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Suvarna
Assistant Professor, Department of Genetics and Plant Breeding, College of Agriculture, UAS, Raichur, Karnataka, India

PM Salimath
Former VC, UAS, Raichur, Karnataka, India

HD Upadhyaya
Former Head, R. S. Paroda Gene Bank, ICRISAT, Patancheru, Hyderabad, Telangana, India

R Lokesha
Dean (Agri.), College of Agriculture, Bheemarayanagudi, UAS, Raichur, Karnataka, India

JM Nidagundi
Professor and Head (Cotton), MARS, UAS, Raichur, Karnataka, India

JR Patil
ADR, RARS, Kalaburgi, UAS, Raichur, Karnataka, India

Ayyanagouda Patil
Assistant Professor, Dept. of Biotechnology, College of Agriculture, Raichur, Karnataka, India

Corresponding Author:
Suvarna
Assistant Professor, Department of Genetics and Plant Breeding, College of Agriculture, UAS, Raichur, Karnataka, India

Collection and characterisation of sorghum landraces from North Karnataka

Suvarna, PM Salimath, HD Upadhyaya, R Lokesha, JM Nidagundi, JR Patil and Ayyanagouda Patil

Abstract
A total of 140 landraces were collected from northern districts of Karnataka, characterised and evaluated during *rabi* 2016 and 2017 along with seven check varieties in an augmented design. Maximum number of collections were made from Vijayapur (52) followed by Kalaburgi district (38). Considerable variability was present among the landraces for six qualitative and fourteen quantitative characters studied. Among the landraces, majority of the landraces have semi loose erect primary branches (104), yellow glume colour (38), 50 per cent grain coverage by glume (108), yellow grain colour (93), circular grain shape (125), easy to thresh (138) and presence of awns (137) at maturity. Among the quantitative characters, peduncle length, panicle weight and grain weight per plant and grain yield showed more variation during *rabi* 2016 and 2017. Grain yield was positively correlated with SCMR, number of green leaves per plant, panicle width, panicle weight and grain weight per plant and 100 grain weight and negatively correlated with peduncle length during both the seasons.

Keywords: Sorghum, landraces, correlation, collection, characterisation

Introduction
Sorghum (*Sorghum bicolor* (L.) Moench) is one of the major cereal crops of the semi-arid tropics and fifth most important crop of the world. It is the staple food in arid and semi arid parts of the world, due to its drought tolerance property. At present, the world is witnessing the vagaries of global climate change. Increasing temperatures, changing rainfall patterns and increases in frequency of extreme events, such as droughts, storms, floods and weather extremes will present important challenges to agriculture and food systems (Ortiz, 2011 and Vermeulen *et al*., 2012) [8, 14]. So there is a need to develop the varieties which are tolerant / resistant to different stresses. For this there is a need to collect and evaluate the plant genetic resources. Traditional crop varieties or landraces are well adapted to current conditions in their local production environments. Landraces tend to possess significant phenotypic variability and some have developed tolerances to particular abiotic and biotic stresses, such as disease resistance or cold tolerance (Eagles and Lothrop 1994) [3].
Sorghum is grown both during rainy (*kharif*) and post rainy (*rabi*) seasons. *Rabi* sorghum is grown in northern Karnataka mainly as rainfed crop and to a very little extent under irrigated conditions. It is widely grown in the districts of Vijayapur, Bagalkot, Bellary, Belgaum, Bidar, Dharwad, Gadag, Gulbarga, Haveri, Koppal and Yadgir. However, the area and production of *rabi* sorghum is shrinking from last two decades owing to the impact of climate change in north Karnataka.
Collection and characterization of sorghum landraces for identification of desirable traits is very much a part of the breeding programme for developing improved varieties. Efforts are being made by the germplasm conservation institutes and research institutes *viz*., National Bureau of Plant Genetic Resources (NBPGR), New Delhi, ICRISAT, Patancheru and Indian Institute of Millets Research (IIMR), Hyderabad etc., in collection of sorghum landraces and their characterisation and maintenance (Mathur *et al*., 1993 [7], Upadhyaya *et al*., 2016 [13], Upadhyaya *et al*., 2017 [12], Elangovan (2007) [4], Elangovan *et al*., 2009 and 2012 [5, 6] from different parts of Karnataka / India / across the world). Pramod (2013) [9] and Shiferaw and Yoseph (2014) [11] also characterised the landraces of sorghum. So an effort was made to collect and characterise the landraces of sorghum from the northern districts of Karnataka.

Material and Methods
The sorghum landraces were collected from the northern districts of Karnataka *viz*., Raichur, Kalaburgi, Vijayapur, Bellary, Yadgiri and Bagalkot during August-September 2016 by keeping the reference set of the earlier collections (1993 year) in the northern districts of

Karnataka made by ICRISAT, Patancheru. Efforts were made to collect the cultivated forms as many landraces as possible presently being grown by the farmers. A total of about 140 landraces were collected from six districts. The released varieties (M 35-1, Muguthi, BJV 44, SPV 2217, DSV 4, GRS 1 and CSV 29) were collected from the three different sorghum research centres *viz.,* ZARS, Kalaburgi, UAS, Dharwad and RARS, Vijayapur were included in the study as check varieties. The 140 landraces along with seven check varieties were characterised at College of Agriculture, Raichur during *rabi* 2016 and 2017 using augmented design. The experiment was sown during October month. Each landrace was sown in a 4 m row following 45 cm x 15 cm spacing. The fertilizer application and plant protection measures were undertaken as per the package of practices. Protective irrigation was given during both the years.

The observations were carried out on the qualitative characters namely inflorescence shape and compactness, grain coverage by glume, glume colour, grain colour, presence of awns at maturity, threshability and quantitative characters namely plant height (cm), days to 50% flowering, number of green leaves per plant, days to maturity, peduncle length (cm), panicle length (cm), panicle width (cm), panicle weight (g) per plant, grain weight per plant (g), hundred grain weight (g), grain yield per row (g) by following descriptors for sorghum (Anon., 1993). The Physiological characters namely flag specific leaf area (FSLA) (cm^2/g) calculated by using the formula FSLA (cm^2 /g) = Flag leaf area (cm^2) / oven dried weight (g); flag leaf temperature (^oC) and SPAD chlorophyll meter reading (SCMR) were taken in flag leaf at flowering stage. Descriptive statistics (mean, range, Standard deviation, variance and coefficient of variation) and correlations were worked out using SPSS software.

Results and Discussion

A maximum of 140 landraces were collected from the six districts of N. Karnataka during 2016. Lot of variability was observed in the collected landraces. The maximum number of collections were made from the Vijayapur district (52) followed by Kalaburgi district (38). The taluk wise landrace collection is presented in table 1. Among the collections, landraces are named by the farmers based on locations prefixed to the landrace (*Vijayapur jola, Hagari local*), landraces also named based on the grain colour (*Bili jola*), based on glume colour (*Kariguni jola, Kempu guni jola*), based on the purpose used for food preparation (*Holige jola / Kadubina jola, Haralina jola*), also based on earhead compactness (Gundu jola, Fareketene, Ghat tene) (Table 2). Similarly the landraces were collected and characterised by Mathur *et al*., 1993 [7], Upadhyaya *et al*., 2016 [13], Upadhyaya *et al*., 2017 [12], Elangovan (2007) [4], Elangovan *et al*., 2009 and 2012 [5, 6], Pramod (2013) [9] and Shiferaw and Yoseph (2014) [11] from different parts of Karnataka / India / across the world. In majority of the villages, farmers are growing the Maldandi variety. A few farmers in the villages are still maintaining the landraces, may be attributed to its special qualities (like cooking qualities, popping quality etc.).

The landraces studied in the present investigation exhibited good variability in both qualitative and quantitative characters. For qualitative characters, variability was observed with respect to all the characters studied except plant pigmentation at harvest (Table 3). Among the landraces, majority of the landraces have semi loose erect primary branches (104), yellow glume colour (38), 50 per cent grain coverage by glume (108), yellow grain colour (93), circular grain shape (125), easy to thresh (138) and presence of awns (137). Mathur *et al*., 1993 [7], Upadhyaya *et al*., 2016 [13], Upadhyaya *et al*., 2017 [12], Elangovan (2007) [4], Elangovan *et al*., 2009 and 2012 [5, 6], Pramod (2013) [9] and Shiferaw and Yoseph (2014) [11] have characterized their respectively collected sorghum landraces from different locations which were under cultivation during their course of study.

For quantitative characters also, variability was observed in the studied landraces both during *rabi* 2016 and 2017 seasons (Table 4 and 5). Almost same trend of range was observed among the landraces for all characters during both the seasons 2016 and 2017 except for SCMR, FSLA (g/cm^2), plant height (cm) and grain yield (g/row). The characters days to 50% flowering (56.0 – 85 days and 54.0 – 82.0 days), days to maturity (104-134 days and 101.0 – 132.0 days), SCMR (26.5-53.1 and 23.3 – 45.0), FSLA (105.4 – 286.3 and 132.9 – 275.6 g/cm^2), flag leaf temperature (23.3 - 33.5^{0}C and 21.9 – 33.2 ^{0}C), no. of green leaves at flowering stage (4.5 – 10.5 and 5.0 – 11.0), plant height (140.3 – 277.7 cm and 180-298.0 cm), peduncle length (15.0-63.0 cm and 16.6 – 65.3 cm), panicle length (8.0-21.3 cm and 7.6 – 24.0 cm), panicle width (8.3 – 22 cm and 6.0 – 21.0 cm), panicle weight per plant (13.8-72.0 g and 12.0 – 74.0 g), grain weight per plant (10.5 – 61.0 g and 10.4 – 62.8 g), hundred grain weight (1.5 - 4.5 g), grain yield per row (160.0 - 950.5 g and 195.5 – 883.8 g) showed good variability during *rabi* 2016 and 2017 respectively.

The existence of variation among the landraces was studied for all the characters based on the variance and coefficient of variation. The trend of variation for all the characters in both the seasons was same (Table 4 and 5). The characters, which showed low variation (C.V. %) were days to 50 per cent flowering (5.9% and 5.9%) and days to maturity (3.9% and 3.8%), flag leaf temperature (^{0}C) (5.7% and 9.6%) and plant height (cm) (12.2% and 12.7%) during *rabi* 2016 and 2017 respectively. Some characters which showed more variation were peduncle length (cm) (32.5% and 31.5%), panicle weight per plant (g) (39.7% and 31.6%), grain weight per plant (g) (42.5% and 34.7%) and grain yield per row (g) (38.7% and 27.7%) during *rabi* 2016 and 2017 respectively.

Variation for morphological characters has also been reported by Upadhyaya *et al*., (2016 and 2017) [13, 12] in the collections from various countries, Mathur *et al*. (1993) [7], Elangovan (2007) [4] and Elangovan, *et al*. (2009) [5] in sorghum landraces collected from Karnataka and from seven states in India respectively.

Majority of the associations between the characters were found same during both the seasons *rabi* 2016 and 2017 except few (Table 6). Positive correlation of grain yield per row (g) was found with SCMR, number of green leaves per plant, panicle width (cm), panicle weight per plant (g), grain weight per plant (g) and 100 grain weight (g), whereas negative correlation of grain yield per row (g) was found with peduncle length (cm) during both the seasons *rabi* 2016 and 2017. Seetharam and Ganesamurthy (2013) was found significant correlation of yield with days to 50% flowering, leaf length, leaf width and panicle weight. Aminon *et al.* (2015) found positive correlation of grain yield with panicle weight and 100 grain weight.

Positive associations was found among the characters, *viz*., days to 50% flowering with days to maturity and 100 grain weight ; days to maturity with 100 grain weight; SCMR with panicle width, panicle weight and grain weight per plant (g); number of green leaves with panicle width (cm), panicle weight (g) and grain weight (g); plant height (cm) with

peduncle length (cm) and panicle length (cm) ; peduncle length (cm) with panicle length (cm) ; panicle width (cm) with panicle weight (g) and grain weight (g); panicle weight (g) with grain weight (g) and 100 grain weight (g).

Peduncle length was negatively correlated with days to 50% flowering, days to maturity, number of green leaves per plant, panicle width (cm), panicle weight per plant (g), grain weight per plant (g) and 100 grain weight (g).

Germplasm collection and characterization is important and initial step in breeding programme. Landraces are valuable sources for biotic or abiotic stress resistance or some quality traits. The collected landraces showed wide variability for some of the traits. Further study is required to screen landraces for abiotic or biotic stress resistances in order to identify the resistance sources.

Table 1: Number of sorghum GBAs and FVAs collected from different districts, taluks and villages in North Karnataka

District	Taluk	No. of Landraces	District	Taluk	No. of Landraces
Vijayapur	B.Bagewaadi	14	Kalaburgi	Kalaburgi	14
	Vijayapur	22		Chincholli	16
	Indi	13		Sedum	02
	Sindagi	02		Jevargi	06
	Total	52		Total	38
Bagalkot	Hungund	07	Bellary	Bellary	01
	Bagalkot	03		Kudligi	06
	Biligi	07		Hadagali	06
	Total	17		Hagari	01
				Total	14
Raichur	Devadurga	05			
	Lingasugur	03	Yadgiri	Surpur	03
	Raichur	05		Shahpur	03
	Total	13		Total	06

Table 2: Types of sorghum landraces collected from different districts of North Karnataka

Sl. No.	Type of landrace	Bagalkote	Bellary	Kalaburgi	Raichur	Vijayapur	Yadgiri	Total
1	Basavanna Muti (Bili jola)	-	-	2	-	-	-	2
2	Beene hale jola	-	1	-	-	-	-	1
3	Bennalli jola	-	1	-	-	-	-	1
4	Bili Gundudinni Jola	1	-	-	-	-	-	1
5	Bili Holige jola			1				1
6	Bili Jola	2	3	13	5	11	4	38
7	Bili Jola (Harakatene)	-	1	1	-	-	-	2
8	Dundaneya Bilijola	-	1	-	-	-	-	1
9	Farkitene Jola	-	-	1				1
10	Gangavati Bili Jola	-	-	-	-	1	-	1
11	Ghat tene Jola	-	-	1	-	-	-	1
12	Gundu tene (Muttina tene)	1	-	4	-	3	-	8
13	Hagari local	-	1	-	-	-	-	1
14	Hale jola	-	1	-	-	2	-	3
15	Haralina Jola	6	-	3	2	7	-	18
16	Holige jola	-		1	-	-	-	1
17	Javari Bili Jola	-	1	-	-	-	-	1
18	Kadubina Jola	-		1	2	-	-	3
19	Kadubina Jola (Bili)	-	-	-	-	3	-	3
20	Kadubina Jola /Holige Jola (Kempu)	1	-	1	-	7	1	10
21	Kagimuti Jola (Haralina Jola)	-	-	-	-	-	1	1
22	Kalaburgi jola	-	1	-	-	-	-	1
23	Kariguni Jola	-	1	-	-	1	-	2
24	Kempu Gundudinni	1	-	-	-	-	-	1
25	Kempu guni jola	-	1	-	-	-	-	1
26	M-35-1 / Maldandi	2	1	7	3	8	-	21
27	MuddihaleJola	-	-	-	-	2	-	2
28	Sakremukre Jola	2	-	1	1	5	-	9
29	Vijayapur Jola	1	-	-	-	-	-	1

Table 3: Characterisation of sorghum landraces for different qualitative characters at college of Agriculture, Raichur during *rabi* 2016

	Character	Frequency		Character	Frequency
1.	**Plant colour at harvest**			**Grain coverage by glume**	
1	Tan	140	1	25% covering	2
2	Pigmented	-	2	50% covering	108
			3	75% coverining	06
2.	**Inflorescence compactness and shape**		4	100% coverining	02
1	Loose erect primary branches	1	5	Glumes longer than grain	22
2	Loose drooping primary branches	3			
3	Semi loose erect primary branches	104		**Grain colour**	
4	Semi compact Elliptic	21	1	Yellow	93
5	Compact Elliptic	11	2	Light yellow	18
			3	White	18
3.	**Glume colour**		4	Light Red	02
1	Yellow (Straw colour)	38	5	Red	07
2	Light yellow	15	6	Light brown	02
3	Light brown	18			
4	Red	4		**Grain shape**	
5	Dark red	2	1	Circular	125
6	Reddish brown	6	2	Elliptic	15
7	Black	13			
8	Light orange red	2		**Threshability**	
9	Mix of yellow and red	5	1	Easy to thresh	138
10	Mix of orange and yellow	1	2	Difficult to thresh	02
11	Light brown & red	1			
12	Yellow and Red	29		**Awns present at maturity**	
13	Yellow and black	6	1	Awns present	137
			2	Awns absent	03

Table 4: Descriptive statistics of sorghum landraces evaluated at College of Agriculture, Raichur during *rabi* 2016

Characters	Mean	Range		Standard Error	Standard Deviation	Variance	Coefficient of Variation (%)
		Min.	Max.				
Days to 50% flowering	75.0	56.0	85.0	0.37	4.4	19.27	5.9
Days to maturity	123.4	104.0	134.0	0.40	4.8	22.59	3.9
SPAD chlorophyll meter reading	37.1	26.5	53.1	0.47	5.6	31.30	15.1
Flag specific leaf area (cm^2/g)	190.5	105.4	286.3	1.98	23.4	547.12	12.3
Flag leaf temperature (^oC)	28.2	23.3	33.5	0.14	1.6	2.63	5.7
Number of leaves at flowering stage	7.4	4.5	10.5	0.11	1.2	1.55	16.9
Plant height (cm)	214.5	140.3	277.7	2.20	26.1	679.15	12.2
Peduncle length (cm)	32.4	15.0	63.0	0.89	10.6	111.49	32.5
Panicle Length (cm)	13.4	8.0	21.3	0.23	2.8	7.58	20.5
Panicle Width (cm)	13.3	8.3	22.0	0.21	2.5	6.45	19.1
Panicle weight per plant (g)	32.6	13.8	72.0	1.10	13.0	168.32	39.7
Grain weight per plant (g)	26.8	10.5	61.0	0.96	11.4	129.45	42.5
Hundred grain weight (g)	2.8	1.5	4.5	0.06	0.7	0.54	26.6
Grain yield per row (g)	413.4	160.0	950.5	13.51	159.9	25567.96	38.7

Table 5: Descriptive statistics of sorghum landraces evaluated at College of Agriculture, Raichur during *rabi* 2017

Characters	Mean	Range		Standard Error	Standard Deviation	Variance	Coefficient of Variation (%)
		Min	Max				
Days to 50% flowering	73.0	54.0	82.0	0.36	4.3	18.3	5.9
Days to maturity	121.4	101.0	132.0	0.39	4.6	21.3	3.8
SPAD chlorophyll meter reading	35.7	23.3	45.0	0.38	4.5	20.2	12.6
Flag specific leaf area (cm^2/g)	216.1	132.9	275.6	2.63	31.1	965.6	14.4
Flag leaf temperature (^oC)	26.7	21.9	33.2	0.22	2.6	6.6	9.6
Number of leaves at flowering stage	8.6	5.0	11.0	0.09	1.1	1.2	12.7
Plant height (cm)	238.3	180.0	298.0	2.29	27.1	735.4	11.4
Peduncle length (cm)	34.1	16.6	65.3	0.91	10.7	115.4	31.5
Panicle Length (cm)	15.1	7.6	24.0	0.28	3.3	11.1	22.0
Panicle Width (cm)	13.6	6.0	21.0	0.20	2.4	5.6	17.4
Panicle weight per plant (g)	38.6	12.0	74.0	1.03	12.2	148.7	31.6
Grain weight per plant (g)	31.7	10.4	62.8	0.93	11.0	121.2	34.7
Hundred grain weight (g)	3.1	1.5	4.5	0.05	0.6	0.4	20.3
Grain yield per row (g)	448.9	195.5	883.8	10.52	124.5	15506.3	27.7

Table 6: Correlation among the quantitative traits studied in sorghum landraces during *rabi* 2016 (upper diagonal) and *rabi* 2017 (lower diagonal)

	DF	DM	CHL	SLA	LTE	GLE	PHT	PEL	PLE	PWI	PWT	GWT	TWT	GYL
DF	1.0000	0.9849**	-0.4201**	0.2126*	-0.1241	-0.0489	0.0433	-0.2997**	-0.1975*	-0.1489	-0.0737	-0.0726	0.3112**	-0.0941
DM	0.9851**	1.0000	-0.4286**	0.2104*	-0.1475	-0.0534	0.0400	-0.2873**	-0.1945*	-0.1591	-0.0969	-0.0985	0.2841**	-0.1245
SCMR	0.0500	0.0430	1.0000	-0.4165**	-0.1090	0.2936**	-0.0565	0.0504	0.2435**	0.4118**	0.3956**	0.3956**	-0.1213	0.4515**
FSLA	0.0202	0.0386	-0.1062	1.0000	-0.0074	-0.2230**	0.1049	0.1383	-0.0052	-0.3105**	-0.3991**	-0.3969**	0.0742	-0.3561**
LTE	-0.0870	-0.0885	-0.1372	0.0841	1.0000	-0.1334	-0.1351	0.1269	0.0447	-0.1340	-0.0773	-0.0990	0.0570	-0.1357
GLE	0.0390	0.0364	0.1605	0.0166	-0.0882	1.0000	-0.0821	-0.2756**	0.0016	0.3997**	0.4755**	0.4769**	0.1818	0.4916**
PHT	0.2143*	0.2031*	0.0674	-0.1193	-0.2933**	0.0002	1.0000	0.2888**	0.2930**	0.0850	0.0563	0.0684	0.0431	0.0402
PEL	-0.2561**	-0.2707**	-0.0827	0.0283	-0.2192*	-0.3266**	0.2241**	1.0000	0.5911**	-0.3439**	-0.3643**	-0.3577**	-0.1960*	-0.2925**
PLE	-0.0954	-0.1138	-0.0751	0.1196	-0.1928*	-0.0803	0.3408**	0.6219**	1.0000	0.0496	0.1073	0.0912	-0.0386	0.0740
PWI	0.1700*	0.1658	0.2847**	-0.1244	-0.1193	0.2708**	0.1567	-0.4609**	-0.0979	1.0000	0.8089**	0.7870**	0.1105	0.6088**
PWT	0.1932*	0.1955*	0.2787**	-0.1504	-0.0448	0.2707**	0.1719*	-0.3934**	0.0425	0.7210**	1.0000	0.9810**	0.2726**	0.7272**
SWT	0.1774*	0.1793*	0.2787**	-0.1247	-0.0651	0.2897**	0.1516	-0.3907**	0.0250	0.7188**	0.9773**	1.0000	0.3160**	0.7540**
TWT	0.3311**	0.3458**	0.0648	-0.0280	-0.0828	0.2545**	0.1211	-0.2889**	-0.0830	0.2779**	0.3029**	0.3596**	1.0000	0.2302**
SYR	0.0915	0.0889	0.2207**	-0.0397	-0.0535	0.3160**	0.1164	-0.3369**	0.0564	0.6299**	0.8169**	0.8422**	0.2842**	1.0000

*significant at 5%, **significant at 1% level.

DF- Days to 50% flowering,
DM – Days to maturity,
SCMR – Spad chlorophyll meter reading,
FSLA – Flag specific leaf area (cm^2/g),
LTE – Flag leaf temperature (^0C)
GLE – Number of green leaves per plant
PHT – Plant height (cm),
PEL – Peduncle length (cm),
PLE – Panicle length (cm)
PWI – Panicle width (cm)
PWT – Panicle weight per plant (g)
GWT - Grain weight per plant (g)
TWT – Hundred grain weight (g)
GYL – Grain yield per row (g)

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