Developing a Mini Core Collection of Sorghum for Diversified Utilization of Germplasm

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ABSTRACT

The sorghum [*Sorghum bicolor* (L.) Moench] germplasm collection at the ICRISAT gene bank exceeds 37,000 accessions. A core collection of 2247 accessions was developed in 2001 to enable researchers to have access to a smaller set of germplasm. However, this core collection was found to be too large. To overcome this, a sorghum mini core (10% accessions of the core or 1% of the entire collection) was developed from the existing core collection. The core collection was evaluated for 11 qualitative and 10 quantitative traits in an augmented design using three control cultivars in the 2004–2005 postrainy season. The hierarchical cluster analysis of data using phenotypic distances resulted in 21 clusters. From each cluster, about 10% or a minimum of one accession was selected to form a mini core that comprised 242 accessions. The data in the mini core and core collections were compared using statistical parameters such as homogeneity of distribution for geographical origin, biological races, qualitative traits, means, variances, phenotypic diversity indices, and phenotypic correlations. These tests revealed that the mini core collection represented the core collection, which can be evaluated extensively for agronomic traits including resistance to biotic and abiotic stresses to identify accessions with desirable characteristics for use in crop improvement research and genomic studies.

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Abbreviations: CR%, coincidence rate; H`, diversity index; REML, residual maximum likelihood; VR%, variable rate.

Sorghum [*Sorghum bicolor* (L.) Moench] is the world's fourth most important cereal crop after wheat (*Triticum* spp.), rice (*Oryza sativa* L.), and maize (*Zea mays* L.) and is grown throughout the arid and semiarid tropics (Smith and Frederiksen, 2000). For example, in 2007 sorghum was grown worldwide on 43.8 million ha in 104 countries, with a total production of 64.6 million Mg and productivity of 1.47 Mg ha^{-1} (http://faostat.fao.org/ verified 8 July 2009). About 80% of sorghum production comes from developing countries. Sorghum is indigenous to Africa, where it is grown in the semiarid zone, spread over a large belt from Senegal to Ethiopia, bordering the Sahara desert in the north, the equatorial forest in the south, and extending southwards through the drier parts of eastern and southern Africa. The major sorghum growing countries include Burkina Faso, Cameroon, Chad, Egypt, Ethiopia, Mali, Mozambique, Niger, Nigeria, Sudan, Tanzania, and Uganda in Africa; India, China, and Yemen in Asia; the U.S. and Mexico in North and Central America; Argentina, Brazil, and Venezuela in South America; and Australia in Oceania (http://faostat.fao.org/). Sorghum is a major staple food and fodder crop in tropical and semi-tropical Africa and Asia (Doggett, 1988). Sorghum grains in many parts of the world are also used for animal (swine, poultry, and cattle) feed (Bramel-Cox et al., 1995). More recently, sweet sorghum has emerged as a 'smart' crop for production of ethanol (biofuel) in Brazil and India, which is becoming popular in many Asian countries (Doggett, 1988; Rao et al., 2004).

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The genus *Sorghum* has five subgenus or sections: *Eu-Sorghum*, *Chaetosorghum*, *Heterosorghum*, *Para-Sorghum*, and *Stiposorghum* (Garber, 1950), of which, *Eu-Sorghum* contains all sorghum races and varieties as *S. bicolor* subsp. *bicolor* ($2n = 2x = 20$ chromosomes) and wild and weedy relatives (Harlan and de Wet, 1971; Doggett, 1988). Further, Harlan and de Wet (1972) recognized five basic races (*bicolor*, *guinea*, *caudatum*, *kafir,* and *durra*) and ten intermediate races (*guinea-bicolor, guinea-caudatum, guinea-kafir, guinea-durra, caudatum-bicolor, kafir-bicolor, durra-bicolor, kafir-caudatum, kafir-durra,* and *durra-caudatum*) that originated as a result of natural intercrossing among basic races, all recognizable on the basis of spikelet/panicle morphology alone, which can be linked back to their specific environments and the nomadic peoples that first cultivated them (Smith and Frederiksen, 2000). Race *bicolor* is widely distributed in Africa and Asia; *guinea,* predominant in West Africa; *caudatum,* throughout Central Africa; *kafir,* south of the equator in Africa; *durra,* in Ethiopia and India (Harlan and de Wet, 1972).

Vast collections of germplasm are locked in national and international genebanks. For example, CGIAR (Consultative Group on International Agricultural Research) institutions alone hold ~600,000 germplasm accessions of its mandate crops. Low use of germplasm in crop improvement programs has resulted in a narrow genetic base in many crops (Dalrymple, 1986; Vellve, 1992; Dowswell et al., 1996; Upadhyaya et al., 2003; Kumar et al., 2004; Bhattacharjee et al., 2007). Large holdings in genebanks and the non-availability of data on traits of economic importance restricted breeders and caused them to repeatedly use their own working collections in crop breeding. Moreover, many of the agronomic and seed quality traits show considerable genotype × environment interaction. Multi-location evaluation of such a large collection is resources consuming, it is also a constraint to obtain reliable phenotypic data from such evaluations to identify useful parents by the breeders. Core collection (~10% of entire collection), representing over 70% of the genetic variation present in the entire collection with 95% certainty (Brown, 1989), has been suggested as a gateway to enhanced utilization of diverse germplasm in crop breeding programs. Core collections, based on phenotypic characterization data, have been reported (see Upadhyaya, 2004) for crops such as pearl millet [*Pennisetum glaucum* (L.) R. Br.] (Bhattacharjee et al., 2007), sorghum (Rao and Rao, 1995; Grenier et al., 2001a,b), quinoa (*Chenopodium **quinoa*** Willd.) (Ortiz et al., 1998), finger millet (*Eleusine coracana* (L.) (Upadhyaya et al., 2006), foxtail millet [*Setaria italica* (L.) P. Beauv.] (Upadhyaya et al., 2008), Caribbean maize (Taba et al., 1998), and USDA rice (Yan et al., 2007). In sorghum, Rao and Rao (1995) were the first to develop core collection of 3475 accessions. Subsequently, Grenier et al. (2001b) used three sampling procedures—constant, logarithmic, and proportional—to establish three subsets of the core collection, each possessing 2247 accessions. The logarithmic subset showed differences for response to the photoperiod that was considered in the stratification of the collection. A core of this size is still large for multi-location evaluation of morphological diversity. The size of the core makes it difficult to identify accessions that are genetically diverse and that also possess beneficial traits for use in crop breeding. To overcome this, Upadhyaya and Ortiz (2001) suggested the mini core collection approach, which is a core of a core (10% of core or 1% of the entire collection) representing the species diversity. A mini core is established after evaluating the core subset for various morphological, agronomic, and seed quality traits, and selecting about 10% of the accessions from the core subset. This study reports the development of a mini core subset in sorghum using the Grenier et al. (2001b) core that was developed using logarithmic sampling, for enhanced utilization of genetically diverse germplasm in sorghum improvement.

MATERIALS AND METHODS

A sorghum core collection consisting of 2247 landrace accessions from 58 countries (Grenier et al., 2001b), was the base material to constitute a sorghum mini core collection. One accession (IS 3422) was excluded from the evaluation as it was de-notified from the in-trust collection. The core collection represented all basic [*bicolor* (6.6%), *guinea* (11.6%), *caudatum* (17.6%), *kafir* (9.9%), and *durra* (10.9%)] and intermediate races [*guinea-bicolor* (1.0%), *guinea–caudatum* (12.6%), *guinea-kafir* (0.6%), *guinea-durra* (0.4%), *caudatum-bicolor* (10.5%), *kafir-bicolor* (0.9%), *durra-bicolor* (4.4%), *kafir-caudatum* (3.4%), *kafir-durra* (1.2%), and *durra-caudatum* (8.5%)]. The entire core collection of 2246 accessions and three controls, IS 9830 (*caudatum;* a striga resistant accession), IS 33844 (*durra;* Parbhani Moti—a released cultivar, India), and IS 2205 (*durra-bicolor,* a shoot-fly- and stem-borer-resistant accession) were evaluated in a Vertisol field in the 2004–2005 post-rainy season (October–April) at the ICRISAT research farm, Patancheru, 18° N lat; 78° E long, at an altitude of 545 masl (meters above sea level). The experiment was sown in an augmented design with one of the three control cultivars repeated after every nine test entries. Each plot was single-row, 9 m long, with a row-to-row spacing of 75 cm, and plant-to-plant spacing within a row of 10 cm. Ammonium phosphate was applied at the rate of 150 kg ha^{-1} as a basal dose, and 100 kg ha^{-1} of urea was applied as top dressing after 3 wk of planting. As the experiment was conducted during the post-rainy season, five irrigations (each with 7 cm water) were provided at equal intervals until grain maturity. All core accessions germinated well and produced panicles. Data on 11 qualitative traits (plant pigmentation, nodal tillers, midrib color, panicle compactness and shape, glume color and covering, threshability, grain color, grain luster, grain subcoat, and endosperm texture), and 10 quantitative traits [days to 50% anthesis, basal tillers, plant height, panicle exsertion, panicle length and width, yield plant^{-1} (g), yield plot^{-1} (kg), grain size (mm), and grain weight (g)] were recorded following sorghum descriptors (IBPGR and ICRISAT, 1993). Midrib color was recorded after 50% anthesis. Grain traits were recorded at post-harvest stage in the laboratory. The number of days to anthesis was recorded as the number of days from the

50% seedling emergence to the date when 50% plants had started anthesis. Data on plant height (cm), tiller number, panicle exsertion, and panicle length and width were recorded on five randomly selected plants. All other observations were recorded on plot basis. Panicle exsertion is measured as the length of exposed peduncle from the flag leaf to the base of the panicle. Panicle length and width were measured at maturity as the maximum length from the base to the tip of the panicle, and maximum width in natural position. Grain covering indicates the amount of grain covered by glumes at maturity and is an important trait in the racial classification of cultivated sorghum. Threshability was recorded as difficult to thresh, partly threshable, and freely threshable. Grain weight is the weight in grams of 100 sound, matured healthy grains at about 120 g kg^{-1} H_2O on wet basis. For quantitative traits data, averages of five plants $plot^{-1}$ values were computed that were used for statistical analyses.

The residual maximum likelihood (REML; Patterson and Thompson, 1971) in GenStat 10 (http://www.vsni.co.uk; verified 9 July 2009) was used to analyze data of 10 quantitative traits, considering genotypes as random and races as fixed. Variance components due to genotype (σ^2g) and its standard errors (SE) were estimated (Table 1). Significance of differences among races was tested using Wald (1943) statistics. Best linear unbiased predictors (BLUPs) (Schönfeld and Werner, 1986) were worked out for all quantitative traits. A phenotypic distance matrix was created for 2246 accessions by calculating differences between each pair of accessions for the 21 (11 qualitative and 10 quantitative) traits. Data on qualitative traits was transformed to numerical scale (IBPGR and ICRISAT, 1993) to calculate phenotypic distance matrix. The diversity index was calculated by averaging all the differences in the phenotypic values for each trait divided by the respective range (Johns et al., 1997). This distance matrix was subjected to hierarchical cluster algorithm (Ward, 1963) at an R^2 (squared multiple correlation value) of 0.75. This method optimizes an objective function because it minimizes the sum of squares between groups. A proportional sampling strategy of selecting the accessions was used, and 10% of the accessions or a minimum of one accession from each cluster was randomly selected to form a mini core collection. Thus, a mini core collection consisting of 242 accessions (10.8% of the core collection and 1.1% of the entire collection) was constituted.

The 58 countries of origin (Table 2) were grouped into 10 regions: Central Africa, Eastern Africa, Southern Africa, Western Africa, Americas, East Asia, South and Southeast Asia, West Asia, Mediterranean, and Oceania. Frequencies of geographic regions, countries within regions, races/intermediate races, and all the qualitative traits in the core and mini core collections were tested by χ^2. Yates (1934) correction was applied if the number of accessions in the core collection was less than five. Means for the core and mini core collections were compared by the Newman-Keuls procedure (Newman, 1939; Keuls, 1952). Homogeneity of variances was tested by Levene's test (Levene, 1960). The variance difference (VD%), mean difference (MD%), coincidence rate (CR%), and variable rate (VR%) were calculated to compare the core and mini core collections (Hu et. al., 2000). Shannon and Weaver (1949) diversity index (H`) was used to measure and compare the phenotypic diversity for each trait in core and mini core collections. Phenotypic correlations among 10 quantitative traits in the core and mini core collections were estimated separately to determine whether associations, which may be under the same genetic control, were conserved in the mini core collection.

RESULTS AND DISCUSSION

Residual Maximum Likelihood (REML) Analysis

Genotypic variance was significant for all the traits indicating the presence of adequate diversity in the core collection (Table 1). The Wald (1943) statistics showed that the five races and 10 intermediate races differed significantly for all the traits.

Clustering

A phenotypic distance matrix created on 21 traits was subjected to hierarchical cluster analysis (Ward, 1963) that resulted in classifying the 2246 accessions of the core collection into 21 clusters. Number of accessions in individual clusters ranged from 27 to 279. A mini core collection of 242 accessions (10.8% of the core collection) was formed using the sampling strategy of 10% or a minimum of one accession from each cluster. This mini core collection captured six shoot-fly-resistant accessions (IS 4360, IS 4515, IS 4581, IS 4631, IS 5094, and IS 8774), two accessions each resistant to anthracnose (IS 4092 and IS 7957) and leaf blight (IS 4951 and IS 7250), and four accessions each resistant to rust (IS 473, IS 7250, IS 7957, and IS 31446) and grain mold (IS 602, IS 603, IS 20727, and IS 20740).

Geographic Origin

χ^2 probabilities for geographic origin of accessions in core and mini core collections were not significant for any of the 58 countries (p = 0.159 to 0.978). Heterogeneity (p = 0.692 to 0.988) and χ^2 probabilities (p = 0.120 to 0.902) for all the 10 geographic regions were nonsignificant. The χ^2 values for accessions according to

Table 1. Variance components due to genotype (σ^2g) and Wald's statistics of different races and intermediate races in sorghum core collection evaluated during the 2004–2005 post-rainy season, Patancheru, India.

Character	σ^2g	Wald's statistic (Races/intermediate races)	df	P
Days to 50% anthesis	218.37***	302.92	14	<0.001
Plant height (cm)	2786.70***	395.77	14	<0.001
Panicle exsertion (cm)	39.95***	117.01	14	<0.001
Panicle length (cm)	25.24***	1293.34	14	<0.001
Panicle width (cm)	15.46***	522.09	14	<0.001
Yield per plant (g)	18.46***	372.17	14	<0.001
Plot yield (Kg ha^{-1})	101793***	322.23	14	<0.001
100-seed weight (g)	0.36***	472.49	14	<0.001
Seed Size (mm)	0.05***	234.06	14	<0.001
Basal tillers (number)	0.45***	143.69	14	<0.001

***Significant at P = 0.001.

Table 2. χ^2 test the frequency distribution of core and mini core collection accessions in different regions and countries within region.

Region	Country within region	Accessions in core	Accessions in mini core	df	χ^2	*P*
Central Africa		164	17	1	0.025	0.873
	Burundi	5	1	1	0.448	0.503
	Cameroon	145	13	1	0.274	0.601
	Chad	11	2	1	0.648	0.421
	Zaire	3	1	1	0.115	0.735
	Heterogeneity			3	1.460	**0.692**
Eastern Africa		402	38	1	0.652	0.419
	Ethiopia	116	12	1	0.098	0.755
	Kenya	50	6	1	0.343	0.558
	Rwanda	8	1	1	0.079	0.779
	Somalia	20	3	1	0.651	0.420
	Sudan	112	6	1	1.987	0.159
	Tanzania	37	4	1	0.072	0.788
	Uganda	59	6	1	0.032	0.858
	Heterogeneity			**6**	**2.610**	**0.856**
Southern Africa		663	65	1	0.580	0.446
	Botswana	58	5	1	0.083	0.774
	Lesotho	91	8	1	0.095	0.758
	Madagascar	3	1	1	0.144	0.704
	Malawi	20	2	1	0.001	0.978
	Mozambique	5	1	1	0.530	0.467
	South Africa	240	25	1	0.092	0.762
	Swaziland	76	9	1	0.322	0.570
	Zambia	23	3	1	0.246	0.620
	Zimbabwe	147	11	1	0.808	0.369
	Heterogeneity			**8**	**1.741**	**0.988**
Western Africa		232	22	1	0.359	0.549
	Benin	9	1	1	0.025	0.874
	Burkina Faso	36	1	1	1.707	0.191
	Gambia	3	1	1	0.163	0.686
	Ghana	11	1	1	0.002	0.966
	Mali	39	6	1	1.433	0.231
	Niger	20	2	1	0.006	0.940
	Nigeria	80	7	1	0.045	0.832
	Senegal	15	1	1	0.125	0.723
	Sierra Leone	2	1	1	0.508	0.476
	Togo	17	1	1	0.232	0.630
	Heterogeneity			9	**3.887**	**0.919**
Americas		162	22	1	1.183	0.277
	Argentina	6	1	1	0.122	0.838
	Cuba	1	1	1	0.977	0.323
	Honduras	1	1	1	0.977	0.323
	Mexico	4	1	1	0.003	0.953
	Nicaragua	1	1	1	0.977	0.323
	USA	148	16	1	0.836	0.361
	Venezuela	1	1	1	0.977	0.323
	Heterogeneity			**6**	**3.685**	**0.719**
East Asia		172	18	1	0.015	0.902
	China	126	12	1	0.107	0.744
	Japan	5	1	1	0.434	0.510
	Republic of Korea	40	5	1	0.158	0.691
	USSR	1	0	1	0.105	0.746
	Heterogeneity			**3**	**0.789**	**0.852**
South & SE Asia		297	36	1	0.500	0.480
	Bangladesh	3	1	1	0.051	0.821
	India	284	30	1	0.569	0.451
	Indonesia	3	1	1	0.051	0.821
	Myanmar	3	1	1	0.051	0.821
	Pakistan	2	1	1	0.274	0.601
	Sri Lanka	1	1	1	1.184	0.277
	Thailand	1	1	1	1.184	0.277
	Heterogeneity			**7**	**2.863**	**0.897**
West Asia		116	18	1	2.421	0.120
	Afghanistan	2	1	1	0.116	0.734
	Iran	1	1	1	0.766	0.381
	Saudi Arabia	1	1	1	0.766	0.381
	Republic of Yemen	112	15	1	0.326	0.568
	Heterogeneity			**3**	**0.447**	**0.930**
Mediterranean		25	5	1	1.975	0.160
	Algeria	3	1	1	0.017	0.897
	Egypt	3	1	1	0.017	0.897
	Morocco	1	1	1	0.450	0.502
	Syrian Arab Republic	1	1	1	0.450	0.502
	Turkey	17	1	1	1.694	0.193
	Heterogeneity			**4**	**0.653**	**0.957**
Oceania	Australia	13	1	1	0.210	0.647
	Heterogeneity			**9**	**7.711**	**0.564**
Over all		2246	242	57	**25.082**	**0.999**

geographical regions and also across the countries within regions were nonsignificant. This indicated that the accessions for countries/regions in the mini core collection are representative of the core collection.

χ^2 Test for Races and Intermediate Races

Distribution of accessions in core and mini core collections for different races and intermediate races were nonsignificant (p = 0.166 to 0.937) for all the races and intermediate races individually. Of the 1272 accessions of five basic races (*bicolor, caudatum, durra, guinea,* and *kafir*) in the core collection, 139 accessions were captured in the mini core collection (χ^2 0.028 and p = 0.868). Similarly, of the 974 accessions of the 10 intermediate races in the core collection, 103 were captured in the mini core collection (χ^2 0.036 and p = 0.849). Heterogeneity for races (χ^2 2.058 and p = 0.725) and intermediate races (χ^2 5.996 and p = 0.740; Table 3) were nonsignificant, indicating that the constitution of the mini core collection was appropriate. *Caudatum, durra*, and *guinea* among races and *caudatum-bicolor* and *guinea-caudatum* among intermediate races were dominant in both the core and mini core collections.

χ^2 Test for Frequency Distribution of Classes in Qualitative Traits

χ^2 probabilities for distribution of classes in all the 11 qualitative traits were nonsignificant (0.164 to 0.955; Table 4). Uniform distribution of classes in the core and mini core collections indicated that the sampling technique to constitute the mini core was appropriate.

Means and Variances

Differences between the means of core and mini core collections were compared using Newman-Keuls procedure (Newman, 1939; Keuls, 1952) and were found nonsignificant for all the traits, resulting in 0% mean difference percentage (Table 5). The homogeneity of variances of all the 10 quantitative traits in the core and mini core collections were tested by Levene's test (Levene, 1960) and were homogeneous ($p = 0.067$ to 0.796) for all the traits, resulting in 0% VD (Table 5).

Shannon-Weaver Diversity Index (H`)

This index is used to measure allelic richness and evenness in the population. A low H` indicates an extremely unbalanced frequency classes for an individual trait and a lack of genetic diversity. The average H` index for the mini core collection (0.460 ± 0.085 for qualitative and 0.587 ± 0.018 for quantitative traits) was comparable to the core collection (0.453 ± 0.085 for qualitative and 0.596 ± 0.016 for quantitative traits). Seed color had the highest value in both the core (0.917) and mini core (0.919) collections (Table 6). These estimates further suggest that the mini core collection has captured adequate diversity from the core collection.

Coincidence Rate (CR%) and Variable Rate (VR%)

The coefficients of variations or variable rate for most of the traits were higher in the mini core collection than in the core collection, resulting in 104.4% VR for quantitative traits

Table 3. Frequency distribution of accessions in different races and intermediate races with χ^2 and probability in sorghum core and mini core collections.

Race/intermediate races	Accessions in core	Accessions in mini core	df	χ^2	P
Races	1272	139	1	0.028	0.868
Bicolor	149	20	1	0.849	0.357
Caudatum	395	39	1	0.402	0.526
Durra	245	30	1	0.389	0.533
Guinea	261	29	1	0.008	0.929
Kafir	222	21	1	0.438	0.508
Heterogeneity			**4**	**2.058**	**0.725**
Intermediate races	974	103	1	0.036	0.849
Caudatum-bicolor	235	30	1	1.067	0.302
Durra-bicolor	98	7	1	1.092	0.296
Durra-caudatum	191	19	1	0.071	0.790
Guinea-bicolor	22	2	1	0.046	0.831
Guinea-caudatum	283	27	1	0.286	0.593
Guinea-durra	10	2	1	0.840	0.359
Guinea-kafir	13	3	1	1.921	0.166
Kafir-bicolor	20	2	1	0.006	0.937
Kafir-caudatum	76	7	1	0.134	0.715
Kafir-durra	26	4	1	0.569	0.451
Heterogeneity			**9**	**5.996**	**0.740**
Over all	2246	242	14	14.587	0.407

Table 4. χ^2 value and probability for frequency distribution of classes in ten qualitative traits in sorghum core and mini core collections.

Traits	df	χ^2	*P*
Plant pigmentation	1	1.941	0.164
Nodal tillers	1	0.115	0.735
Midrib color	3	2.537	0.469
Panicle compactness and shape	12	8.737	0.725
Glume color	11	4.445	0.955
Glume covering	8	11.003	0.202
Seed color	10	4.248	0.936
Seed luster	1	0.743	0.389
Seed subcoat	1	0.503	0.478
Endosperm texture	6	7.406	0.285
Threshibility	2	2.104	0.349

Table 5. Descriptive statistics for comparison of ten quantitative traits in core and mini core collection of sorghum.

Character	Range		Mean†		Variance‡			
	Core	Mini core	Core	Mini core	Core	Mini core	*F* value	*P*
Days to 50% anthesis	47.79–117.62	50.36–117.36	82.2a	82.6a	212.93	204.97	0.29	0.592
Plant height (cm)	84.32–393.29	118.28–393.29	228.5a	234.7a	2556.58	2230.57	2.04	0.153
Panicle exsertion (cm)	3.27–40.15	3.27–40.15	18.3a	18.8a	32.77	35.34	0.60	0.400
Panicle length (cm)	8.98–39.01	9.72–37.51	21.1a	21.5a	19.12	23.21	3.36	0.067
Panicle width (cm)	1.71–42.35	2.66–40.59	7.5a	7.7a	14.60	18.65	0.72	0.397
Yield per plant (g)	15.26–29.48	16.94–29.48	21.3a	21.4a	4.45	4.35	0.07	0.796
Plot yield (Kg ha^{-1})	751.24–2172.82	853.95–2172.82	1206.4a	1221.5a	27646.4	31016.30	0.83	0.364
100-seed weight (g)	1.72–5.71	1.75–5.71	2.9a	2.9a	0.20	0.26	3.20	0.074
Seed Size (mm)	2.12–3.96	2.15–3.89	3.0a	3.0a	0.04	0.05	3.27	0.071
Basal tillers (number)	1–10	1–8	2.1a	2.2a	0.72	0.92	2.20	0.138

†Means were tested by Newman-Keul test and were nonsignificant for all traits at $P = 0.05$.

‡Variances were tested by Levene test and were nonsignificant for all traits at $P = 0.05$.

Table 6. Coincidence rate (CR%), variable rate (VR%), and Shannon-Weaver diversity index in sorghum core and mini core collections.

Character	CR%	VR%	H`-index	
			Core	Mini core
Quantitative traits				
Days to 50% anthesis	95.9	97.6	0.607	0.609
Plant height (cm)	89.0	90.9	0.625	0.633
Panicle exsertion (cm)	100.0	101.1	0.630	0.636
Panicle length (cm)	92.5	108.0	0.625	0.607
Panicle width (cm)	93.3	110.3	0.494	0.443
Yield per plant (g)	88.2	98.6	0.631	0.624
Plot yield (Kg ha^{-1})	92.8	104.6	0.623	0.586
100-seed weight (g)	99.2	113.4	0.612	0.576
Seed Size (mm)	94.6	112.7	0.601	0.617
Basal tillers (number)	77.8	107.0	0.511	0.545
Mean	92.3	104.4	0.596	0.587
SE(±)	2.02	2.30	0.016	0.018
Qualitative traits				
Plant pigmentation	-†	–	0.049	0.069
Nodal tillers	–	–	0.174	0.180
Midrib color	–	–	0.254	0.253
Panicle compactness and shape	–	–	0.715	0.725
Glume color	–	–	0.820	0.835
Glume covering	–	–	0.548	0.554
Seed color	–	–	0.917	0.919
Seed luster	–	–	0.294	0.288
Seed subcoat	–	–	0.286	0.280
Endosperm texture	–	–	0.601	0.602
Threshibility	–	–	0.331	0.353
Mean			0.453	0.460
SE(±)			0.085	0.085
Mean-all			0.521	0.521
SE(±)			0.047	0.047

† = not estimated.

(Table 6). The variances and coefficients of variation in the selected collection should be higher than in the entire collection (Hu et al., 2000). High range (80–100) variation or CR% was captured in 9 out of 10 quantitative traits in the mini core collection. The high CR% captured for quantitative traits (92.3%) (Table 6) in the mini core collection confirmed that the mini core was representative of the core collection.

Correlation Coefficients

Phenotypic correlations were performed for all quantitative traits in the core and mini core collections separately and the pattern was found to be similar, demonstrating that associations observed in the core collection were well preserved in the mini core collection. Further, the proportion of variance in one trait that can be attributed to its linear relationship with a second trait is indicated by the square of correlation coefficient (Snedecor and Cochran, 1980). Estimates of this value greater than 0.71 or lower than −0.71 have been suggested as meaningful correlations (Skinner et al., 1999). In our study we found such high correlation coefficients in both the core (r = 0.712) and mini core (r = 0.702) collections between plot yield and yield per plant (Table 7).

There is a need to enhance the use of basic germplasm in sorghum breeding for widening the genetic base of the newly bred cultivars. Precise evaluation of the present core collection of sorghum (2246 accessions) using replications and multi-locations would be costly because of limited resources. This mini core collection has been developed using data of one environment and consists of 242 accessions, representing nearly the full diversity of the core collection and would provide an opportunity for precise evaluation and identification of valuable parental lines. The mini core collections in chickpea (*Cicer arietinum* L.), groundnut (*Arachis hypogaea* L., and pigeon pea (*Cajanus cajan* (L.) Millsp.) have already proved to be very useful in identifying agronomically valuable traits. Evaluation of 211 chickpea mini core accessions (Upadhyaya and Ortiz,

Table 7. Correlation coefficient between ten quantitative traits in sorghum core and mini core collections†. Above diagonal = mini core collection correlations; below diagonal = core collection correlations.

Character	Days to 50% anthesis	Plant height	Panicle exsertion	Panicle length	Panicle width	Yield per plant	Plot yield	100-seed weight	Seed size	Basal tillers
	d	cm				g	kg ha^{-1}	g	mm	no.
Days to 50% anthesis	1	0.653	−0.265	0.210	−0.009	−0.093	−0.247	−0.047	−0.146	0.006
Plant height (cm)	0.645	1	0.038	0.408	0.292	−0.056	−0.160	0.068	−0.028	0.015
Panicle exsertion (cm)	−0.202	0.088	1	0.088	−0.044	−0.193	−0.061	0.115	0.108	0.081
Panicle length (cm)	0.258	0.391	0.100	1	0.582	−0.107	−0.081	−0.126	−0.073	0.087
Panicle width (cm)	0.146	0.337	−0.073	0.507	1	0.042	0.034	−0.162	−0.046	0.057
Yield per plant (g)	−0.057	−0.048	−0.084	−0.032	0.070	1	0.702	0.312	0.327	−0.208
Plot yield (Kg ha^{-1})	−0.156	−0.142	−0.029	−0.040	0.058	0.712	1	0.118	0.159	−0.014
100-seed weight (g)	−0.064	0.076	0.097	−0.028	−0.125	0.182	0.064	1	0.618	−0.217
Seed Size (mm)	−0.078	0.006	0.054	−0.034	−0.108	0.150	0.104	0.565	1	−0.242
Basal tillers (no.)	−0.098	−0.038	0.035	0.044	0.041	−0.139	−0.063	−0.158	−0.164	1

†$r \geq 0.150$ significant at 1% p for mini core collection (DF 240); $r \geq 0.049$ significant at 1% p for core collection (DF 2244).

2001), resulted in identifying lines with deep root systems that avoid drought (Krishnamurthy et al., 2003; Kashiwagi et al., 2005), genotypes with high salinity tolerance (Serraj et al., 2004; Vadez et al., 2007), genotypes resistant/tolerant to wilt, ascochyta blight, botrytis gray mold, and dry root rot (Pande et al., 2006). Similarly, the groundnut mini core collection was the source of 18 genotypes that have drought tolerance (Upadhyaya, 2005). Likewise, the sorghum mini core collection with a reduced number of accessions (242) could be evaluated more extensively for traits of economic importance and therefore used in crop improvement research.

The identity of accessions of the sorghum mini core collection, country of origin, race, and data on plant height, days to 50% anthesis, and 100-seed weight is given in Appendix 1 and also on the website http://www.icrisat.org.

Appendix Table 1. Identity, country of origin, race, and data on days to 50% anthesis, plant height (cm), and 100-seed weight (g) of sorghum mini core accessions at ICRISAT Patancheru, 2004–2005.

Sl. no.	Identity	Country of origin	Race	Days to 50% anthesis	Plant height	100-seed weight
				d	cm	g
1	IS 2426	Afghanistan	Caudatum-bicolor	78.63	230.20	2.86
2	IS 31681	Algeria	Bicolor	69.46	191.81	2.77
3	IS 14090	Argentina	Caudatum	75.47	142.11	3.23
4	IS 12697	Australia	Bicolor	88.14	289.67	2.39
5	IS 19389	Bangladesh	Caudatum	83.14	230.22	2.61
6	IS 26484	Benin	Guinea	89.21	283.98	3.97
7	IS 14290	Botswana	Kafir-durra	74.38	221.24	2.91
8	IS 19445	Botswana	Kafir	79.86	188.99	3.46
9	IS 19450	Botswana	Guinea-kafir	75.07	202.14	3.64
10	IS 22239	Botswana	Kafir	83.70	201.04	3.01
11	IS 22294	Botswana	Kafir	89.59	240.75	3.15
12	IS 27557	BurkinaFaso	Guinea	100.08	287.42	2.85
13	IS 31557	Burundi	Caudatum	96.00	279.08	2.31
14	IS 14779	Cameroon	Caudatum	78.37	247.35	2.85
15	IS 14861	Cameroon	Caudatum	103.9	319.38	3.95
16	IS 15170	Cameroon	Caudatum	79.35	228.88	3.23
17	IS 15466	Cameroon	Caudatum	88.19	213.19	3.17
18	IS 15478	Cameroon	Guinea-caudatum	81.93	277.15	3.20
19	IS 15744	Cameroon	Durra-caudatum	76.08	210.35	3.63
20	IS 15931	Cameroon	Guinea	84.48	213.39	3.58
21	IS 15945	Cameroon	Guinea-caudatum	86.84	277.15	3.00
22	IS 16151	Cameroon	Caudatum-bicolor	76.13	222.74	2.80
23	IS 16382	Cameroon	Guinea	56.01	190.31	3.34
24	IS 16528	Cameroon	Guinea	115.90	312.20	3.46
25	IS 30572	Cameroon	Guinea-caudatum	61.00	190.22	3.13
26	IS 30838	Cameroon	Guinea	79.47	247.72	4.09
27	IS 10757	Chad	Caudatum	102.95	358.19	3.46
28	IS 10867	Chad	Guinea-caudatum	101.49	287.53	3.79
29	IS 1212	China	Kafir-bicolor	61.30	229.79	2.57
30	IS 1219	China	Guinea-bicolor	64.89	237.59	2.96
31	IS 1233	China	Bicolor	59.00	204.35	2.48
32	IS 29654	China	Kafir-bicolor	78.58	253.87	3.04
33	IS 30383	China	Caudatum-bicolor	67.79	254.74	2.59
34	IS 30400	China	Caudatum-bicolor	70.03	262.67	2.81
35	IS 30417	China	Caudatum-bicolor	60.92	260.28	2.77
36	IS 30443	China	Caudatum-bicolor	78.86	258.05	2.77
37	IS 30450	China	Caudatum-bicolor	69.75	208.57	2.61
38	IS 30451	China	Caudatum-bicolor	66.10	246.05	2.88
39	IS 30460	China	Caudatum	64.14	205.42	3.19
40	IS 30466	China	Caudatum-bicolor	64.33	244.42	2.72
41	IS 12965	Cuba	Caudatum	66.63	135.65	2.75
42	IS 2872	Egypt	Caudatum-bicolor	68.63	158.47	3.67
43	IS 11026	Ethiopia	Durra	90.41	302.34	4.24
44	IS 11473	Ethiopia	Caudatum	68.59	214.14	3.82
45	IS 11619	Ethiopia	Durra-bicolor	95.80	315.09	2.62
46	IS 11919	Ethiopia	Durra-bicolor	88.93	188.58	2.59
47	IS 12937	Ethiopia	Kafir	78.96	252.45	2.67
48	IS 23514	Ethiopia	Caudatum	74.48	181.28	2.63
49	IS 23521	Ethiopia	Guinea-caudatum	81.30	156.72	2.78
50	IS 23579	Ethiopia	Guinea-caudatum	70.50	201.97	2.89
51	IS 23586	Ethiopia	Guinea-caudatum	81.30	202.89	3.26

Appendix Table 1. Continued.

Sl. no.	Identity	Country of origin	Race	Days to 50% anthesis	Plant height	100-seed weight
				d	cm	g
52	IS 23590	Ethiopia	Guinea-caudatum	86.21	229.67	2.85
53	IS 25249	Ethiopia	Durra-bicolor	97.23	360.05	2.01
54	IS 25301	Ethiopia	Durra-bicolor	104.10	393.29	2.28
55	IS 23644	Gambia	Guinea	100.83	264.76	2.55
56	IS 25089	Ghana	Guinea	101.93	243.18	3.08
57	IS 33090	Honduras	Durra	108.21	207.65	2.56
58	IS 1004	India	Durra	94.77	298.90	3.68
59	IS 1041	India	Durra	68.26	219.49	3.37
60	IS 3971	India	Durra	74.41	185.63	2.20
61	IS 4060	India	Durra-bicolor	64.10	199.68	2.66
62	IS 4092	India	Caudatum	75.50	232.34	2.89
63	IS 4360	India	Durra	83.24	255.81	3.17
64	IS 4372	India	Guinea-durra	72.04	225.66	3.92
65	IS 4515	India	Durra	78.33	235.49	3.32
66	IS 4581	India	Durra	76.37	205.94	3.10
67	IS 4613	India	Durra	84.22	246.57	2.90
68	IS 4631	India	Durra	78.29	224.92	3.27
69	IS 4698	India	Durra	78.29	220.30	3.09
70	IS 4951	India	Guinea	97.95	264.82	2.49
71	IS 5094	India	Durra	79.27	230.46	2.88
72	IS 5295	India	Guinea	100.89	225.11	2.26
73	IS 5301	India	Guinea-caudatum	91.08	203.88	2.44
74	IS 5386	India	Durra	78.08	260.77	2.73
75	IS 5667	India	Durra	87.90	255.23	2.36
76	IS 5919	India	Durra	79.06	247.84	3.04
77	IS 6351	India	Durra	86.48	243.24	2.84
78	IS 6354	India	Durra	86.48	249.70	2.92
79	IS 6421	India	Durra	86.48	247.86	3.13
80	IS 12883	India	Durra	72.20	188.20	2.38
81	IS 17941	India	Caudatum	60.82	147.28	2.41
82	IS 17980	India	Durra	65.33	224.21	2.17
83	IS 18039	India	Durra-bicolor	69.29	217.21	3.41
84	IS 19859	India	Durra	66.30	189.01	3.45
85	IS 24348	India	Caudatum	60.73	155.43	2.68
86	IS 32349	India	Guinea	106.96	267.11	2.63
87	IS 32439	India	Guinea	100.08	254.18	3.31
88	IS 20956	Indonesia	Durra-caudatum	79.86	222.23	2.93
89	IS 2413	Iran	Bicolor	74.37	274.91	2.34
90	IS 8012	Japan	Bicolor	81.27	215.80	2.68
91	IS 9108	Kenya	Caudatum	80.01	240.68	2.21
92	IS 9113	Kenya	Caudatum	82.96	232.37	2.66
93	IS 9177	Kenya	Caudatum	92.78	236.98	2.67
94	IS 21083	Kenya	Caudatum	87.07	285.63	3.11
95	IS 33353	Kenya	Caudatum	83.72	202.35	2.32
96	IS 30507	Republic of Korea	Caudatum-bicolor	70.03	229.42	2.60
97	IS 30508	Republic of Korea	Caudatum-bicolor	66.45	194.06	2.72
98	IS 30533	Republic of Korea	Caudatum-bicolor	83.23	249.53	2.62
99	IS 30536	Republic of Korea	Caudatum-bicolor	68.26	246.27	2.68
100	IS 30562	Republic of Korea	Bicolor	79.28	189.04	3.03
101	IS 29358	Lesotho	Kafir	72.81	194.46	2.79
102	IS 29392	Lesotho	Kafir	67.90	187.99	3.01
103	IS 29441	Lesotho	Kafir-caudatum	60.43	189.72	2.79
104	IS 29468	Lesotho	Guinea-caudatum	74.64	209.56	2.99
105	IS 29519	Lesotho	Kafir-caudatum	68.29	198.95	2.71
106	IS 29565	Lesotho	Guinea-caudatum	81.52	223.41	3.18
107	IS 29568	Lesotho	Kafir-caudatum	71.23	234.04	2.85
108	IS 29582	Lesotho	Kafir	74.65	160.61	2.81
109	IS 26617	Madagascar	Caudatum-bicolor	93.84	243.86	2.42
110	IS 21512	Malawi	Guinea	71.37	175.19	2.36
111	IS 21645	Malawi	Guinea	80.21	184.42	2.49
112	IS 25732	Mali	Durra	75.81	234.43	2.86
113	IS 25836	Mali	Durra	73.85	198.42	2.47
114	IS 25910	Mali	Guinea	84.26	240.41	2.09
115	IS 25989	Mali	Guinea	82.21	277.51	1.95

Appendix Table 1. Continued.

Sl. no.	Identity	Country of origin	Race	Days to 50% anthesis	Plant height	100-seed weight
				d	cm	g
116	IS 26025	Mali	Guinea	100.99	278.43	2.83
117	IS 26046	Mali	Guinea	100.99	299.67	2.70
118	IS 13549	Mexico	Caudatum-bicolor	103.62	320.62	2.35
119	IS 27786	Morocco	Durra-bicolor	65.81	162.44	3.20
120	IS 23684	Mozambique	Guinea	114.57	292.46	2.39
121	IS 22616	Myanmar	Bicolor	96.39	269.50	2.46
122	IS 12945	Nicaragua	Kafir	95.64	285.70	2.81
123	IS 20195	Niger	Bicolor	81.31	230.77	3.73
124	IS 20298	Niger	Caudatum-bicolor	57.47	175.64	3.16
125	IS 2902	Nigeria	Caudatum-bicolor	77.47	232.34	3.42
126	IS 7250	Nigeria	Guinea	113.78	355.22	2.93
127	IS 7305	Nigeria	Caudatum	93.77	268.00	3.25
128	IS 7310	Nigeria	Guinea	79.42	275.80	2.97
129	IS 7679	Nigeria	Guinea	101.12	333.59	2.80
130	IS 7957	Nigeria	Guinea-bicolor	98.64	317.63	3.58
131	IS 7987	Nigeria	Guinea	94.25	292.96	3.29
132	IS 8348	Pakistan	Durra	72.73	214.61	2.56
133	IS 25548	Rwanda	Caudatum	93.08	274.16	2.74
134	IS 12735	Saudi Arabia	Caudatum-bicolor	67.29	220.89	3.01
135	IS 19975	Senegal	Guinea	110.99	345.44	2.95
136	IS 27697	SierraLeone	Guinea	98.12	208.93	2.07
137	IS 22720	Somalia	Durra	73.59	213.12	2.99
138	IS 22799	Somalia	Durra	73.59	210.35	3.37
139	IS 32787	Somalia	Durra	65.01	212.27	2.72
140	IS 2379	South Africa	Caudatum	65.53	195.50	2.85
141	IS 2382	South Africa	Caudatum	88.11	254.60	2.69
142	IS 2389	South Africa	Kafir	78.99	214.14	2.91
143	IS 2397	South Africa	Kafir	73.1	176.28	2.97
144	IS 2864	South Africa	Caudatum	63.57	139.17	2.70
145	IS 3158	South Africa	Kafir	73.06	128.72	3.34
146	IS 8774	South Africa	Kafir-durra	76.35	196.30	2.87
147	IS 13782	South Africa	Kafir-durra	78.31	179.68	2.69
148	IS 13893	South Africa	Kafir-caudatum	106.46	230.72	2.83
149	IS 13919	South Africa	Kafir-caudatum	94.68	229.79	3.04
150	IS 13971	South Africa	Caudatum	102.95	271.39	2.62
151	IS 14010	South Africa	Caudatum-bicolor	67.01	196.42	3.44
152	IS 24453	South Africa	Caudatum-bicolor	98.75	216.16	2.44
153	IS 24462	South Africa	Caudatum-bicolor	63.4	118.28	3.01
154	IS 24463	South Africa	Kafir	78.16	247.72	3.04
155	IS 24492	South Africa	Kafir	87.97	238.48	2.99
156	IS 24503	South Africa	Bicolor	108.17	262.11	1.75
157	IS 26694	South Africa	Caudatum	97.99	267.69	2.68
158	IS 26701	South Africa	Caudatum-bicolor	105.62	247.56	2.35
159	IS 26737	South Africa	Kafir	96.81	231.10	2.77
160	IS 26749	South Africa	Kafir	81.10	148.91	2.73
161	IS 27887	South Africa	Caudatum-bicolor	96.78	287.26	2.88
162	IS 27912	South Africa	Kafir-caudatum	84.98	215.57	2.85
163	IS 29606	South Africa	Kafir	88.40	230.79	3.48
164	IS 29627	South Africa	Durra-caudatum	83.50	235.35	2.90
165	IS 22609	Sri Lanka	Caudatum	104.66	226.81	1.80
166	IS 9745	Sudan	Caudatum	68.23	205.59	3.85
167	IS 12447	Sudan	Durra-caudatum	69.21	137.40	3.32
168	IS 19153	Sudan	Guinea-caudatum	73.17	152.07	2.68
169	IS 19262	Sudan	Guinea-caudatum	61.31	119.25	2.48
170	IS 22986	Sudan	Caudatum	78.41	245.92	2.82
171	IS 27034	Sudan	Durra	96.43	309.23	3.78
172	IS 29187	Swaziland	Guinea-caudatum	98.84	276.67	2.84
173	IS 29233	Swaziland	Kafir	92.45	187.99	2.92
174	IS 29239	Swaziland	Kafir	86.56	202.77	3.05
175	IS 29241	Swaziland	Kafir-caudatum	88.90	257.13	2.68
176	IS 29269	Swaziland	Guinea-caudatum	88.04	238.81	2.88
177	IS 29304	Swaziland	Guinea-kafir	99.61	285.25	2.84
178	IS 29314	Swaziland	Durra-caudatum	104.11	277.82	2.54

Appendix Table 1. Continued.

Sl. no.	Identity	Country of origin	Race	Days to 50% anthesis	Plant height	100-seed weight
				d	cm	g
179	IS 29326	Swaziland	Caudatum-bicolor	88.04	267.43	2.52
180	IS 29335	Swaziland	Caudatum	97.24	232.58	2.83
181	IS 21863	Syrian Arab Republic	Bicolor	65.26	178.19	2.99
182	IS 24139	Tanzania	Guinea	73.46	305.97	2.36
183	IS 24175	Tanzania	Guinea	68.55	299.50	2.66
184	IS 24218	Tanzania	Guinea	110.77	294.89	3.23
185	IS 33023	Tanzania	Guinea	104.01	303.12	2.57
186	IS 10302	Thailand	Caudatum	77.43	230.76	3.15
187	IS 26222	Togo	Guinea-caudatum	104.92	261.81	3.42
188	IS 12804	Turkey	Bicolor	72.43	263.81	2.64
189	IS 7131	Uganda	Durra-caudatum	87.88	250.45	2.87
190	IS 8777	Uganda	Caudatum-bicolor	74.31	176.96	2.92
191	IS 8916	Uganda	Guinea-caudatum	81.91	234.41	2.76
192	IS 31043	Uganda	Caudatum	94.03	301.24	3.24
193	IS 31186	Uganda	Guinea-caudatum	98.55	247.82	3.05
194	IS 31446	Uganda	Guinea-caudatum	89.71	262.60	2.47
195	IS 473	United States of America	Guinea-kafir	71.14	208.6	2.34
196	IS 602	United States of America	Bicolor	73.72	190.49	2.56
197	IS 603	United States of America	Bicolor	73.72	231.12	2.93
198	IS 608	United States of America	Bicolor	87.47	229.28	2.52
199	IS 995	United States of America	Caudatum-bicolor	84.13	213.89	2.44
200	IS 3121	United States of America	Bicolor	80.59	217.27	2.65
201	IS 10969	United States of America	Guinea-caudatum	67.13	210.88	3.06
202	IS 12706	United States of America	Caudatum-bicolor	103.62	267.06	2.53
203	IS 20625	United States of America	Durra-caudatum	90.66	310.88	2.26
204	IS 20632	United States of America	Caudatum	99.83	322.10	3.39
205	IS 20679	United States of America	Guinea-caudatum	72.77	227.35	3.27
206	IS 20697	United States of America	Caudatum	66.45	144.34	2.40
207	IS 20713	United States of America	Guinea-caudatum	76.70	206.11	3.02
208	IS 20727	United States of America	Bicolor	65.60	203.99	2.54
209	IS 20740	United States of America	Bicolor	69.53	229.85	2.71
210	IS 20743	United States of America	Bicolor	63.64	226.15	2.91
211	IS 20816	United States of America	Bicolor	77.74	180.85	2.12
212	IS 13294	Venezuela	Caudatum-bicolor	117.36	320.62	2.60
213	IS 23891	Republic of Yemen	Durra	83.41	277.76	5.71
214	IS 23992	Republic of Yemen	Caudatum	63.68	246.85	2.99
215	IS 28141	Republic of Yemen	Durra-caudatum	87.67	285.82	4.73
216	IS 28313	Republic of Yemen	Durra-caudatum	50.36	164.86	2.36
217	IS 28389	Republic of Yemen	Durra-caudatum	67.05	179.63	2.70
218	IS 28449	Republic of Yemen	Guinea-caudatum	67.38	243.90	2.94
219	IS 28451	Republic of Yemen	Guinea-caudatum	65.42	242.98	3.00
220	IS 28614	Republic of Yemen	Durra-caudatum	67.05	215.64	2.55
221	IS 28747	Republic of Yemen	Durra-caudatum	70.98	252.58	2.50
222	IS 28849	Republic of Yemen	Durra-caudatum	59.20	169.47	2.86
223	IS 29091	Republic of Yemen	Durra-caudatum	70.98	245.19	3.50
224	IS 29100	Republic of Yemen	Durra-caudatum	76.62	241.81	4.98
225	IS 31706	Republic of Yemen	Durra	94.46	290.76	4.85
226	IS 31714	Republic of Yemen	Durra-caudatum	61.54	206.06	3.90
227	IS 32245	Republic of Yemen	Durra-caudatum	68.41	200.52	2.65
228	IS 31651	Zaire	Caudatum	77.83	264.22	2.56
229	IS 23216	Zambia	Caudatum-bicolor	117.36	264.29	2.61
230	IS 24939	Zambia	Bicolor	108.17	258.42	2.78
231	IS 24953	Zambia	Guinea-caudatum	105.67	307.61	2.75
232	IS 12302	Zimbabwe	Caudatum	100.01	284.32	3.09
233	IS 19676	Zimbabwe	Kafir	95.48	190.88	3.54
234	IS 29689	Zimbabwe	Kafir	112.94	250.18	2.88
235	IS 29714	Zimbabwe	Kafir-durra	84.20	201.84	2.33
236	IS 29733	Zimbabwe	Guinea-durra	99.61	288.94	2.56
237	IS 29772	Zimbabwe	Guinea-caudatum	99.19	291.74	2.88
238	IS 29914	Zimbabwe	Caudatum	83.77	172.17	2.39
239	IS 29950	Zimbabwe	Guinea-caudatum	70.81	164.36	3.18
240	IS 30079	Zimbabwe	Durra-caudatum	84.48	186.41	2.78
241	IS 30092	Zimbabwe	Durra-caudatum	101.16	261.26	3.22
242	IS 30231	Zimbabwe	Kafir	101.16	276.03	2.76

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