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Ashwini Karadi
Indian Institute of Horticultural Research, Hesarghatta, Karnataka, India

ST Kajjidoni
College of Agriculture, Professor (HAG)University of Agricultural Sciences, Dharwad, Karnataka, India

Correspondence
Ashwini Karadi
Indian Institute of Horticultural Research, Hesarghatta, Karnataka, India

Genetic variability and diversity for productivity traits and grain quality including nutritional quality traits in selected mini core and promising released varieties of sorghum

Ashwini Karadi and ST Kajjidoni

Abstract
An investigation was carried out to assess nature and magnitude of genetic variability for productivity, grain and nutritional quality traits in selected mini core collection and promising varieties of sorghum. High estimates of PCV and GCV were recorded for most of the characters in selected mini core accessions except for seed bulk density and seed true density. Similarly, among promising varieties observed in grain yield per plant and fodder yield per plot. Based on D^2 statistics and tocher method an attempt was made, 25 selected mini core accessions and 16 promising varieties were grouped into 6 and 5 cluster, respectively. Selected mini core collection exhibited wide variation for seed hardness ranging from hard (33.33%) to very hard (66.67%) seeds which is primary source of variability for improvement. Whereas, promising released varieties had hard (62.5%) to very hard (37.5%) seeds with round and lustrous in appearance.

Keywords: Sorghum, mini core, variability, heritability, diversity

Introduction
Sorghum (*Sorghum bicolor* (L.) Moench) is an important staple food in several regions of Africa, China and the Indian subcontinent particularly in the semi-arid tropics. It is the fourth most important cereal crop following rice, wheat, maize and staple food in the same central parts of the world. Worldwide, it is cultivated on 41.07 million ha with production of 58.42 million tones (Anonymous 2019a) [1]. In India, sorghum having 5.00 million ha area with 4.5 million tones production and 900 kg/ha productivity (Anonymous 2019b) [2]. Rabi sorghum is superior over *kharif* sorghum with respect to grain and fodder quality as they are less prone to diseases and pests. In *rabi* sorghum, breeding for grain quality components like seed size, colour, shape, seed lustre, grain hardness and nutritional quality traits like amylose and protein content are as important as that of the breeding for higher yield. Test weight is used as an indicator of general grain quality and is a measure of grain bulk density. Grain hardness is one of the important quality trait is related to protein content (Rooney and Miller 1982) [3] and assessing dry milling quality in sorghum. Nutritional quality traits like seed protein and amylose content are related to *roti* quality. Improvement towards these aspects is possible only when there is genetic variability and diversity exists for these traits, which is the basic prerequisite for crop improvement. In addition to the wider range genetic variability, knowledge on heritability and genetic advance helps the breeder to employ the suitable breeding strategy. Understanding the wealth of genetic diversity in sorghum will facilitate further improvement of this crop for its genetic architecture (Santosh *et al.*, 2015) [4]. However, reports on genetic diversity among the *rabi* sorghum is very limited. Mini core collection (10% accessions of the core collection or 1% of entire collection) represents the whole range of variation of cultivated sorghum and is an ideal material for assessing the exact nature and magnitude of variability of the crop. Mini core collection is considered as a gateway for utilization of diversity present in large germplasm collection for crop improvement (Upadhyaya, *et al.* 2009) [5]. Available scientific evidences indicated that the improved sorghum hybrids and cultivars were less diverse as compared to wild and weedy relatives and landraces [Muraya *et al.*, (2011) [6] and Mace et al., (2013) [7]. The low diversity of crop cultivars is mainly because most crop breeders use their working collections containing limited numbers of adapted and improved materials that have the most desirable traits and avoid using wild and weedy relatives and unadapted landraces in the hybridization program. (Upadhyaya, *et al.* 2019) [8]. The identification of trait-specific germplasm from large ex situ collections is key to successful introgression of new diversity into the crop improvement programs

(Upadhyaya, *et al.* 2014) [9]. Plant genetic resources are essential components to meet future food security needs of world. Greater use of such diversity in sorghum breeding programs so as to develop cultivars with a broad genetic base will result in sustainable sorghum production. A good understanding of genetic variability among the accessions will enable precision breeding. So profiling the genetic diversity of sorghum is imminent (Sinha *et al*., 2015) [10]. The aim of the present investigation was to assess the agronomic performance of sorghum selected mini core collection, to assess the magnitude of genetic variability and diversity studies for productivity, grain and nutritional quality traits in *rabi* sorghum.

Material and Methods

The plant material for this experiment comprised of (a) 24 selected mini core collection out of 208 mini core accessions based on grain hardness, grain colour and grain lustre along with M 35-1 as check variety(Table-1). The mini core collection of sorghum obtained from DSR Hyderabad. (b) Sixteen selected released/promising varieties of *rabi* sorghum which are commonly grown in northern Karnataka. The experiment was laid out in medium deep black soil under rain fed condition. The randomized block design was followed separately with two replications and each entry was sown in four rows of 4 m length with inter row spacing of 45 cm and intra row spacing of 15 cm. Observations on all quantitative characters like plant height (cm), panicle length (cm), panicle width (cm), seed yield per plot (g), 100 seed weight (g), seed volume (ml), bulk density (g/ml), true density (g/ml), seed size (mm), seed protein (%), seed amylose (%), seed amylopectin (%) and seed yield/plot (kg). Mean of five plants for each entry was worked out and used for statistical analysis software.

Estimation of biochemical parameters

(a) Seed protein (per cent): Protein content of selected genotypes was estimated by using Microkjeldhal method. Total nitrogen was estimated by using Kel-plus (digestion and distillation unit). Crude protein value was obtained by multiplying the total nitrogen by the conversion factor.

(b) Amylose content and amylopectin content (percent): Total amylose was estimated by following the method of Soubhagya and Bhattacharya (1979) [11], 100 mg sample was taken in a 100 ml volumetric flask, disperse 1 ml of alcohol followed by 10 ml of 1 N NaOH leave it for overnight, make the volume upto 100 ml from distilled water. From this extract 2.5 ml was taken, add 20ml distilled water, add 3 drops of phenolphthalein indicator, it will change to pink color, add 0.1 N HCl, till it becomes colourless, now add 1 ml of 0.2 per cent iodine solution, make volume made up to 100 ml. The purple-blue was read at 590 nm. Amylopectin will be calculated by subtracting total amylose from 100.

Results and Discussion

In the present investigation which included 25 mini core and 16 promising varieties of rabi sorghum was carried out in order to study the nature and amount of variability, heritability and genetic advance for 12 quantitative characters. The selected mini core collection exhibited highly significant differences for all the characters like plant height, panicle length, panicle width, seed yield per plant, 100 seed weight, seed volume, bulk density, true density and seed size. Among 16 promising varieties, significant differences were recorded for all the characters except true density. This indicates that the selected mini core collection indicating wide genetic variability. from each other and there is ample scope for selection of characters from these diverse sources for yield and its components. These findings were in accordance with the findings of Vedansh *et al*. (2010) [12] and Khandelwal *et al*. (2016) [13].

Presence of genetic variability is an important prerequisite in any crop improvement programme. Breeder has to quantify the fixable and non fixable component of variation for further crop improvement. Selection will be effective when the character is controlled by additive gene action. Hence, for successful crop improvement programme, the knowledge of genetic variability, heritability and genetic advance is of prime importance. In general the phenotypic coefficient of variance was higher than genotypic coefficient variance for all yield and its contributing characters indicate the influence of environmental factors on these traits. In present study, a wide range of variance was observed for all the 13 characters. High PCV and GCV were observed for ear head length (38.08% and 18.35%), ear head width (27.23% and 26.20%), seed yield per plot (68.37% and 66.51%),fodder yield per plot (39.43% and 37.30%), 100 seed weight (25.13% and 24.04%), seed volume (31.24% and 30.91%),bulk density (20.53% and 20.43%) and seed amylose (21.28% and 20.67%) in selected mini core collection. Similarly, among promising varieties observed in grain yield per plant (23.03% and 21.80%) and fodder yield per plot (24.84% and 23.72%) (Table-2), indicating the presence of high degree of variability which is more useful for exploitation process. Similar, results were reported by Biradar *et al.* (1996) [14], Reddy *et al.* (1996) [15], Godbharle *et al.* (2010) [16] and Seetharam and Ganesamurthy (2013) [17]

Selected mini core exhibited moderate PCV and GCV for plant height (18.88% and 18.35%), seed size (10.50% and 9.65%) and seed protein content (16.37% and 16.03%). It is due to, selection process made in the mini core based on grain hardness and grain colour, so variability was reduced in selected mini core. Whereas, the traits like plant height (10.36% and 10.32%), panicle width (16.63% and 15.57%), panicle length (15.05% and 14.84%), seed volume (11.11% and 10.83%) and 100 seed weight (18.56% and 16.95%) also showed moderate GCV and PCV estimates in selected promising varieties, which could be due to conscious selection practiced for improvement of these traits. Similar results were reported Tiwari *et al.* (2003) [18] and Negash *et al.* (2005) [19] for plant height

Magnitude of PCV and GCV estimates were high for ear head length, ear head width, 100 seed weight, seed volume and bulk density among selected mini core accessions. Whereas, the magnitude was moderate for these traits among selected promising/ released varieties which could be due to conscious selection by the plant breeder towards high seed yield and seed quality attributes there by reducing extent of variability and enhancement of homogeneity.

Among selected mini core, low values of PCV and GCV were noticed for seed true density and seed amylopectin content, similar estimates were also noticed for seed size (4.03% and 3.44%), seed true density (8.51% and 7.19%), seed bulk density(9.72% and 9.35%), seed protein (7.87% and 7.51%), seed amylose (8.58% and 8.07%) and seed amylopectin content (2.7% and 2.54%) among promising varieties. Improvement in these characters can be brought about by hybridization or induced mutagenesis to widen genetic base. Interestingly, selected promising released varieties exhibited lower PCV and GCV values for seed protein and seed amylose content when compared to selected mini core indicating greater scope to improve the released varieties with reference to the above traits by generating variability.

High heritability indicates the effectiveness of selection based on phenotypic performance but does not necessary mean and high genetic gain for particular character. Consideration of both heritability and genetic advance is more important for predicting effectivenessof selection than heritability alone. Among selected minicore, high heritability coupled with genetic advance as per cent of mean were estimated for all characters like plant height (99.3% and 21.18%), ear head length (97.3% and 30.16%), earhead width (87.7% and 42.2%), seed yield per plot (23.09% and 21.80%) except seed true density (95.3% and 5.36%) and seed size (84.5% and 18.27%) in selected mini core. Among promising varieties which was recorded for plant height (99.3% and 21.18%), ear head length (97.3% and 30.16%), ear head width (87.7% and 42.4%), seed yield per plot (89.1% and 42.4%), fodder yield per plot (91.2% and 46.67%), 100 seed weight (83.4% and 31.88%) and seed volume (95% and 21.74%). This indicates that there was low environment influence and greater role of genetic component of variation suggested that these traits are control by additive gene action. Where, directional phenotypic selection could be effective for genetic improvement. High value of additive gene effects is an indication of high breeding value. Selection for superior genotypes can be done effectively in early generation to bring genetic improvement for desired traits and which can be exploit in breeding programs. These results are in confirmation with the results of Kumer and Singh (1986) [20], Nimbalkar *et al.* (1988)[21], Prabhakar (2001) [22], Veerabadhiran and Kennedy (2001)[23], Umakanth *et al.* (2004) [24], Deepalakshmi *et al.* (2007) [25], Bello *et al.* (2007) [26] and Seetharam and Ganesamurthy (2013) [17].

Selected mini core accessions exhibited high heritability but moderate genetic advance for seed size (84.5% and 18.27%) and seed amylopectin (94.6% and 17.72%). Whereas in selected released varieties high heritability with moderate GAM were noticed for true density (71.3% and 12.5%), seed protein content (91.1% and 14.77%) and seed amylose content (88.3% and 15.62%). This could be due to control of traits by both additive and non additive gene actions. . The high heritability is being exhibited due to favorable influence of environment rather than genotype and selection for such traits may not be rewarding. This suggests that the expected improvement through selection for this character would be minimum and would limit the individual plant selection for any improvement for this trait. Similar results were reported by Rosaiah *et al.* (1995) [27] indicating low to moderate genetic advance for seed protein content.

High heritability but moderate genetic advance was observed for true density in selected mini core accessions. Among selected promising varieties, high heritability with low GAM was observed for seed bulk density and seed amylopectin content, which could be due to presence of non-additive gene effects coupled with high genotypic and environment (G x E) interaction.

The knowledge regarding the extent of variability and genetic diversity is of much importance while making improvement in a complex trait like yield. Several plant breeders used the D^2 technique for selection of divergent parents and their further exploitation in hybridization programmes which helped breeders in genetic interpretation of material under investigation. Assessment of available germplasm is of immense importance for further crop improvement and identifies the superior progenies. It is therefore, necessary to study the nature and magnitude of genetic diversity systematically for its exploitation in genetic upgradation of biological population. However, reports on genetic diversity among the *rabi* sorghum is very limited. Based on D^2 statistics and tocher method an attempt was made, 25 selected mini core accessions and 16 promising varieties were grouped into 8 and 5 cluster, respectively with variable number of entries revealing the presence of considerable amount of genetic diversity in the material. Among the selected mini core, cluster I had largest with 12 accessions whereas most of the clusters had one with minimum accessions reflecting with narrow genetic diversity among cluster. Whereas, cluster IV and VI had with four accessions each. Among promising varieties, cluster V had with 5 accessions, cluster 2 and 5 with minimum two accessions each. Cluster III and I with four and three accessions, respectively. The narrow genetic diversity may be attributed to similarity in the base material from which they have been evolved and selected (Table-3).

Among 12 quantitative traits studied, the highest contribution towards the divergence was ear head length (46%) in the selected mini core and plant height (67%) in the promising varieties, respectively. Similar results were reported by Kukadia *et al.* (1981) [28], Sisodia *et al.* (1983) [29], Dabholkar *et al.* (1983) [30] and Mehendiratta and Sindhy (1972) [31] for plant height. Among selected mini core, ear head length (46%) more divergence followed by grain yield (15.33%) and ear head width (5%) respectively. Among promising varieties, minimum divergence showed towards the yield character like ear head length (3.33%), grain yield per plot (3.33%) with negligible amount of divergence by ear head width (0.83%) mainly because of conscious selection for yield and other agronomical characters which leads to narrow genetic diversity. Interestingly, grain and nutritional quality traits like protein and amylose contributing more compared to other grain quality traits in both the set. Amylopectin (15.67%)and (9.17%) contributing in mini core and promising varieties, respectively. Grain quality traits like bulk density (5.83%) and true density (3.33%) contributing for in promising varieties (Table-4).

The average intra (diagonal) and inter cluster (off diagonal) D^2 values are presented in the table-. The inter cluster distance D^2 value ranged widely with minimum values of (D^2=225.39 and D^2 =192.82) and maximum value (D^2=5720 and D^2=4540.74) in mini core and promising varieties respectively, indicating high diversity among selected mini core and it was desirable to select mini core from clusters showing high inter cluster distance. Diversity among cluster varied from between the inter cluster distance. The clustering pattern obtained in the present study revealed that genetic diversity was not necessarily associated with geographical origin (Table-5). Katiyar and Singh (1990) [32], Arora *et al.*, (1991) [33] and Singh *et al.*, (2001) [34] have also reported the similar results in Faba Beans, Guar and Sorghum, respectively.

In the present investigation, the inter cluster distance was higher than intra cluster distance which indicated substantial diversity among the mini core accessions and there may be a greater opportunity for obtaining the rare but superior segregants from crosses between more divergent accessions. Similar results were also obtained by earlier investigators (Swami *et al.*, 2015; Jain and Patel, 2013; and Mohanraj *et al.*, 2006) [35-37]

The maximum inter cluster distance observed was between cluster II and V (5720.71) followed by cluster IV and V (4869.4), cluster I and V (2431.62) and cluster I and II (1206.94) in selected mini core. Among promising released varieties, the maximum inter cluster distance observed was between cluster VI and VIII (4540.74) followed by cluster IV and VI (3066.67), cluster IV and VII (2672.79) and cluster III and VI (2645.39), respectively. The intra cluster distance D^2 value ranged widely with minimum value of 225.39 was observed between cluster II and II in mini core and cluster III and IV (192.82) in promising varieties, respectively. Intra cluster distance D^2 ranged from 0 to 317.75 and 0 to 517.46 in selected minicore and promising varieties, respectively. The most of inter cluster distance was zero.

Among selected mini core, Cluster II exhibited the highest mean for plant height, Cluster IV showed highest for earhead length and Cluster II exhibited the highest mean for ear head width. Similarly, Cluster I recorded for maximum 100 seed weight, Cluster III exhibited highest for seed yield, maximum seed volume observed in cluster I, maximum bulk density and true density is recorded in cluster III and cluster I, respectively. Cluster V exhibited maximum seed size. Nutritional traits, Cluster III highest for protein, cluster I for amylose and cluster V for amylopectin, respectively (Table-5).

Among promising verities, Cluster VI exhibited the highest mean for plant height, Cluster VI for earhead length and Cluster VI for earhead width. Similarly, Cluster IV recorded for maximum 100 seed weight, Cluster V exhibited highest for seed yield, Cluster IV for maximum seed volume, maximum bulk density and true density is recorded in cluster V and cluster V, respectively. Cluster V exhibited maximum seed size. Nutritional traits like, Cluster VI highest for protein, cluster II for amylose and cluster IV for amylopectin respectively. It could be suggested that genotypes present in respective cluster with high mean performance for particular quantitative traits can be utilized in breeding programme to improve these traits (Table-6).

Intercrossing of divergent groups would lead to wide genetic base in the base population and greater opportunities for crossing over to occur, which inturn may release hidden variability by breaking close linkage. The progenies derived from such crosses are expected to show wide variability, providing greater scope for isolating transgressive segregants in the advanced generations (Damor *et al*., 2017) [38]. Hence, these acessions may be used repeatedly in the crossing programmes to recover transgressive segregants, which can be either released as a variety or can be utilized in the genetic enhancement of productivity and grain quality traits in rabi sorghum.

Wide range of variability was found for ear head and grain quality traits in selected mini core and promising released varieties (Table-7). Most of them had white seed colour, round seed shape and hard to very hard seeds with lustrous in appearance. Hardness is one of the important quality trait which linked to milling and food quality, as most of selected mini core collection exhibited wide variation and also a good source for seed hardness ranging from hard (33.33%) to very hard (66.67%) seeds which is primary source of variability for improvement. Whereas, promising released varieties had hard (62.5%) to very hard (37.5%) seeds with round and lustrous in appearance. Grain hardness is also one of the important quality traits in sorghum, recorded by measuring the grinding time required to obtain a fixed volume of flour from the grains. It has been linked to milling yield or food quality, moisture and protein content as well as resistance to insects and mold. Harder kernel with pearly white appearance has the best milling properties and highest milling yields. Hardness in sorghum was related to protein content. The hardness of sorghum correlates with milling yield, particle size index, test weight and kernel density by Reichert *et al.* (1988) [39].

Table 1: List of selected genotypes of mini core collections and promising varieties of sorghum (2012-13).

	Selected Mini core accession number
25	IS-473, IS-1041, IS-2379, IS-3971, IS-4515, IS-5295, IS-5301, IS-12697, IS-12937, IS-12945, IS-13294, IS-13459, IS-13971, IS-15931, IS-19153, IS-22720, IS-24139, IS-28849, IS-29358, IS-30443, IS-30450, IS-30572, IS-13893, IS-13782 and M35-1
	Selected promising varieties
16	DSV-4, SPV-86, SPV-1829, BJV-44, DSV-5, A-1, CSV-216R (Phule Yashoda), Phule Vasudha, Phule Revathi, M35-1 (Akola source), M35-1 (Bijapur source), Barsi Jowar, Kodmurki (popular local), SVD-803 (ABL), SVD-808 (ABL), SVD-770 (ABL),

Table 2: Estimation of variability parameters for yield and grain quality components in selected mini core collection and selected varieties of sorghum (*Rabi* 2012-13).

Parameters	Plant height (cm)	Ear head length (cm)	Ear head width (cm)	Seed yield/plot (kg)	Fodder yield/ plot (kg)	100-seed weight (gm)	Seed volume (ml)	Bulk density (g/ml)	True density (g/ml)	Seed size (mm)	Seed protein (%)	Seed Amylose (%)	Seed amylopectin (%)
Selected mini core collection													
PCV	18.88	38.08	27.23	68.37	39.43	25.13	31.24	20.53	2.73	10.5	16.37	21.28	9.09
GCV	18.35	37.65	26.2	66.51	37.3	24.04	30.91	20.43	2.67	9.65	16.08	20.67	8.84
Heritability (%)	97.6	97.8	92.6	94.7	89.5	91.6	97.9	99	95.3	84.5	96.4	94.6	94.6
GA	84.41	19.6	3.14	1.14	4.37	1.34	0.02	0.37	0.07	0.62	3.48	12.42	12.42
GAM (5%)	37.96	76.69	51.93	133.3	72.66	47.4	63	41.86	5.36	18.27	32.53	41.47	17.72
C.D. 5 %	13.44	3.01	0.92	0.28	1.6	0.43	0.003	0.04	0.02	0.29	0.68	3.06	3.06
Mean	222.37	25.56	6.05	0.85	6.02	2.83	0.04	0.88	1.3	3.39	10.69	29.94	70.06
Range	164.7-299.5	7-41.4	4.05-10.26	0.14-2.30	3.5-10.85	1.88-4.34	0.022-0.06	0.04-0.93	1.18-1.3	2.7-3.83	7.66-13.78	17.5-36.84	63.16-82.5
Selected promising varieties													
PCV	10.36	15.05	16.63	23.09	24.84	18.56	11.11	4.03	9.72	8.513	7.87	8.58	2.7
GCV	10.32	14.84	15.57	21.8	23.72	16.95	10.83	3.44	9.35	7.19	7.51	8.07	2.54
Heritability (%)	99.3	97.3	87.7	89.1	91.2	83.4	95	73	92.4	71.3	91.1	88.3	88.3

GA	53.38	5.91	1.73	1.02	4.41	1.03	0.01	0.23	0.17	0.17	1.43	3.74	3.74
GAM (%)	21.18	30.16	30.05	42.4	46.67	31.88	21.74	6.06	18.52	12.5	14.77	15.62	4.92
C.D%%	6.79	1.46	1.01	0.55	2.09	0.73	0.004	0.23	0.07	0.18	0.68	2.12	2.93
Mean	251.91	19.61	5.77	2.39	9.44	3.21	0.05	3.73	0.92	1.32	9.66	23.95	76.05
Range	191.6-290	12.1-23.5	4.3-7.4	1.56-3.15	5.75-13.75	2.41-3.77	0.038-0.06	3.34-3.99	0.72-0.98	1.13-1.55	8.10-11.15	20.86-26.84	74.14-79.15

Table 3: Distribution of 25 selected minicore collections of rabi sorghum accessions and selected varieties of *rabi* sorghum into different clusters.

Group K	**N**	**Cluster members**											
1	12	13	23	11	3	8	6	10	24	9	2	19	12
2	1	15											
3	1	18											
4	4	5	7	25	16								
5	1	21											
6	4	14	20	17	22								
7	1	1											
8	1	4											
Group K	N	Cluster members											
1	3	3	7	8									
2	2	6	14										
3	4	4	5	9	10								
4	5	1	2	11	12	16							
5	2	13	15										

Table 4: Per cent contribution of characters towards divergence 25 selected mini core collections and promising released varieties of *rabi* sorghum

Source	**Mini core**		**Promising varieties**	
	Times ranked 1st	**Cotriution (%)**	**Times ranked 1st**	**Cotriution (%)**
Plant Height	16	5.33%	81	67.50%
Earhead legth	138	46%	4	3.33%
Earhead width	15	5%	1	0.83%
100 seed weight	1	0.33%	0	0.00%
Grain yeild	46	15.33%	4	3.33%
Seed volume	0	0	0	0.00%
Seed size	0	0	0	0.00%
Bulk density	0	0	7	5.83%
True density	0	0	4	3.33%
Protien	18	6%	6	5%
Amylose	19	6.33%	2	1.67%
Amylopectin	47	15.67%	11	9.17%

Table 5: Average D^2 values of intra and inter cluster distances among 25 selected mini core collections of *rabi* sorghum germplasm lines evaluated during rabi 2012-13.

Cluster	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**
Cluster 1	317.75	1206.94	446.25	993.33	2431.62
Cluster 2		225.39	901.57	461.06	5720.71
Cluster 3			0	745.4	3643.4
Cluster 4				0	4869.4
Cluster 5					0

Table 6: Average D^2 values of intra and inter cluster distances among promising varieties of *rabi* sorghum germplasm lines evaluated during rabi 2012-13.

Cluster	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**	**Cluster 7**	**Cluster 8**
Cluster 1	308.74	589.66	554.71	1032.91	526.95	1523.99	837.54	1287.42
Cluster 2		0	134.27	280.31	368	2645.39	2020.59	451.9
Cluster 3			0	368.35	192.82	2072.95	1809.65	802.52
Cluster 4				307.15	724.01	3066.67	2672.79	737.17
Cluster 5					0	1721.23	1680.61	1019.27
Cluster 6						517.46	1096.16	4540.74
Cluster 7							0	2990.33
Cluster 8								0

Table 7: Classification of mini core collections and promising varieties of sorghum based on grain quality attributes (Rabi, 2012-13).

Sl. No.	Character	Score	No. of genotypes		Percentage	
			Selected mini core	Promising varieties	Selected mini core	Promising varieties
I.	Ear head compactness					
a.	Very loose	1	10		41.67	
b.	Loose	2	7	1	29.17	6.25
c.	Semi compact	3	2	13	8.33	81.25
d.	Compact	4	5	2	20.83	12.5
II.	Glume coverage					
a.	Very short	1	2	1	8.3	6.25
b.	Short	2	8	13	33.3	81.25
c.	Medium	3	2	2	8.3	12.5
d.	Long	4	9		37.5	
e.	Very long	5	3		12.5	
III.	Glume colour					
a.	Green white	1	15		7.21	
b.	Yellow white	2	53	16	25.48	100
c.	Greyed yellow	3	9		4.33	
d.	Greyed orange	4	15		7.21	
e.	Greyed red	5	57		27.4	
f.	Greyed purple	6	59		28.37	
I.	Grain colour					
a.	White	1	9	16	37.5	100
b.	Chalky white	2	3		12.5	
c.	Creamy straw	3	1		4.17	
d.	Light yellow	4	1		4.17	
e.	Yellow	5	1		4.17	
f.	Light brown	6	3		12.5	
g.	Brown	7	3		12.5	
h.	Reddish brown	8	1		4.17	
i.	Light red	9	1		4.17	
j.	Red	10	1		4.17	
II.	Grain shape					
a.	Completely flat	1	1		4.17	
b.	Round	2	6	16	25	100
c.	Sub-lenticular round but flat from other side	3	4		16.67	
d.	Oval	4	13		54.16	
III.	Seed hardness					
d.	Hard	4	8	10	33.33	62.5
e.	Very hard	5	16	6	66.67	37.5
IV.	Grain lustre					
a.	Non-lustre	0	2		8.33	
b.	Lustre	1	16	16	66.67	100
c.	Medium	2	6		25	
	Total		24			

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