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Sorghum [*Sorghum bicolor* (L.) Moench] landrace variation and classification in North Shewa and South Welo, Ethiopia

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Summary

Fourteen phenotypic characters were chosen for the purpose of obtaining taxonomic evidence on the resemblances of 177 accessions of sorghum from North Shewa and South Welo regions of Ethiopia. Canonical Discriminant Analysis (CDA) and Modeclus cluster analysis were conducted to see if the 177 accessions could form clusters based on their morphological characters, and to test the consistency of farmers' naming of the five most common Sorghum landraces represented by 44 accessions. Multivariate analyses grouped the 177 accessions into three clusters linked by a few phenotypic intermediate landraces. A botanical key was established for easy classification of the Sorghum crop plants grown in the study area. The number of accessions of the five most common landraces named by the farmers formed dissimilar groups, suggesting that farmers' naming of these Sorghum landraces are consistent. Midrib color, grain color, grain size, glume color, glume hairiness, and grain shape were the leading morphological characters used by the farmers in naming these Sorghum landraces.

Introduction

Highly variable and complex taxa are known to offer challenges of classification to taxonomists and biosystematists. Sorghum is one of the domesticated crop plants which presents this challenge due to its wide diversity (House, 1995). In 1794, Moench established the genus *Sorghum* and brought all the sorghums together under the name *Sorghum bicolor* (House, 1978; Clayton, 1961). Snowden (1936) classified *Sorghum* into 52 species composed of 31 cultivated, 17 wild, and 4 weedy species. On the basis of the absence of genetic barriers among the *Sorghum* taxa, De Wet and Huckabay (1967) combined the 52 species into a single species. Harlan and de Wet (1972), using inflorescence type as a grouping criterion, divided all the cultivated sorghum taxa of the world into five races and fifteen intermediate races, under *S. bicolor* ssp. *bicolor*. Four of the five major races of the cultivated Sorghum and one intermediate race are found in Ethiopia (Stemler et al., 1977).

These and other approaches to classification and estimation of genetic variations have their own inherent advantages and disadvantages, particularly in the primary center of origin of *Sorghum,* Ethiopia, where it was domesticated (Vavilov, 1926, 1951) and diversified (Harlan, 1969). Folk taxonomy and botanical taxonomy should be taken into consideration to facilitate the understanding of the challenges of variation and diversity for today's needs of holistic, comprehensive, yet clearly defined and scientifically acceptable biotic classifications.

In the present investigation, morphological characters were used to estimate the levels of variation among the sorghum landraces grown in north Shewa and south Welo regions of Ethiopia. We hypothesized that if farmers are selecting and maintaining landraces, a consensus folk taxonomy must exist with some degree of consistency with conventional botani-

Table 1. The fourteen phenotypic descriptors and their coded characters

Midrib color	Grey (0) Greyed-orange (0) Greyed-purple (0) Dull-green (1) Dark-yellow (2) Light-yellow (2) Yellow (2) Orange-yellow (3) Brown (4) Moderate-brown (4) Light-olive (5) Reddish-yellow (6) Red (6) White (7)
Stem juiciness	Dry (0) Juicy (1)
Awns	Absent (0) Present (1)
Glume color	Black (0) Purple (1) Yellow (2) Yellow-orange (3) Orange (4)
Glume constriction	Absent (0) One-sided (1) Two-sided (2)
Glume hairiness	Light (0) Medium (1) Dense (2)
Grain covering	25% (1) 50% (2) 75% (3) Total (4) Glume>Grain (5)
Grain plumpness	Dimple (0) Plump (1)
Grain color	Black (0) Grey (1) Yellow (2) Orange-yellow (3) Brown (4) Red (5) White (6)
Grain size	Small (0) Intermediate (1) Large (2)
Grain shape	Shape I (0) Shape II (1) Shape III (2) Shape IV (3) Shape V (4)
Lodicule hair distribution	No hair (0) One-sided only (1) Two-sided only (2) Uniform (3) Dense (4)
Lodicule nerve-setting	Undefined (0) Defined (1) Well-defined (2)
Inflorescence	Durra (1), Caudatum (2), Bicolor (3), Durra-Bicolor (4), Guinea (5)

cal taxonomy. The main objectives were: 1) to examine the variation of sorghum landraces and to examine if the landraces form clusters based on their morphological similarities, and 2) to assess the consistency of farmers' naming of the sorghum landraces they grow.

The terms landrace and accession are used throughout this paper. Landraces are defined as variable plant populations adapted to local agroclimatic conditions which are named, selected and maintained by the traditional farmers to meet their social, economic, cultural and ecological needs. In the absence of farmers' manipulations, landraces may not exist in the ecological dynamics that are known today. Thus, landraces and farmers are interdependent, in need of each other for their survival.

Accessions are samples collected by the first author from farmers' fields for research purposes including this study. An accession or group of accessions would be labelled according to the farmers' description of the Sorghum landrace. Thus, the term accession will be used throughout this paper until the point where farmers' naming of landrace is found to be consistent in the analyses.

Materials and methods

To study the phenotypic similarities of the Sorghum landraces grown by the farmers, 230 accessions were randomly collected from a total of 457 hectares of farmers' fields in north Shewa and south Welo regions of Ethiopia. The study area ranges altitudinally from 1,200 to 2,400 meters above sea level. After discarding the incomplete or contaminated samples, 177 accessions were analyzed for their variation using clustering and multivariate statistics (Sneath and Sokal, 1973; Morrison, 1967; Pimentel, 1979). The number of accessions of the Sorghum landraces identified by individual farmers ranged from one to nineteen.

To characterize each plant taxonomically, fourteen phenotypic characters were chosen. Table 1 lists the morphological characters and their codes used in the analyses. The morphological characters chosen were easy to score, quick and simple to evaluate, often without requiring high levels of technical skill unlike biochemical or molecular markers. Most of the selected characters could be described with little difficulty by the farmers, and many are related to the essential reproductive functions of sorghum.

Size and shape factors of seeds were determined by means of an image analyzer, Interaktives Bild – Analysen System (IBAS2, 1990), located at the Plant Research Center of Agriculture Canada in Ottawa. To determine the size and shape of each accession approximately 100 seeds from each accession were mounted on a petri dish. For matching purposes, ranges of figures representing the various sizes and shapes of the landrace seeds were taken from a chart of simple symmetrical plane shapes (Exell, 1960 and 1962) and mounted on two petri dishes. The image analyzer then analyzed the reference figures and the actual Sorghum seeds using the same scale, camera and light require-

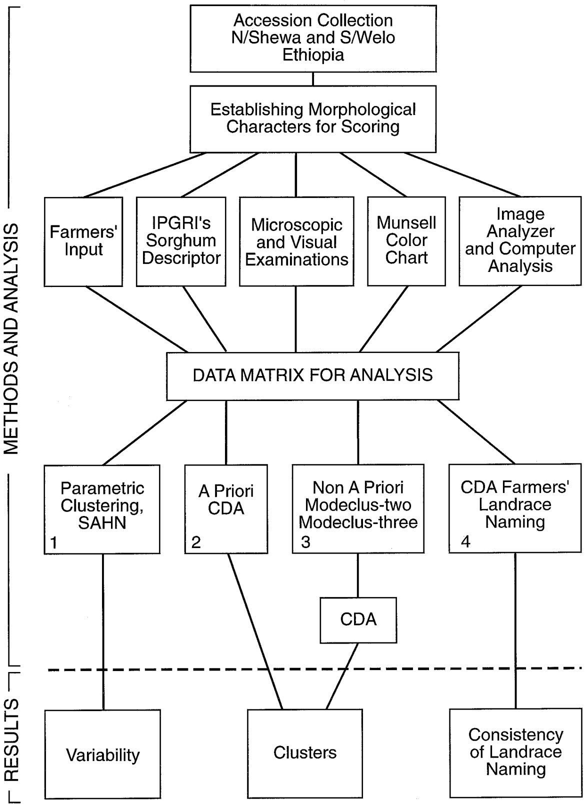

Figure 1. Steps undertaken in the analysis of variation and clustering of *Sorghum* accessions, and consistency of *Sorghum* landrace naming by farmers. CDA = canonical discriminant analysis.

ments and generated size and shape factor scores for each seed accession and the reference seed figures. The accession size factors were categorized into 3 groups (Table 1), while the shape factors formed 5 classes (Table 1).

Lodicules were boiled in water, dissected and mounted on microscope slides with lactophenol (Sass, 1958). Lodicule hair distribution and lodicule nerve patterns were examined, photographed and scored with the aid of a Carl Zeiss microscope with Nomarski interference contrast optics. The photographs were used to look for differences in lodicule hair distributions and nerve patterns. Five classes of lodicule hair distribution and three classes of nerve patterns were observed among the accessions (Table 1).

Seed colour, glume colour and midrib colour were examined and scored using the Munsell colour chart (1957). IPGRI's (International Plant Genetic Resource Institute) sorghum descriptor manual (1993) was employed to categorize each accession according to its grain plumpness and percent grain covering by the awn.

During accession collection farmers provided the information on the stem juiciness of each accession. The presence of awns, and glume hairiness and constriction were observed and scored in the laboratory. Sorghum inflorescence shape and compactness, used by Harlan and de Wet (1972), Stemler et al. (1977) and Doggett (1988) as a discriminant character in global sorghum classification into botanical races, was also used.

The 14 morphological characters (Table 1) were scored to make a 177 x 14 data matrix on which clustering and various univariate and multivariate analyses were conducted. Figure 1 shows the steps undertaken in the analyses of variation and clustering of Sorghum accessions, and consistency of sorghum landrace naming by farmers.

SAHN (Sequential, Agglomerative, Hierarchical, and Nested) clustering methods (Sneath & Sokal, 1973) were used to generate dendograms for the 177 accessions. The data were also subjected to Modeclus (SAS, 1992) non-parametric clustering method using Euclidean distance, to determine if the accessions form significant groupings.

Canonical Discriminant Analysis (CDA) (Pimentel, 1979; Morrison, 1967) was employed to assess various *a priori* criteria for potential groupings of the accessions and to evaluate the clusters obtained from Modeclus procedure (Figure 1). CDA was instrumental in identifying the morphological characters with higher discriminatory power. The *a priori* criteria for the grouping solutions in CDA were stem juiciness and grain plumpness. CDA was also used to find altitudinal ranges as grouping criteria. The *a priori* selected characters were useful in testing if the groupings were justified or supported by the characters not used as group criteria. When CDA was used to evaluate the clustering from Modeclus, the group criterion was cluster membership instead of any particular character (Figure 2).

The magnitude of the F-value from the analysis of variance in CDA was used for ranking according to order of importance and for selecting the most important variables among the 14 morphological characters used as group criteria in the clustering of the 177 accessions. The five most common landraces, as named by the farmers, with 5 or more accessions each were subjected to CDA so as to test the consistency of farmers' naming of sorghum landraces in the research area. The magnitudes of the F-value from CDA were instrumen-

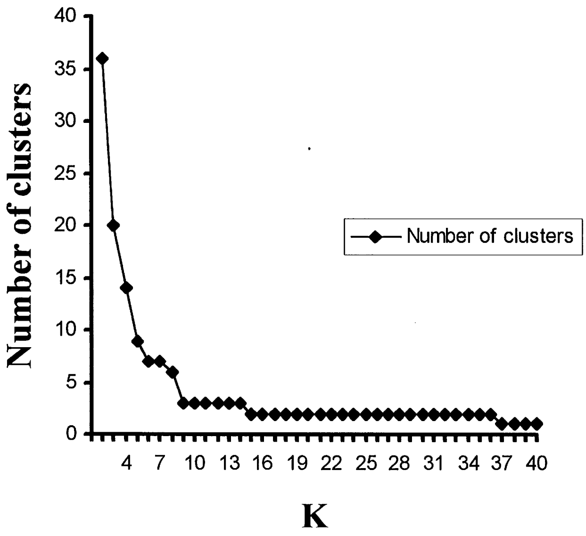

Figure 2. Generating MODECLUS groupings. Three cluster membership was the first stable area in the curve between K = 9-14. Two cluster is stable with K = 15 - 36. K measures the neighborhoodiness among accessions in forming MODECLUS groupings.

tal in ranking the morphological characters most useful in naming sorghum landraces by farmers.

The computations were conducted using SAS (1992) release 6.10 and NTSYS-pc (Rohlf, 1992), on Dell pentium computer.

Results

The dendograms generated by the parametric clustering method (Figure 1, Box 1) demonstrated extensive variation of the accessions but no clear taxonomic structure. The univariate analyses of frequencies, means, variances and standard deviations for each of the 14 morphological descriptors indicated clearly that the accessions were variable (statistics not shown here).

A priori grouping using CDA

When stem juiciness was used as the primary grouping criterion the Mahalanobis distance between the two centroids of the juicy and non-juicy landraces was 3.19. The F-value (6.13) testing the Mahalanobis distance between the multivariate centroids indicates that the two groupings are not equal (P<0.0001). In descending order, grain plumpness (F=33.24; P<0.0001), grain shape (F=19.96; P< 0.0001) and grain size (F=19.68; P< 0.0001), glume hairiness (F=9.86; P< 0.002), grain covering (F=4.53; P<0.035), and awn presence (F=4.46; P<0.036) played the greatest roles in segregating the accessions into two groupings when stem juiciness was used as the primary grouping criterion. The Wilks' lambda (0.67) indicates that the two groups are independent (F=6.48, P<0.0001). In the membership analyses, there were 144 non-juicy and 33 juicy accessions.

Using grain plumpness as a membership criterion generated 122 accessions with dimple and 55 with plump grains. With grain plumpness as a membership criterion, some of the accessions of one group overlapped into the other. The Mahalanobis distance (3.86), the F-value (11.44) and the Wilks' lambda (0.54) indicate that the two accession groupings formed by grain plumpness are significantly different (P<0.0001). Grain covering (F=45.78; P<0.0001), stem juiciness (F=33.24; P<0.0001), glume constriction (F=26.31; P<0.0001), and grain color (F=21.91; P<0.0001), grain shape (F=14.80; P<0.0002), grain size (F=8.51; P<0.004) and glume hairiness (F=5.71; P<0.01) were the leading morphological characters in grouping the accessions into dimple and plump grain types, when grain plumpness was used as the primary membership criterion. The Wilks' lambda (0.54) suggests that the two grain plumpness groupings are significantly different (F=11.4, P<0.0001).

The inflorescence shape and compactness, as a group criterion, indicated clearly the representation of four of the five global races and one of the 15 intermediate races proposed by Harlan and de Wet (1972), Stemler et al. (1977) and Doggett (1988). Stem juiciness (F=27.57; P<0.0001), midrib color (F=15.37; P<0.0001), grain shape (F=15.06; P<0.0001), grain size (F=10.99; P<0.0001), grain covering (F=10.73; P<0.0001), grain color (F=10.52; P<0.0001), grain plumpness (F=8.82; P<0.0001), awn presence (F=5.64; P<0.0003), glume hairiness (F=5.46; P<0.0004) and glume constriction (F=3.37; P<0.01) played the greatest roles in grouping the accessions into five groups (P<0.0001) when inflorescence was used as a clustering criterion. There were 40, 44, 24, 29 and 40 accessions in each of the five inflorescence groupings.

Three altitude classes were used as class criteria in grouping the accessions into three clusters. There were 81, 74 and 22 accessions in the lowland, intermediate and highland altitudinal ranges, respectively. In descending order, glume hairiness (F=18.51; P<0.0001), midrib color (F=6.21; P<0.0025), grain

Table 2. Mahalanobis distances, F-values and P-values with Modeclus three cluster solution as a group criterion

Clusters (From/To)	Mahalanobis distance	F-value	P-value
Cluster1-Cluster2	7.57	18.06	0.0001
Cluster1-Cluster3	9.75	18.88	0.0001
Cluster2-Cluster3	1.25	1.84	0.0462

Table 3. Summary of landrace classification according to the three cluster solution

Character	Cluster 1	Cluster 2	Cluster 3
Juicy	0	0	33
Not juicy	108	36	0
Dimple	105	8	10
Plump	3	28	23

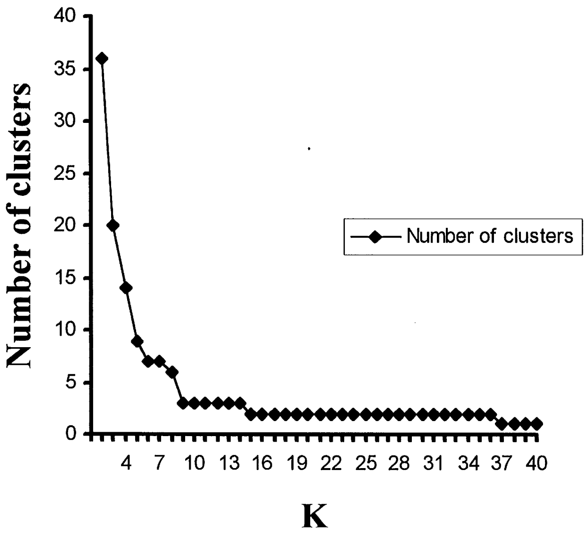

Figure 3. *Sorghum* landrace ordination by canonical discriminant analysis, using the two-cluster solution obtained by MODECLUS, as group criterion. The two clusters are almost completely supported by the 14 morphological characters.

color (F=5.47; P<0.0050) and stem juiciness (F=5.40; P<0.0053) were the most important morphological characters in the three altitude-based accession groupings (P<0.005).

Clustering (Figure 1, Box 3)

With Modeclus, the first area of stability of cluster number as a function of K (Figure 2) is with K=9-14 with three clusters. The second area of stability is with K=15-36 (Figure 2) with two clusters. The two cluster membership solution yielded 141 accessions that fell in cluster one and 36 accessions in cluster two. CDA of the two clusters generated the following statistics. The Mahalanobis distance (65.17) indicated that the centroids of the two clusters are significantly different (F=123.58; P=0.0001). Stem juiciness (F=1533.47; P<0.0001), grain size (F=23.05; P<0.0001), grain shape (F=21.98; P<0.0001), glume hairiness (F=10.36; P<0.0015), inflorescence (F=5.21; P<0.0237), grain covering (F=4.73; P<0.0311) and lodicule nerves (F=4.42; P<0.0370) were the characters with greatest discriminatory power in creating the two clusters. The high F-value for stem juiciness reaffirms the suitability of stem juiciness used in the *a priori* selection. The Wilks' lambda (0.08) indicates that the two groups are different (P<0.0001). Figure 3 shows the two clusters of accessions with almost no intermediates.

With Modeclus, the three cluster solution yielded 100 accessions in cluster one, 44 accessions in cluster two and 33 accessions in cluster three. In descending order, grain plumpness (F=79.86; P<0.0001), grain shape (F=26.72; P<0.0001), grain covering (F=19.32; P<0.0001), grain size (F=17.10; P<0.0001), grain color (F=10.95; P<0.0001), glume hairiness (F=8.37; P<0.0003), glume constriction (F=5.82; P<0.0036), and lodicule hairs (F=4.18; P<0.0168) had the greatest contribution in support of the three groups. The Wilks' lambda (0.29) indicates that the three cluster solutions are significantly independent from each other at 0.0001 P-value. Table 2 summarizes the Mahalanobis distance, the F - and P - values when Modeclus three cluster solution was used as a primary membership criterion. Visual inspection of Figure 4 shows that there are three groupings of accessions linked by intermediates, in which more intermediates are seen between clusters 2 and 3 than with cluster 1.

Based on the combined results of the Modeclus three cluster solution and using grain form as a membership criteria (Table 3), a botanical key was established for easy classification of the Sorghum plants in north Shewa and south Welo regions of Ethiopia:

1) juicy stem .... Cluster III
11) non-juicy stem 2
2) dimple grain .... Cluster I
22) plump grain .... Cluster II

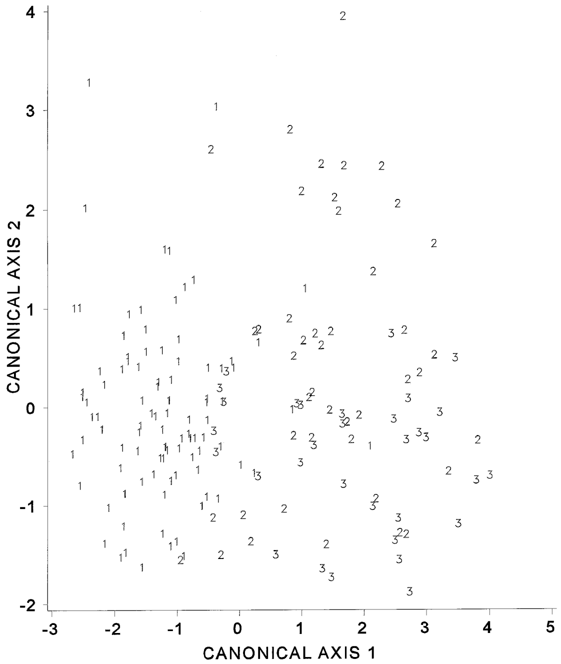

Figure 4. *Sorghum* landrace ordination by canonical discriminant analysis, using the three-cluster solution obtained by MODECLUS, as group criterion. The three clusters are to a degree supported by the 14 morphological characters. Clusters 2 and 3 show more intermediates than with cluster 1.

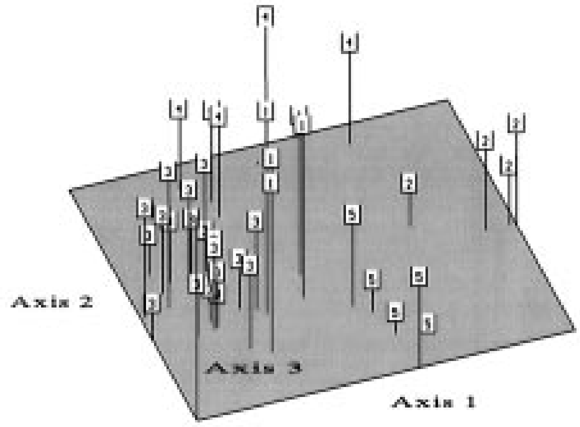

Figure 5. *Sorghum* landrace ordination by canonical discriminant analysis, using farmers=naming of *Sorghum* accessions as group criterion. The landraces named by the farmers are supported by the 14 morphological characters and form distinct groups on the ordination plot as well as in the analysis (see text). Variation explained by axes 1, 2 and 3 were 58.18%, 25.19% and 12.05%, respectively.

Table 4. Mahalanobis distances, F-values and P-values, with farmers' naming of landraces used as group criterion

Landrace (From/To)	Mahalanobis distance	F-value	P-value
Aehyo-Ganseber	44.01	5.56	0.0002
Aehyo-Gedalit	52.06	6.58	0.000
Aehyo-Wogere	45.71	6.30	0.0001
Aehyo-Zengada	29.24	5.85	0.0001
Ganseber-Gedalit	28.66	3.62	0.0035
Ganseber-Wogere	53.16	7.33	0.0001
Ganseber-Zengada	20.75	4.15	0.0014
Gedalit-Wogere	28.07	3.87	0.0023
Gedalit-Zengada	30.25	6.05	0.0001
Wogere-Zengada	63.92	14.74	0.0001

Farmers' classification into landraces (Figure 1, Box 4)

The accessions named by the farmers form discrete groups. Midrib color (F=34.27; P<0.0001), grain color (F=15.11; P<0.0001), grain size (F=6.88; P<0.0003), glume color (F=5.51; P<0.0015), glume hairiness (F=3.69; P<0.0131), and grain shape (F=2.65; P<0.05) were the leading discriminant morphological characters in grouping the accessions according to the names given by the farmers. Table 4 summarizes the Mahalanobis distance, the F- and P-values, when farmers' naming was used as a primary membership criterion. The Wilks' lambda (0.004) as a test of independence of the groupings created by the farmers indicates that the names given to the accessions by the farmers are consistent and highly dissimilar. The Wilks' lambda for farmers' classification was far the lowest of all the analyses. Figure 5 gives the three dimensional representation of the groups of accessions as named by the farmers. The groupings are distinct, different from each other, and the variations explained by the 1^{st}, 2^{nd} and 3^{rd} axes were 58.18%, 25.19% and 12.05%, respectively. Although only five landraces (44 accessions) could be included in this analysis for the reasons mentioned earlier, the evidence in the analyses has led us to generalize that the remaining 55 landraces (133 accessions) identified by the farmers (Appendix) in the research area represent 60 different populations in total.

Discussion

The foregoing results indicate that the *Sorghum* landraces in north Shewa and south Welo regions of Ethiopia are variable populations which group into three clusters, and that names given by the farmers to the accessions are consistent and represent morphologically different *Sorghum* landraces. These landraces represent four of the five cultivated global *Sorghums* as proposed by Harlan and de Wet (1972) and all of the four cultivated *Sorghum* races and one intermediate race described by Stemler et al. (1977) within the Ethiopian borders. The presence of the four races and one intermediate race in the small area indicates that these farmers deliberately maintain a wide diversity of *Sorghum* landraces. Landrace diversity in *Sorghum* has been the subject of two recent studies on a much wider geographic scale. One study included 157 “ecotypes” in Africa and Asia (Chantereau et al. 1989), the other study included 4000 accessions from the Indian subcontinent (Appa Rao et al. 1996). Both of these studies found the presence of the five major races of *Sorghum* based on Harlan and de Wet (1972). It is remarkable that in the small geographic area of the present study, 496 hectares of North Shewa and South Welo, Ethiopia, the farmers are maintaining such a wealth of *Sorghum* diversity.

Overall the analyses suggest a remarkable degree of consistency between farmers’ naming of landraces and numerical taxonomy. Stem juiciness is the best class criterion in grouping the accessions into two clusters. In the numerical taxonomy, stem juiciness, grain plumpness, grain shape, grain covering, grain size, and grain color had the greatest contribution in supporting the three cluster solution. The farmers used stem juiciness, midrib color, grain color, glume color, glume hairiness, grain size and grain shape to distinguish the landraces. Considerable commonality exists between the morphological characters supporting the significant clustering of the landraces as named by the farmers and the subset of the morphological characters supporting the significant clusters created by the Modeclus cluster solutions.

The pigmentation associated with the morphological characters is perceptually salient to the farmers but probably has little adaptive significance for the survival of the *Sorghum* plant. For example, midrib color, which is not obviously important to reproduction and survival, is one of the most important field characters used by the farmers to differentiate the grain-forming from the juicy sorghums, and to further distinguish variations within both juicy and non-juicy populations. Harlan (1975) claimed that landraces are the products of human selection for such characteristics as color, flavour, texture and storage quality and interestingly these characteristics are commonly used by the farmers of this region in naming their *Sorghum* landraces.

Unlike the botanical classification, which is mostly hierarchial and purely taxonomic, the folk classification accommodates utilitarian, psychological and linguistic factors along with the taxonomic features (Berlin et al, 1973 and 1974; Brush et al, 1981; Hunn, 1982; Martin, 1995). The group of accessions which the farmers identified by five different names formed five highly significant dissimilar groupings (Figure 5), confirming that these farmer-identified landraces are distinct plant populations. If the agronomic importance of each landrace were included in the analysis, the distance between the clusters of accessions would increase and one landrace would be found to be more different from the others than the current analysis indicates.

The different groups formed by the various membership class criteria resulted in varying numbers of intermediates between clusters. According to Harlan et al. (1976), intermediates are naturally occurring taxa arising from the interfertile and conspecific character of the major races of sorghum. Inbreeding of *Sorghum bicolor* produces small intra-population variation, while outbreeding produces wide interpopulational variations (Doggett, 1957). In north Shewa and south Welo, farmers intentionally tolerate the growth of wild relatives and weedy species. As a consequence, hybridization and gene flow among the outcrossing and selfing cultivated sorghums, wild relatives and weedy species in the study area is free and extensive, thereby increasing variation by producing fertile hybrids and morphologically intermediate individuals which may be selected by the farmers as seedstock for future use.

Intermediates are also the result of phenotypic plasticity and ecotypification, which are alternative strategies which are important in evolution in natural systems (Stace, 1989). The observed presence of some landraces over a wide elevation range could be attributed to ecotypification processes making the landrace capable of occupying agricultural habitats over larger elevational ranges. The recognition of intermediates in the dynamics of *Sorghum bicolor* by Harlan (1969), Doggett (1988), De Wet (1978), and Stace (1989) strengthens the findings that the sorghum landraces of north Shewa and south Welo are correctly grouped into three clusters linked by a few intermediates based on the Modeclus analysis, a non a priori grouping analysis. The combined outcome of the Modeclus three cluster solution and the use of grain plumpness as a membership criterion support the grouping of the landraces into three classes. In the three cluster solution (Table 3), the percentage of intermediate landraces in cluster 1 (1.7%) and cluster 2 (4.5%) are very low compared to the proportion of the accession collection correctly classified. The intermediates are hybrid derivatives (Harlan and de Wet, 1972), and we believe that eventually, through natural and human selection pressures, each intermediate landrace will either join one of the well-defined clusters of *Sorghum*, evolve into their own distinct grouping, or disappear, and that new intermediate landraces will originate.

Farmers play an important role in the dynamics of the creation, perpetuation and extinction of crop plants. Farmers provide opportunities for hybridization by bringing together otherwise geographically and ecologically isolated, but interfertile, landraces. Farmers' selection for desirable agronomic traits are major forces in shaping the dynamics of the crop plant population on a farmland. We agree with de Wet and Huckabay (1967), Frankel (1974), Harlan (1975), and Hawkes (1983) that the complex morphological variations that we see today are the result of the thousands of years of human activities of isolation, selection and hybridization.

Conclusion

The taxonomic evidence indicates that the *Sorghum* landraces of north Shewa and south Welo regions of Ethiopia group into three clusters with nine characteristics – stem juiciness, grain plumpness, grain shape, grain covering, grain size, grain color, glume hairiness, glume constriction, and lodicule hairs – supporting the grouping.

Analyses of the five most common landraces suggests that the names given by the farmers are consistent and indeed represent different *Sorghum* landraces. It is therefore important to document further the folk taxonomy of the study area along with the distribution, richness and equitability of each *Sorghum* landrace to safeguard the rare landraces from genetic erosion or disappearance. Threats from non-native sorghums and elite landraces also make it important to design complementary *in situ* and *ex situ* conservation strategies in order to ensure the survival and perpetuation of all the *Sorghum* landraces, including the intermediates.

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References

Appa Rao, S., Prasada Rao, K.E., Mengesha, M.H., & V. Gopal Reddy, 1996. Morphological diversity in sorghum germplasm from India. Genetic Resources and Crop Evolution, 43: 559–567.

Berlin, B., D.E. Breedlove & P.H. Raven, 1973. General principles of classification and nomenclature in folk biology. American Anthropologist 75: 214–242.

Berlin, B., D.E. Breedlove & P.H. Raven, 1974. Principles of Tazetal plant classification. An introduction to the botanical ethnography of a Mayan-speaking people of highland Chiapas. Academic Press. New York and London.

Brush, S.B., H.J. Carney, & Z. Huaman, 1981. Dynamics of Andean potato agriculture. Economic Botany, 35: 70–88.

Chantereau, J., Arnaud, M., Ollitrault, P., Nabayaogo, P. & J.L. Noyer, 1989. Etude de la diversité morphophysiologique et classification des sorghos cultivés. Agronomie Tropicale, 44: 223–232.

Clayton, W.D., 1961. Proposal to conserve the generic name Sorghum Moench (Gramineae) versus Sorghum Adans (Gramineae). Taxon 10: 242–243.

de Wet, J.M.J., 1978. Systematics and evolution of *Sorghum* sect. *bicolor* (Gramineae). American Journal of Botany 65: 477–484.

de Wet, J.M.J. & J.P. Huckabay, 1967. Origin of *Sorghum bicolor*. II. Distribution and Domestication. Evolution 21: 787–802.

Doggett, H., 1957. Tetraploid varieties of *Sorghum vulgare*, Nature. 179: 786.

Doggett, H., 1988. Sorghum. 2nd edition Longman, Burnt Mill, Harlow, Essex, England.

Exell, A.W., 1960. Systematic Association Committee For Descriptive Terminology. Taxon 9: 240–257.

Exell, A.W., 1962. Systematic Association Committee for Descriptive Terminology. Taxon 11: 145–156.

Frankel, O.H., 1974. Genetic Conservation: Our evolutionary responsibility. Genetics. 78: 53–65.

Harlan, J.R., 1969. Ethiopia: A center of diversity. Economic Botany 23: 309–314.

Harlan, J.R., 1975. Crops and Man. The American Society of Agronomy, Inc. and the Crop Science Society of America, Inc. Madison, Wisconsin.

Harlan, J.R & J.M.J. de Wet, 1972. A simplified classification of cultivated sorghum. Crop Science 12: 172–176.
Harlan, J.R., J.M.J. de Wet & A.B.L. Stemler, 1976. Origin of African plant domestication. Mouton, The Hague.
Hawkes, J.G., 1983. The diversity of crop plants. Harvard University Press, Cambridge, Massachusetts, London, England.
House, L.R., 1978. A guide to Sorghum breeding. International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, A.P., India.
House, L.R., 1995. Sorghum and Millets: History, Taxonomy, And Distribution. In: D.A.V. Dendy (Ed.), Sorghum and Millets: Chemistry and Technology. American Association of Cereal Chemists. St. Paul, Minn.
Hunn, E., 1982. The Utilitarian Factor in Folk Biological Classification. American Anthropologist 84: 830–847.
IBAS, 1990. (Interaktives Bild - Analysen System/Interactive Image Analysis System) User's Manual, Rel 2.0. 1990. Kontron Elektronik Gambh.
International Plant Genetic Resources Institute (IPGRI), 1993. Descriptors for *Sorghum [Sorghum bicolor (L.) Moench]*. IBPGR/ICRISAT. Rome, Italy.
Martin, G.J., 1995. Ethnobotany. Chapman and Hall, London, UK.
Morrison, D.F., 1967. Multivariate Statistical Methods. McGraw-Hill. NY.
Munsell Color Company, 1957. Nickerson Color Fan. Maximum Chromas-40 Hues. Munsell color Co., INC. Baltimore, Maryland.
Pimentel, R.A., 1979. Morphometrics. The Multivariate Analyses of Biological Data. Hunt, Dubuque. Iowa.
Rohlf, F.J., 1992. NTSYS-pc, Numerical Taxonomy and Multivariate Analysis System, Version 1.70. Users' Manual. Exeter Publishing, Setauket, NY.
SAS Institute, 1992. SAS/STAT Users' Guide. Volume 1, SAS Institute Inc. Cary, NC.
Sass, J.E., 1958. Botanical microtechnique. 3rd ed. Iowa State College Press. Ames, Iowa.
Sneath, P.H.A. & R.R. Sokal, 1973. Numerical Taxonomy: The Principles and Practice of Numerical Classification. W.H. Freeman. San Francisco.
Snowden, J.D., 1936. The cultivated races of sorghum. Adlard and Son, London.
Stace, C.A., 1989. Plant Taxonomy and Biosystematics. 2nd edition, Routledge, Chapman and Hall Inc, NY.
Stemler, A.B.L., J.R.Harlan & J.M.J. de Wet., 1977. The Sorghums of Ethiopia. Economic Botany 31: 446–460.
Vavilov, N.I., 1926. Studies on the origin of cultivated plants. State Press, Leningrad.
Vavilov, N.I., 1951. The origin, variation, immunity, and breeding of cultivated plants. In: Selected Writings of N.I. Vavilov. Chronica Botanica.

Appendix

Sorghum landrace classification according to stem juiciness and grain plumpness membership criteria.

Landrace accessions	Non-juicy landraces				Juicy landraces	
	Cluster 1		Cluster 2		Cluster 3	
	Dimple	Plump	Dimple	Plump	Dimple	Plump
Abaerie	2					
Adow				1		
Aehyo	5					
Aeyfere	1					
Afeso	4					
Amelsi						1
Bakelo	1					
Barchukie	2		1			
Basohe				1		
Betenie						1
Borie	3					
Buskie	2					
Cherekit				3		
Chomogo	1	1				
Delgome				3		
Dekussie						3
Dobie	3					
Ganseber	3			2		
Gedalit	5					
Gorade	4					
Goronjo	4					
Gubete	2		1			
Jamuye	2					
Jegretie	1					
Jemaw	3		2			
Jiru	5					
Jiru tk					2	
Jofa tk						3
Keyo tk						2
Kumie	1					
Keteto				2		
Kilo				4		
Mali tk						2
Megali tk						1
Meltae	3					
Merabete				3		
Mogayefere	1					
Mognayakish						4
Mokakie	4					
Motie					4	
Necho tk					2	2
Nchero				4		
Rayo	1					
Senklie	1					
Serergie						2
Tenglaye	4					
Tuba	2					
Tuba tk					1	
W/aeyblash	3			1		
Wanesie			3			
Watigela	3					
Wogere	5					
Wogere tk					1	
Wuncho	3	1				
Yegenfoehel				1		
Yekermendaye	3			1		
Yekersolatie	2			1		
Zengada	16	1				
Zengada tk						2
Zeterie			1	1		

tk="Tinkish"=Sweet stalk