC343563	Sedam maldandi gurang	Aurangabad	Maharashtra
38	EP – 65	IC343564	Gurang maldandi	Aurangabad	Maharashtra
39	EP – 68	IC343567	Dadar	Dhule	Maharashtra
40	EP – 78	IC343577	Gurang	Ahmednagar	Maharashtra
41	EP – 79	IC343578	Bandri	Ahmednagar	Maharashtra
42	EP – 80	IC343579	Gurang sabet	Solapur	Maharashtra
43	EP – 81	IC343580	Gurang dagdi	Solapur	Maharashtra
44	EP – 82	IC343581	Sabet ganga gopargaon	Solapur	Maharashtra
45	EP – 84	IC343583	Valsangh maldandi local	Solapur	Maharashtra
46	EP – 86	IC343585	Vadgaon maldandi	Solapur	Maharashtra
47	EP – 87	IC343586	Vadgaon dagdi maldandi	Solapur	Maharashtra
48	EP – 88	IC343587	Tongraligaon maldandi	Solapur	Maharashtra
49	EP – 89	IC343588	Tongraligaon dagdi	Solapur	Maharashtra
50	EP – 90	IC343589	Sultanpur local dagdi	Solapur	Maharashtra
51	EP – 91	IC343590	Sultanpur maldandi	Solapur	Maharashtra
52	EP – 92	IC343591	Harni jogdi (dagdi)	Solapur	Maharashtra
53	EP – 93	IC343592	Harni jogdi	Solapur	Maharashtra
54	EP – 94	IC343593	Chungi maldandi	Solapur	Maharashtra
55	EP – 95	IC343594	Musti local (maldandi)	Solapur	Maharashtra
56	EP – 96	IC343595	Chungi kuch-kachi	Solapur	Maharashtra
57	EP – 97	IC345186	Bile maldandi	Raichur	Karnataka
58	EP – 102	IC345191	Bili jola	Raichur	Karnataka
59	EP – 103	IC345192	Kodumurugu jola	Raichur	Karnataka
60	EP – 104	IC345193	Kanaggu jola	Raichur	Karnataka
61	EP – 105	IC345194	Allin jola	Raichur	Karnataka
62	EP – 106	IC345195	Bili jola	Raichur	Karnataka
63	EP – 107	IC345196	Kanaggu jola	Raichur	Karnataka
64	EP – 112	IC345201	Kadapu jola	Raichur	Karnataka

S.No.	Collector number	Indigenous collection number	Vernacular name	District	State
65	EP – 114	IC345203	Maldandi bili	Raichur	Karnataka
66	EP – 115	IC345204	Allur jola	Raichur	Karnataka
67	EP – 117	IC345206	Bili maldandi	Kappal	Karnataka
68	EP – 120	IC345209	Farm maldandi	Bellary	Karnataka
69	EA – 1	IC345243	Irungu cholam	Dindigul	Tamil Nadu
70	EA – 2	IC345244	Vella cholam	Dindigul	Tamil Nadu
71	EA – 4	IC345246	Karum cholam	Dindigul	Tamil Nadu
72	EA – 6	IC345248	Matthappu cholam	Dindigul	Tamil Nadu
73	EA – 10	IC345252	Irungu cholam	Dindigul	Tamil Nadu
74	EA – 11	IC345253	Sevappu cholam	Madurai	Tamil Nadu
75	GGUB - 19	IC319862	Moli jowar	Jhabua	Madhya Pradesh
76	GGUB - 20	IC319863	Chikni jowar	Jhabua	Madhya Pradesh
77	GGUB - 21	IC319864	Pili local	Jhabua	Madhya Pradesh
78	GGUB - 22	IC319865	Dhavali jowar	Jhabua	Madhya Pradesh
79	GGUB - 23	IC319866	Dadar rabi jowar	Jhabua	Madhya Pradesh
80	GGUB - 25	IC319868	Syalu rabi	Jhabua	Madhya Pradesh
81	GGUB - 27	IC319870	Katrae	Jhabua	Madhya Pradesh
82	GGUB - 29	IC319872	Local jowar	Jhabua	Madhya Pradesh
83	GGUB - 30	IC319873	Lahi jowar	Jhabua	Madhya Pradesh
84	GGUB - 31	IC319874	Barsati jowar	Jhabua	Madhya Pradesh
85	GGUB - 32	IC319875	Badi jowar	Jhabua	Madhya Pradesh
86	GGUB - 34	IC319877	Meethi jowar	Jhabua	Madhya Pradesh
87	GGUB - 35	IC319878	Local kajri jowar	Jhabua	Madhya Pradesh
88	GGUB - 36	IC319879	Syalu rabi jowar	Jhabua	Madhya Pradesh
89	GGUB - 37	IC319880	Chikni pilia	Jhabua	Madhya Pradesh
90	GGUB - 38	IC319881	Kale tonsa ki jowar	Jhabua	Madhya Pradesh
91	GGUB - 39	IC319882	Bajri jowar	Jhabua	Madhya Pradesh
92	GGUB - 40	IC319883	Moti rabi jowar	Jhabua	Madhya Pradesh
93	GGUB - 43	IC319886	Chikni jowar	Jhabua	Madhya Pradesh
94	GGUB - 44	IC319887	Lahi jowar	Betul	Madhya Pradesh
95	GGUB - 46	IC319889	Somji jowar	Betul	Madhya Pradesh
96	GGUB - 47	IC319890	Local sehra	Betul	Madhya Pradesh
97	GGUB - 48	IC319891	Ramtak local	Betul	Madhya Pradesh
98	GGUB - 50	IC319892	Charsi local	Betul	Madhya Pradesh
99	GGUB - 51	IC319893	Aathner mohali	Betul	Madhya Pradesh
100	GGUB - 52	IC319894	Badi sahera jowar	Betul	Madhya Pradesh
101	GGUB - 54	IC319895	Satpari	Khargaom	Madhya Pradesh
102	GGUB - 55	IC319896	Kantolli	Khargaom	Madhya Pradesh
103	GGUB - 56	IC319897	Safeda	Dewas	Madhya Pradesh
104	GGUB - 57	IC319898	Gudagi	Vidisha	Madhya Pradesh
105	GGUB - 58	IC319899	Pili safed	Vidisha	Madhya Pradesh
106	GGUB - 59	IC319900	Safed tinopal	Vidisha	Madhya Pradesh
107	GGUB - 60	IC319901	Somkatch safeda	Vidisha	Madhya Pradesh
108	GGUB - 61	IC319902	Mehara jowar	Vidisha	Madhya Pradesh
109	GGUB - 62	IC319903	Pilimotia	Vidisha	Madhya Pradesh
110	GGUB - 63	IC319904	Murga jowar	Vidisha	Madhya Pradesh
111	GGUB - 64	IC319905	Somkath safea	Guna	Madhya Pradesh
112	GGUB - 65	IC319906	Arom safed	Guna	Madhya Pradesh
113	GGUB - 67	IC319907	Safed jowar	Vidisha	Madhya Pradesh
114	GGUB - 68	IC319908	Mehara jowar	Vidisha	Madhya Pradesh
115	E – 1	IC338968	Jowari local	Udaipur	Rajasthan
116	E – 3	IC338970	Barmada local	Udaipur	Rajasthan
117	E – 4	IC338971	Gudli local	Udaipur	Rajasthan
118	EJ – 3	IC338983	Commedi	Pali	Rajasthan
119	EJ – 42	IC339022	Deshi-chari	Tonk	Rajasthan
120	EB – 1	IC332460	Deshi sabet	Indore	Madhya Pradesh
121	EB – 2	IC332461	Deshi dhawli	Indore	Madhya Pradesh
122	EP – 1	IC305882	Tamalwadi dhagdi	Osmanabad	Maharashtra
123	EP – 9	IC305890	Yermala joot	Osmanabad	Maharashtra
124	EP – 11	IC305892	Yemala lakdi	Osmanabad	Maharashtra
125	EP – 12	IC305893	Yermala dukri	Osmanabad	Maharashtra
126	EP – 13	IC305894	Shirala dagdi	Osmanabad	Maharashtra
127	EP – 14	IC305895	Shirala gota	Osmanabad	Maharashtra
128	EP – 16	IC305897	Jamgaon dagdi	Solapur	Maharashtra
129	EP – 17	IC305898	Jamgaon joot	Solapur	Maharashtra

S.No.	Collector number	Indigenous collection number	Vernacular name	District	State
130	EP – 22	IC305903	Dagdi maldandi	Solapur	Maharashtra
131	EP – 23	IC305904	Dagdi local	Solapur	Maharashtra
132	EP – 24	IC305905	Local maldandi	Solapur	Maharashtra
133	EP – 37	IC305918	Dharunyak danda local	Gulberga	Karnataka
134	EP – 41	IC305922	Hurdajola	Gulberga	Karnataka
135	EP – 42	IC305923	Jevari local	Gulberga	Karnataka
136	EP – 45	IC305926	Gundu jola	Gulberga	Karnataka
137	EP – 46	IC305927	Bagadahali local	Gulberga	Karnataka
138	EP – 52	IC305933	Hale jola	Bijapur	Karnataka

respectively. The *allur jola* from Karnataka is used to prepare allu dish during the nagapanchami (festival of snake God). The *pachcha jonna* from Andhra Pradesh, *barmuda local*, *deshi chari* and *gudli local* from Rajasthan and *bendri dagdi* and *khondya* from Maharashtra are very good fodder types.

Valsangh maldandi local, Vadgaon dagdi maldandi, tongraligaon maldandi, tongraligaon dagdi, sultanpur local dagdi, sultanpur maldandi, harni jogdi (dagdi), harni jogdi, chungi maldandi, musti local (Maldandi), chungi kuch-kachi, baddi jowar, chakur maldandi from Maharashtra, and *sai jonna* from Andhra Pradesh are considered by the farmers as drought tolerant landraces.

The accessions studied exhibited good variability in both qualitative and quantitative traits. In quantitative traits, the time to 50% flowering (56 – 121), plant height (110 – 411 cm), earhead length (8 – 36.2 cm), stem fresh weight (110 – 955 g/plant), stem dry weight (30 – 557 g/plant) and grain yield (3.6 – 92 g/plant) showed good variability. The preliminary characterization of sorghum landraces revealed that stem fresh weight, stem dry weight, plant height, and grain yield are the most variable characters. The descriptive statistics on the quantitative characters of sorghum landraces are presented in Table 3.

The qualitative characters have also shown variability. The higher seedling vigour (59 acc.), tan leaf pigmentation (128 acc.), dark green leaf colour (118 acc.), drooping leaf orientation (80 acc.), white midrib colour (55 acc.), elliptical earhead shape (80 acc.), semi compact earhead (91 acc.), straw glume colour (52 acc.), 50% glume coverage (44 acc.), presence of awns (105 acc.), bold seed size (71 acc.), pearly white seed colour (81 acc.), non-senescence (stay green) plant type (133 acc.), durra race (78 acc.), and non-lustrus seed (52 acc.) recorded maximum frequency in qualitative characters. The frequency of qualitative characters is given in Table 4.

The correlation coefficients of the quantitative traits revealed highly positive correlations for in time to 50% flowering and time to maturity; number of leaves with leaf length, leaf width, plant height, stem thickness, stem fresh weight, and stem dry weight; leaf length with leaf width, plant height, stem thickness, stem fresh weight and stem dry weight; leaf width with stem fresh weight and stem dry weight; plant height with stem fresh weight and stem dry weight; stem thickness with stem fresh weight and stem dry weight; stem fresh weight with stem dry weight; and grain yield with 100-seed weight (Table 5). Highly negative correlations were observed for grain yield with number of leaves, leaf length, plant height and earhead

Table 3. Statistical analysis of quantitative characters

Characters	Min.	Max.	Range	Mean	SE	SD	Variance
Time to 50% flowering (days)	56.0	121.0	65.0	79.0	0.8	9.1	82.9
Number of leaves	6.0	19.0	13.0	12.0	0.2	2.8	7.7
Leaf length (cm)	50.9	101.6	50.7	71.2	1.1	12.8	163.9
Leaf width (cm)	4.8	10.8	6.0	7.5	0.1	1.3	1.6
Plant height (cm)	110.0	411.0	302.0	218.0	6.0	70.0	4902.9
Ear head length (cm)	8.0	36.2	28.2	17.9	0.5	5.3	28.5
Ear head width (cm)	3.3	10.9	7.5	6.4	0.1	1.4	1.9
Stem thickness (cm)	1.0	2.9	1.9	1.6	0.0	0.3	0.1
Stem fresh weight (g)	110.0	955.0	845.0	343.2	13.2	153.2	23482.8
Stem dry weight (g)	30.0	557.0	527.0	172.5	7.6	87.9	7730.3
Brix (%)	3.0	23.0	20.0	15.0	0.3	4.0	16.0
Grain yield (g)	3.6	92.0	88.4	41.7	1.7	19.6	383.0
100-seed weight (g)	0.9	4.6	3.7	2.9	0.1	0.8	0.6

Table 4. Frequency of qualitative characters

Character	Frequency
Seedling vigour	Good-47
	Poor-30
	Very good-59
	Unclassified-2
Leaf pigmentation	Non-tan-8
	Tan-128
	Unclassified-2
Leaf colour	Dark green-118
	Light green-17
	Pale green-1
	Unclassified-2
Leaf orientation	Drooping-80
	Erect-56
	Unclassified-2
Midrib colour	Colourless-16
	Dark green-1
	Dull green-51
	Green-1
	Pale green-7
	Purple-5
	White-55
	Unclassified-2
Ear head shape	Broom corn-1
	Elliptical-80
	Loose-1
Ear head shape	Oblong-24
	Ovate-23
	Round-2
	Unclassified-7
Ear head compactness	Compact-34
	Loose-2
	Semi compact-91
	Semi loose
	Unclassified-7
Glume colour	Black-10
	Brown-20
	Dark red-2
	Light red-3
	Orange-3
	Pink-1
	Purple-8
	Red-30
	Straw-52
	Unclassified-9
Glume covering	25% -12
	50% -44
	75% -26
	100% - 25
	Unclassified -31
Awn	Absent-26
	Present-105
	Unclassified-7
Seed size	Bold-71
	Medium-21
	Small-9
	Very bold-25
	Unclassified-12
Seed colour	Brown-1
	Chalky white-7
	Light brown-1
	Light orange-2
	Light yellow-1
	Orange-3
	Pearly white-81
	White-27
	Yellow-2
	Unclassified-13
Stay green	Non-senescence-133
	Senescence-1
	Unclassified-4
Race	Bicolor-5
	Durra-78
	Durra bicolor-2
	Durra caudatum-13
	Guinea-6
	Guinea caudatum-6
	Unclassified-28
Lustre	Lustrus-24
	Non lustrus-52
	Unclassified-62
Remarks	Broad leaves-7
	Good-10
	Late flowering-4
	Red pigmented seed-2
	Twin seed-2
	Very good-15
	Very good, blunt end of panicle-1

length; the 100-seed weight with leaf length, plant height, and earhead length; and the time to maturity with leaf width.

The variation in sorghum landraces for morphological characters has been reported by many workers in different countries. The evaluation of 152 accessions collected from Rwanda showed that the sorghum from Rwanda grows very tall (up to 500 cm), and takes more days to flower during long days (rainy season) and less no. of days during short days indicating strong photoperiod sensitivity. Enormous variation was observed for panicle and grain characters (Appa Rao *et al.,* 1999).

Thirty four sorghum landraces collected from five agroecological sites (ecosites) in North Shewa and South Welo regions of Ethiopia have exhibited morphological variation for the 14 qualitative characters that showed two or more phenotypic classes. Panicle compactness and shape contributed relatively more to altitudinal and ecological

differentiation. This differential distribution of landraces with panicle types with respect to compactness and shape revealed the adaptive significance of panicle compactness and shape that reflected the patterns of distribution of different races in North Shewa and South Welo (Abdi *et al.*, 2002). The present study also observed the variation in panicle compactness.

The study to assess the phenotypic diversity and pattern of distribution among Sudanese sorghum landraces collected from different geographical regions revealed high phenotypic diversity among landraces with large range of variation for mean quantitative traits. Collections from Kassala showed a higher frequency of landraces with kernels that were more difficult to thresh. Landraces from Blue Nile tended to have greater agronomic eliteness with higher proportion of landraces with white kernels, poorly covered and were easy to thresh. Sorghums from the Upper Nile tended to have loose panicles with poorly covered kernels that may have resulted from the adaptation to high rainfall area in southern region (Grenier *et al.,* 2004).

Field survey data of sorghum landrace populations grown by traditional farmers in four adjacent communities in the Ethiopian highlands were used to analyze and project the local risk of loss of individual landraces under three scenarios: wild population, traditional farming and agricultural modernization. The risk of loss in the wild population scenario is based on landscape ecology theory which evaluates total population size, spatial distribution and patch occupancy, with high values for each factor and the sum of the factors decreasing the risk. In the traditional farming scenario, the deliberate actions of farmers must be taken into account like farmers favour for various traits of the sorghum for specific reasons – yield, taste, storability etc., which will balance plant numbers according to quantity and quality requirements. In the agricultural modernization scenario, introduction of high-yielding varieties tendency toward monocultures, use of agricultural chemical force the traits of the landraces that are most likely to be displaced and also bring in nature of the landraces that are likely to be retained on the basis of cultural or other factors (Tunstall *et al.,* 2001). Hence, the collection and protection of Indian sorghum landraces is very important.

Landraces are the sources of diversity for further use in crop improvement programmes. Unless landraces are collected, and conserved and protected, we can not

Table 5. Correlation coefficient of quantitative characters

Characters	DFL	NOL	LL	LW	PH	EHL	EHW	ST	SFW	SDW	BX	GY	SW	DM
Time to 50% flowering (days)	1.00													
Number of leaves	0.012	1.00												
Leaf length (cm)	-0.078	0.838**	1.00											
Leaf width (cm)	-0.138	0.672**	0.681**	1.00										
Plant height (cm)	-0.068	0.852**	0.791**	0.463**	1.00									
Ear head length (cm)	-0.243**	0.338**	0.407**	0.118	0.389**	1.00								
Ear head width (cm)	0.278**	-0.020	-0.173*	-0.052	-0.058	0.091	1.00							
Stem thickness (cm)	0.268**	0.612**	0.542**	0.437**	0.424**	0.191*	0.172*	1.00						
Stem fresh weight (g)	0.106	0.688**	0.622**	0.504**	0.672**	0.081	0.021	0.636**	1.00					
Stem dry weight (g)	0.101	0.665**	0.607**	0.491**	0.672**	-0.001	-0.029	0.550**	0.902**	1.00				
Brix (%)	-0.063	0.426**	0.473**	0.305**	0.361**	0.167	-0.115	0.250**	0.272**	0.324**	1.00			
Grain yield (g)	0.309**	-0.494**	-0.580**	-0.206*	-0.590**	-0.435**	0.256**	-0.204*	-0.351**	-0.335**	-0.272**	1.00		
100-seed weight (g)	0.338**	-0.341**	-0.433**	-0.128	-0.471**	-0.452**	0.299**	-0.113	-0.229*	-0.133	-0.144	0.651**	1.00	
Time to maturity (days)	0.690**	-0.250**	-0.277**	-0.442**	-0.301**	-0.176*	0.240**	0.072	-0.210*	-0.172*	-0.058	0.380**	0.411**	1.00

** Significant at 1% level; * Significant at 5% level

- DFL=Days to 50% flowering (days), NOL=Number of leaves, LFL=Leaf length (cm), LFW=Leaf width (cm), PHT=Plant height (cm), EHL=Ear head length (cm), EHW=Ear head width (cm), STS=Stem thickness (cm), SFW=Stem fresh weight (g), SDW=Stem dry weight (g), BRX=Brix (%), GRY=Grain yield (g), SWT=100-seed weight (g), DYM=Days to maturity (days)

have legal right on these diverse lines. Hence, they need to be registered first with NBPGR and then protect them under Plant Variety Protection Act 2001 in India, so that bio-piracy and extinction of these valuable resources, is prevented. It is the responsibility of all engaged in sorghum research to collect, conserve and protect them in a scheduled timeframe on mission mode basis.

Sorghum in India is grown in two seasons, namely, rainy (*kharif*) and post-rainy (*rabi*) season in India. The requirements of varieties are different for two seasons. The emphasis is that the rainy season adapted varieties should be photosensitive, dwarf stature, and short duration to escape with infection by grain mold. On the other hand, varieties for the post-rainy season adaptation should be tall, high yielding with reasonable levels of terminal drought tolerance to sustain receding residual moisture. During the past four decades, remarkable progress has been made by diversifying the parental lines for yield (both grain and fodder), maturity, height, disease and insect resistance and quality improvement by utilization of indigenous and exotic germplasm.

Notable varieties developed during the early period through the landraces and still under cultivation are the Co-series in Tamil Nadu; the PJ kharif and rabi selections, Saoner, Ramkel, Aispuri, the Maldandi, Guntur and Anakapalle series of Andhra Pradesh; the bilichigan, fulgar white, fulgar yellow, kauvi, Nandyal, hagari, yanigar varieties of the erstwhile Mysore state. Indian germplasm line *karad local* was crossed with American material IS 3922 to develop the MS line 296A, which was the best combiner. By utilizing local variety Vidisha 60-1 at Indore centre, the ms line of CSH 18 (ms IMS 9A) was developed. The local variety, Vidisha 60-1 not only contributes for high stover yield but also for improved grain quality. The grain yield levels of rainy season hybrids have reached the plateau and there is a need to exploit unused germplasm and land races to diversify the genetic base (Elangovan *et al*., 2005).

Post-rainy season varieties were developed by crossing Indian locals, M 35-1 and IS 2644 with American germplasm lines. Marginal improvement was achieved for grain yield over the most popular local variety M 35-1. Recently released variety, CSV 216R (CSV 16) is a landrace selection from *rabi* germplasm from Maharashtra. Another variety which became very popular, SPV 462, (from Coimbatore) was developed from multiple cross involving IS 2947 and IS 3687 from USA and IS 1151 and BP 53, locals of Maharashtra and Gujarat in India, respectively.

The need for further critical evaluation of germplasm and its utilization in grain and forage sorghum improvements is keenly felt. Sorghum collection missions may be further arranged on the specific targeted germplasm availability areas based on the usage like sweet sorghum, pop sorghum, dual-purpose sorghum and sorghums resistant to pests and diseases etc. Landraces are known to possess local adaptation and stability and may offer opportunities for direct utilization. On the other hand, improved varieties with diverse genetic base are likely to show wider adaptation and enhanced performance. Judicious combination of both in recombination breeding programmes can further lead to upgradation of yield potential. So far *caudatum* and *durra* types have been exploited. Inclusion of *guinea* germplasm may bring further increase in yield potential, tolerance to grain mold and lodging resistance.

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