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Full Length Research Paper

Participatory variety selection and characterization of Sorghum (*Sorghum bicolor* (L.) Moench) elite accessions from Malawian gene pool using farmer and breeder knowledge

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Participatory approaches for variety selection, breeding, *ex-situ* and *in-situ* conservation of neglected crops in Malawi was initiated in 1998. The specific objective of the present study was to select diverse and productive sorghum lines adapted to local conditions and accepted by farmers and consumers at large using farmers' knowledge and breeders' scientific approach. Participatory rural appraisals (PRAs) were conducted on the major characteristics of sorghum landraces. This was done in village meetings by focused group discussions (FGDs), matrix ranking, and individual interviews. Participatory variety selection was applied to select diversified sorghum lines that possess farmer-preferred plant and grain traits. During the first season, male and female farmers were invited to research stations to select 20 accessions from a pool of 101 landraces. These 20 accessions were evaluated by farmers on community plots managed by them at several sites in different agroecological areas for two years. Selection was based primarily on agronomic traits such as time to maturity, height, drought tolerance, insect resistance, and grain yield. Protein content and genetic differences assessed by the breeders were also used as selection tools. Overall, the results of the present study showed that farmers' characterization of several accessions combined with statistical, nutritional, and genetic analyses performed by the breeders has allowed selection of sorghum landraces that have out-performed breeder-developed lines on more than one criterion. These lines have been adopted by the farmers and are still being grown in many communities five years avec local release.

Key words: Participatory variety selection, *Sorghum bicolor*, Malawi, agrobiodiversity.

INTRODUCTION

Situated in Southern Africa, Malawi is a landlocked, densely populated country, in the Southern part of the Great East African Rift Valley. Malawi produces a wide range of crops. Sorghum and millets, the staple foods prior to the introduction of maize in Malawi, are still widely produced by many local farmers. Plant breeding and agricultural promotion programs continue to be patterned after those in western industrialized countries, emphasizing the use of modern innovations that practice the development of high yielding varieties that perform well in environments that are stabilized through the use of irrigation, fertilizers, pesticides and other inputs. Single genotypes have been widely promoted, to be grown in pure stands regardless of the system in which the crop is

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currently being grown or the availability of risk reducing inputs. This strategy has not produced the desired results of sustainable and increased crop yields. It has also failed to make use of the significant agricultural biodiversity available in Malawi and its potential to address food security concerns and issues in the country.

Plant breeding strategies that make use of and maintain crop diversity have been formulated in recent years. They are premised on the observation that the agronomic and socio-economic requirements of small-holder farmers and consumers in marginal or stressed environments are too diverse to be filled by a limited number of genotypes. Farmer-developed local varieties are an important resource and logical starting point for plant breeding programs that seek to strengthen these diverse systems. Close cooperation between scientists and farmers in evaluating plant material and in establishing plant-breeding goals is also a key feature of these strategies, known as the method of participatory research. Farmer participation in the breeding of crop varieties for low-resource farmers is regarded by some as necessary to help ensure acceptance and eventual adoption (Franzel et al., 1995; Gyawali et al., 2007; Maurya et al., 1988; Mekbib, 2006; Prain et al., 1992; and Sperling et al., 1993). Despite its importance as a staple food, little research has been carried on sorghum in Malawi compared to maize and cassava.

A small farmer deals with a variable environment and has multiple production objectives that will affect his or her choice of crops and selection of genotypes. Next to yield, which in formal breeding programmes is by far the most important objective, yield stability, adaptation to production techniques and conditions, and various consumption purposes are selected for. This range of objectives often results in the use of a large number of varieties by individual farmers and the use of genetically heterogeneous varieties. Farmers need adaptation to the local and variable water and soil conditions in combination with a variety of characteristics related to labour and food availability, intercropping, and weed competition (Almekinders et al., 1994; Haugerud and Collinson, 1990; Sperling et al., 1993). Consumption objectives include culinary and cultural preferences regarding taste, color, consistence, size, cooking time, processing quality and suitability for preparation of traditional dishes or drinks. Consumption criteria also include secondary uses, such as leaves of sweet potato, cowpea, and cassava as vegetables or animal feed, and sorghum straw for roofing (Almekinders et al., 1994, Ashby, 1989; and Hernandez, 1985).

This paper describes how plant breeders and farmers worked together to test a range of sorghum accessions in a participatory varietal selection (PVS) program. Because it relies on already existing varieties, the impacts of a PVS can be rapidly obtained. Involving farmers in the breeding process in participatory plant breeding (PPB) takes longer as several years elapse before varieties can be obtained from the variable breeding materials that are created. Farmers' requirements have to be identified first so that they can be given more appropriate genetic materials to test. This can be done by using several methods, either separately or in combination. The methods include participatory rural appraisal (PRA), the examination of farmers' crops around harvest time, and the pre-selection, by farmers, of varieties from trials of many entries, grown either on a research station or on farm. In areas where there is a diversity of landraces in farmers' fields, and where resources allow, the local germplasm can be collected and grown in a trial, on station or on farm, with recommended cultivars as a control. This provides information that a PRA cannot reveal because: the best–performing landraces can be identified; the performance of recommended cultivars can be compared to local germplasm; the extent of diversity can be evaluated in the trial; and, the degree of agreement between the names given to landraces by farmers and their phenotypes can be determined (Witcombe et al., 1996)

The specific objective of the present project was to select diverse and productive sorghum lines adapted to local conditions and accepted by farmers and consumers' at large using farmers' indigenous knowledge and breeders' scientific approach.

MATERIALS AND METHODS

Participatory rural appraisal

Sorghum is grown by many farmers from several villages in the Central and Northern regions of Malawi. These villages are grouped in administrative Agricultural Development Districts (ADD) in Salima, Machinga, and Karonga for lowlands and Shire Valley ADD for highland regions. Maize is the most important crop in all the ADDs, however farmers grow sorghum, pearl millet, finger millet, cowpea, groundnuts, beans, sweet potatoes, cassava, and several other cash crops such as cotton, bananas, rice, sugarcane, yam, and cabbage as part of the food security continuum. Participatory rural appraisals (PRAs) were conducted on the major characteristics of sorghum landraces. This was done in village meetings by focused group discussions (FGDs). A number of other PRA techniques were employed such as 'matrix ranking" where local landraces were assessed by ranking them for multiple traits. Individual interviews were also conducted. Project officers (POs) and development officers (DOs) along with their field assistants assisted in identifying farmers who participated in the focus groups discussions. For each ADD two FGDs were held - one for women and one for men. This was done to facilitate an open discussion and uninhibited speech for women. In total 44 farmers (22 per ADD) participated with equal representation of men and women. All the socio-economic classes perceived by the community were represented adequately.

Participatory variety selection

PVS was applied in the present study to select diversified sorghum lines that possess farmer's preferred plant and grain traits. In the 1998/1999 season, forty men and women were invited to each of Chitala and Kasinthula research stations to evaluate 101 local col-

collections and traditional landraces of sorghum. The participant farmers were selected based on their indigenous knowledge. A purposive sampling was undertaken to target specific people in the villages (both men and women) who were believed to possess more indigenous knowledge about sorghum, and also to ensure gender and age representation for men and women. These criteria were met with the help of field extension workers and the village chiefs who were more familiar with farmers in the study sites.

The sorghum accessions were provided by the Chitedze genetic resource unit (National Gene Bank) and some materials were obtained from local farmers. Each material was planted on four row plots of 10 m length at the two research stations. Research staff managed the plots. The best twenty landraces were selected based on farmers' criteria from germination to harvest. This trial at the research station was managed by the breeder.

In the 1999/2000 season, these best 20 lines were planted in community plots (on-farm trial) at Chitala East, Kalamba West and Kalamba Central in Salima Agricultural Development Division (ADD) and at Mlomba, Mbande and Mwasiya in the Shire Valley ADD (Figure 1). The planting was done in a randomized block design with three replicates under breeder supervision. In total 90 men and women were grouped to assess the 20 selected lines. Pilira and Kawala, the commercially released varieties developed through conventional breeding by scientists were included as controls. Rather than being provided with a package of improved technologies, as usually happens under conventional on-farm testing, each group of farmers was advised to conduct the trial in community plots using existing management practices. The objective was to enable the farmers to select those genotypes with better performance *per se* rather than genotypes which perform better in a higher-input management environment that they may be unable to sustain once external support is withdrawn. Farmers carried out all cultural operations including planting, thinning, weeding, fertilizer applications, harvesting and grain processing. The selection was based on plant growth, stem thickness, resistance to lodging, drought resistance, and insect resistance, time to maturity, grain size, and grain color. For each evaluation, farmers in the village assembled and visited all the plots together. All the data except for yield were recorded on a 1 to 5 scale (1 being the lowest score and 5 the highest). Informal interviews were used immediately after the field review to elicit farmers' preliminary evaluation of the varieties tested. Following harvesting, threshing, milling, and cooking, further interviews allowed farmers to make any necessary reassessment of their initial evaluation. Yields were measured by separate weighing of grain produced from the entire trial plot.

Nutritional analysis

Protein content and digestibility of each of the 20 elite accessions measured by the breeders were also used as a selection tool. This nutritional analysis was performed at Purdue University (Indiana, USA) through collaboration with the sorghum breeding program. Seeds were homogenized in a micro mill and extracts for protein analyses were obtained in three sets of assays. The analysis of protein content was carried by means of the bicinchonic acid method (Shih 1991). Protein digestibility was assessed by *in vitro* pepsin digestibility method (Hamaker et al., 1987).

Genetic analysis

To determine any redundancy and to identify closely related accessions, RAPD analysis was performed using the procedure described by Nkongolo et al. (2003). This genetic study was carried out in the Biotechnology research laboratory at Laurentian University, (Ontario, Canada). The total cellular DNA from 1 g of bulk samples was extracted from whole seeds and excised embryos using the method described by Nkongolo et al. (2003). The concentration of each bulk sample was determined using the DNA quantitation kit from Bio-Rad and the purity was determined using a spectrophotometer (Varian Cary 100 UV-VIS spectrophotometer).

Ten RAPD primers described by Nkongolo et al. (2003) were chosen for amplification of DNA samples. They include OPA 2, OPA 4, OPA 8, OPA 16, OPB 01, OPB 08, E-1, E-4, E 11, and E 10. Each PCR reaction was performed in a 25 µl volume containing 5 ng of genomic plant DNA, 10 mM Tris-HCl, pH 8.3 [at 25°C]; 50 mM KCl; Applied Biosystems, Foster City, CA), 3.5 mM $MgCl_2$, 200 µM of each dNTP (Applied Biosystems, Foster City, CA), 0.5 µM primer and 0.625 U of *Taq* DNA polymerase (Applied Biosystems, Foster City, Calif.). For each primer, a negative control reaction with double distilled water was included. A drop of mineral oil was added to each reaction and the samples were amplified on a DNA thermal cycler (Perkin Elmer, Foster City, CA). The cycles performed were as follows: an initial denaturation at 95°C for 5 min followed by a 2 min incubation at 85°C at which point the polymerase was added; 42 cycles of 90 s at 95°C, 2 min at 55°C and 60 s at 72°C were performed; a final extension at 72°C for 7 min and a subsequent incubation at 4°C followed. PCR products were loaded onto 1% agarose gels (invitrogen) in 0.5 X Tris-borate-EDTA (TBE) buffer containing ethidium bromide and run at 2.8 V/cm for 90 min. The agarose gels were documented using the Bio-Rad ChemiDoc XRS system and analyzed with the Discovery Series Quantity One 1 D Analysis Software.

Only the RAPD primers which gave consistent profiles across the populations were considered for the analysis. The presence and absence of bands were scored as 1 or 0 respectively. Faint bands were not recorded for analysis. The data were analyzed using the RAPDistance Program version 1.04 (Armstrong et al., 1995). Jaccard's similarity coefficients were generated to determine the genetic distances among populations. Dendrograms were constructed using the neighbour-joining analysis (Saitou and Nei 1987).

Quality test

Seven lines selected based on agronomic data by the farmers and with protein content at least equal to the currently released Pilira I variety were planted again in a second trial managed by farmers at eight locations. The lines were assessed again based on the agronomic traits. In addition, farmers considered polished grain quality, flour quality, and food palatability taste to compare these lines using the 1 to 5 scales.

RESULTS

Indigenous knowledge and gender analysis

Farmers grow various varieties for different traits. The sorghum varieties that are grown in the area include Pilira 1, Kawala (tall, white grain), Kasonthe (short, white large grain), Kalombo (short but taller than Kasonthe, reddish grain), Shabalala (early maturing, white grain), Phatamfuli (tall, red grain), and Misale (sweet stem, red grain). Pilira 1 is grown for early maturity, drought tolerance and white grain. Kawala is not well received because it matures late and is therefore prone to bird attacks. Among the varieties now being grown, Pilira 1 is most preferred by farmers for early maturity, drought tolerance, and white grain, and also has a high grain yield. This variety was develop

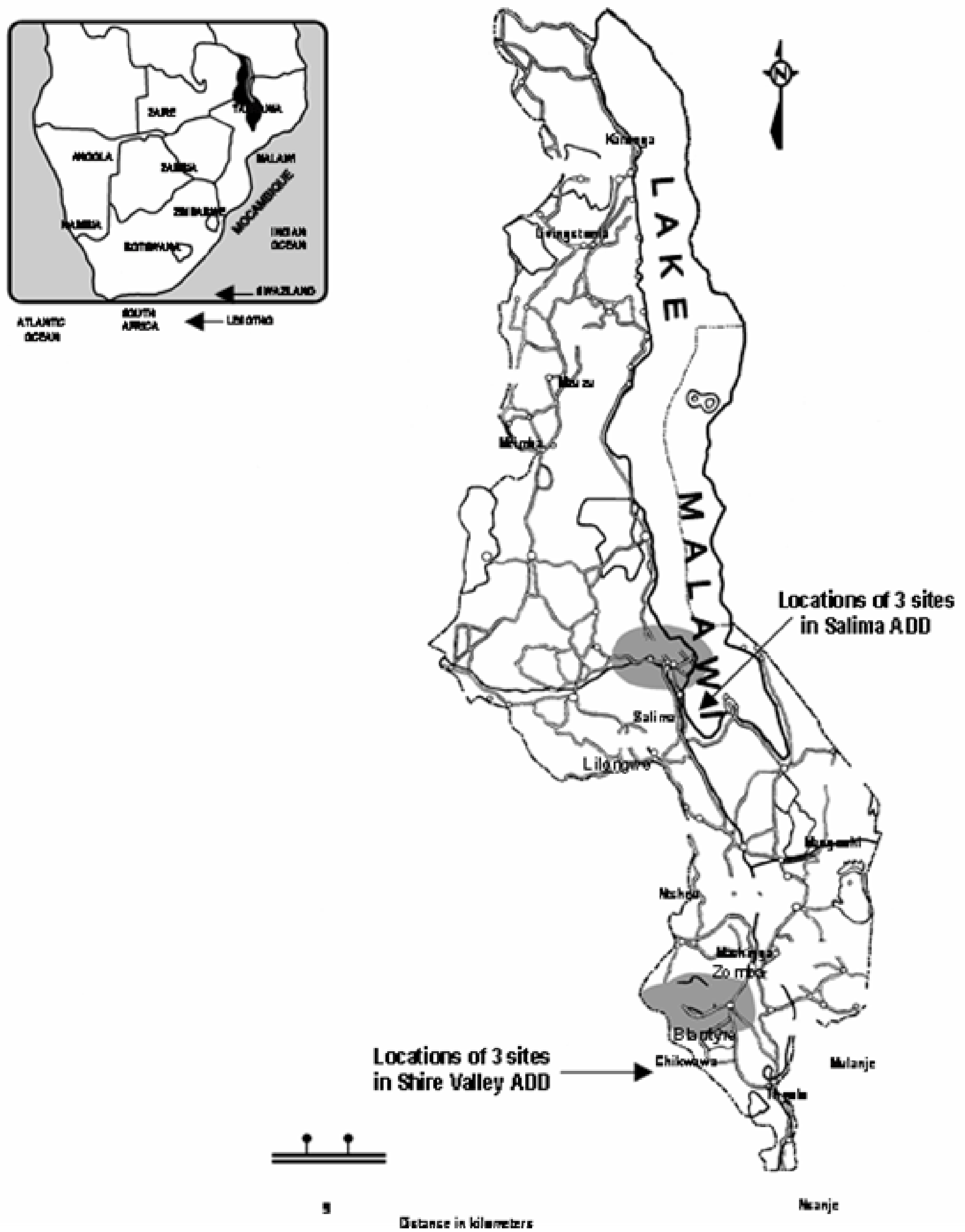

Figure 1. Malawi map showing different sampling sites.

ed through conventional breeding and is being distributed by the Ministry of agriculture. Kalombo, Shabalala, and Kasonthe are preferred because of early maturity. Kawala, one of the currently commercialized varieties is not much liked (see above). Gonkho variety that is a high yielding variety has since been lost because of the unreliable rainfall. The Kawala is another long season variety that may be lost soon for the same reason. Pure varieties are grown separately for ease of selection and harvesting, and to preserve seed purity. The early maturing and late maturing varieties would pose problems during harvesting if mixed in the same field. Farmers indicated a number of desirable traits that should be considered for any breeding activity. These include the taste, seed colour, and time to maturity, cooking time, and seed size. Surprisingly, unlike with other crops such as cowpea, beans, corn and cassava, yield was not among the key factors for selection. But still farmers need good yielding varieties for food security provided that they have the other traits.

The sources of seed for planting include buying from neighbors, storing own seed, barter with neighbors and working for others in exchange for seed. Sorghum is planted in November/ December at the onset of the rains. The crop is grown once a year because of bird attacks. Some farmer's plant seeds at 35 cm apart while others do not have specific plant spacing. Normally six seeds are planted in one small hole and thinned to three plants later. Head smut (locally known as "kontho") was the only disease that farmers identified. But a whole range of pests that attack sorghum in the field was mentioned as the common problem. These include birds; stem borer "mphutsi or mphanzi", cutworm "mhutsi", grubs, aphids and weevils, green grasshoppers "mphombo" and termites.

Seeds are harvested first and then the rest of the plant. Seeds are selected in the field from well-matured, good-looking ears that are free from disease. The unthreshed ears are tied together, kept in a covered pot and pre-served from weevil attack by applying ash. Some farmers keep the tied ears together in the kitchen so that the soot preserves the seed from pest attack and also to maintain the seed viability. These seeds can also be dusted with actellic or Sevin for long-term storage. Threshed seed are stored in bags for selling in local markets.

Sorghum processing and use

Sorghum is grown for number of uses. The main use is for food (nsima) and brewing beer. Fresh grain can be eaten as a snack or for making porridge ("chingowe" or "chibwata"). The stems are chewed especially the sweet stem varieties. The main food dish in Malawi "Nsima" is made from corn or sorghum flour. Threshed sorghum grains are winnowed, pounded and milled into flour. To prepare the beer ("mpunthiko"), the sorghum is threshed, winnowed and the grain is soaked for a day to germinate. Fresh grain is processed for snacks by putting the ears in the sun for a time and threshing the grains out. These grains are then winnowed and are ready for chewing. Sorghum stems can also be chewed especially the sweet stem varieties.

Gender issues

Both men and women are involved in the production of sorghum. There is no difference in the preference of characteristics of sorghum varieties between men and men. The only activities that are exclusively for women are threshing and winnowing, while making of hoe handles and construction of storage sheds are activities solely for men.

Participatory variety selection

The evaluations of 101 accessions at the research stations were carried out by 40 men and women farmers at Chitala (Salima) and Kasinthula (Shire Valley) stations. There were significant differences among the entries based on selection criteria used. These included drought resistance and insect resistance, plant height, time to maturity, yield, and time to maturity. The farmer ranking was compiled by the breeder and the best 20 accessions were distributed to farmers for on farm evaluation.

Farmer scores of the 20 accessions are summarized in Table 1. Grain yield were much higher in Salima ADD than in Shire Valley ADD with yield average of 2,465 and 1, 428 kg per ha, respectively. Overall, seven accessions including Acc 1052, Acc 952, Acc 953, Acc 1002, Acc 756, Acc 965, and Acc 953 were selected at all the sites in both ADD in two growing seasons based on agronomic performance and grain quality test results. These lines performed better or were equal to the currently released variety Pilira (Tables 1, 2a, and 2b). In addition, protein content varied between 6.9 and 13.5% (Table 3). The digestibility of this protein varies from 68.4 to 82.6% resulting in digestible protein content of 5.7 to 9.7%. An ANOVA analysis of both protein content and digestible protein content indicated a significant difference among accessions. More importantly, all the 20 accessions had significantly higher content of protein than currently released Pilira variety (Table 3). All the seven accessions selected by farmers based on agronomic data and taste results have protein content higher than 10% and digestible protein content above 7%.

Based on combined results and rankings at all locations (Tables 2a and 2b), five accessions including Acc 1052, Acc 952, Acc. 953, Acc. 1002, Acc. 967 were retained. Non-participants farmers were engaged to validate the results and also tested the accessions during open field days.

In Shire Valley, Acc. 1052, 952 were selected because of the ease to make polished grain, the excellent taste of their thick porridge with or without relish. Acc. 1002 was selected because apart from having the above qualities, the white color of its polished grain and flour, the pleasant taste, and smell of its thick porridge.

In Machinga, Salima and Karonga, three varieties also were selected. Variety Acc. 967, Pilira 1, and Acc 953 were selected because of their hard grain and ease to make polished grain. Farmers liked their fine textured white flour quality and the taste of their thick porridge, which, they said, was pleasant to smell with or without relish. These five accessions were released in 2002 in the sorghum growing areas of the ADDs.

Genetic analyses

A genetic analysis of 20 elite lines was conducted using RAPD markers. This analysis revealed that the level of polymorphism among accessions was 53%. The analysis of molecular variance revealed that among accessions (within regions) variations accounted for 96.4% of the total molecular variance. These data were consistent with pre-

Table 1. Performance and farmer ratings (scale 1 to 5)* based on agronomic traits (maturity, height, drought tolerance, insect tolerance, and grain yield) of 20 selected sorghum landraces and Pilira variety in Salima and Shire Valley Administrative districts (ADD) in 1999/2000. `

Accessions No		Scores (1 to 5 scale)								Grain yield	
		Maturity		Height		Drought tolerance		Field insect resistance		Kg/ha	
		Shire Valley	Salima	Shire Valley	Salima	Shire Valley	Salima	Shire Valley	Salima	Shire Valley	Salima
Acc-	409	4	4	5	4	5	5	5	5	2375	2648
Acc-	620	1	2	1	3	3	5	4	5	456	1379
Acc-	1052	5	5	4	4	5	5	5	5	2358	3485
Acc-	999	5	5	4	4	5	5	5	5	2129	3485
Acc-	901	1	2	5	5	3	5	4	5	717	1725
Acc-	952	5	5	5	4	5	5	5	5	1797	2805
Acc-	953	5	5	5	4	5	5	5	5	2118	3045
Acc-	910	1	4	4	4	3	5	3	5	876	1992
Acc-	985	4	5	3	3	5	5	5	5	1007	3405
Acc-	980	5	5	5	4	5	5	5	5	1413	2272
Acc-	967	4	5	4	5	5	5	5	5	1882	3461
Acc-	881	1	2	2	2	3	5	5	5	219	1088
Acc-	1024	5	5	5	4	5	5	5	5	1312	736
Acc-	1002	5	5	5	4	5	5	5	5	2146	3651
Acc-	902	1	4	4	4	2	5	5	5	198	2168
Acc-	897	4	4	4	5	5	5	5	5	1691	2403
Acc-	854	1	4	3	3	4	5	5	5	234	2643
Acc-	965	5	5	5	5	5	5	5	5	1437	2122
Acc-	756	4	5	4	5	5	5	3	5	2055	3175
Kawara		2	4	4	4	2	5	2	5	1441	2187
Pilira		3	4	4	4	4	5	4	5	2055	2496
LSD0.05										557	740

5 is the highest score and score 1 the lowest.

Table 2a. Farmer evaluation of seven elite lines based on quality traits in the Shire Valley Agricultural district (highland) in 1999/2000 season.

Accessions	Polished grain	Flour quality	Food palatability		Across traits means	Rank
	Quality		with side dish	without side dish		
ACC-1052	4. 5	3.5	5.0	5.0	4.5	1
ACC-952	5.0	5.0	3.5	3.0	4.1	3
ACC-953	4.5	4.0	3.5	4.0	4.0	4
ACC-1002	5.0	2.0	4.0	5.0	4.3	2
ACC-965	1.5	3.0	1.0	1.5	1.4	8
ACC-967	3.0	1.5	4.5	3.0	3.3	6
ACC-756	1.0	2.5	4.5	4.5	3.0	7
Pilira-1	4.5	4.0	3.5	3.5	3.9	5

Table 2b. Farmer evaluation of seven elite lines based on quality traits in the Salima, Machinga, and Karonga Agricultural districts (lowlands) in 1999/2000 season.

Accessions	Polished grain	Flour quality	Food palatability		Across traits means	Rank
	Quality		with side dish	without side dish		
ACC-1052	3.8	3.3	3.8	3.3	3.6	4
ACC-952	3.3	4.0	3.2	3.5	3.5	5
ACC-953	4.3	3.7	4.2	4.3	4.1	3
ACC-1002	3.8	3.0	3.7	2.7	3.3	6
ACC-965	1.8	2.2	2.3	1.7	1.9	8
ACC-967	4.5	4.0	4.2	4.7	4.3	1
ACC-756	2.3	1.8	3.0	2.7	2.4	7
Pilira-1	4.5	4.2	4.5	4.0	4.3	1

previous results (Nkongolo and Nsapato 2003). In general all the 20 accessions analyzed were unique and have distinctive banding patterns.

However the accession 1052 was genetically close to the released variety Kawala. But the agronomic data showed that the grain yield for the acc 1052 was much higher than that of Kawala variety at all the six sites in the two ADDs. This indicates that the acc 1052 and Kawala are likely two different lines.

The five lines that were selected based on agronomic, culinary, and nutritional data were genetically diverse and all belong to different clusters or sub-branch on the dendrogram (Figure 2).

These elite accessions along with the released variety Pilira 1 were recommended to farmers for food production in the two ecological areas.

They are all still being grown by farmers in several communities five years after their local release. These lines are also conserved both *ex situ* at the National gene bank and *in situ* by the farmers.

DISCUSSION

Documentation of indigenous knowledge and gender issues on sorghum

The majority of the people in the rural areas derive their livelihood from agriculture. The average farm size was small throughout the study area. Land tenure is customary meaning that the right to cultivate is granted by the village chief and inheritance is matrilineal.

The documentation of indigenous knowledge of sorghum was done as part of participatory variety selection and breeding and *in situ* and *ex situ* conservation of sorghum landraces. The main goal was to document available indigenous knowledge with a view to using such knowledge to complement participatory selection and conservation of sorghum landraces *in situ* and *ex situ*. The accessions selected with such farmer participation would be more acceptable for adoption and use by the farmers and communities at a large.

To get a grasp of indigenous knowledge (IK), scientists

Table 3. Protein content and In vitro digestibility of 21 sorghum lines.

Accessions	Protein (%)	Digestibility (%)	Digestible protein (%)	Ranking
409	10.8±0.02	72.2±0.93	7.8	13
620	11.8±0.08	68.4±0.81	8.1	11
756	10.7±0.06	72.0±0.56	7.7	14
854	10.9±0.09	69.8±1.10	7.6	16
881	12.2±0.01	76.3±0.74	9.3	04
897	12.8±0.02	72.7±1.10	9.3	03
901	9.9±0.05	73.1±0.66	7.2	19
902	10.2±0.15	74.8±0.55	7.6	15
910	12.4±0.28	70.3±0.93	8.7	08
952	10.6±0.11	76.9±1.02	8.2	10
953	12.8±0.04	73.1±0.48	9.4	02
965	10.3±0.05	78.5±0.59	8.0	12
967	11.0±0.04	75.7±0.25	8.3	09
980	12.4±0.15	70.7±1.24	8.8	07
985	13.2±0.00	73.7±0.53	9.7	01
999	11.8±0.06	74.6±0.82	8.8	06
1002	13.5±0.09	68.6±1.12	9.3	05
1024	9.3±0.15	76.1±0.52	7.1	20
1052	10.1±0.01	73.6±0.27	7.4	18
Pilira	6.9±0.22	82.3±0.51	5.7	21
Kawala	10.1±0.02	74.9±0.87	7.5	17
LSD 0.05	0.56	3.8	0.41	-

need to look at issues and aspects of varietal selection and breeding from the point of view of the local people.

The general approach adopted was participatory where men and women played a key role in the IK documenttation process. There were two elements to the adopted approach. The first element was community participation. Local community capacity building through mobilization and participation was a key guiding principle for the IK documentation exercise. The participatory approach was therefore aimed at bringing communities into the loop of documenting their knowledge. The second element was the context. Participatory research maintains that the context of the community is important. The context can be explored from a quantitative and qualitative approach. The quantitative approach included understanding aspects of socio-economic, demographic, geographical and political data. Collecting these data helped place the study area within a regional and national perspective. The qualitative approach on the other hand included understanding social phenomena from the participants' own perspective.

It was observed that the gender division of labor is not only related to the work done by men and women but also recognizing that men and women do different work and hence possess different types of indigenous knowledge. Women have more knowledge of cooking, food processing, preservation and storage. On the other hand, men seemed more knowledgeable about land preparation techniques, cutting the ridges/beds and pest control. Some types of knowledge were found to be complementary meaning that both men's and women's knowledge is needed to understand particular dimensions of agricultural productions. Examples of these include selection of sites, characterization of soils and land preparation techniques, amongst others.

The farmer selection of sorghum landraces and varieties was done through ranking and scoring male and female farmers separately. Although the scores between males and female farmers were very close, the slight difference was an indication that male and female farmers have particular preferences for certain traits. Men and women have different preferences because they are related to the food chain in different ways, and often at different times and places. Men and women play different

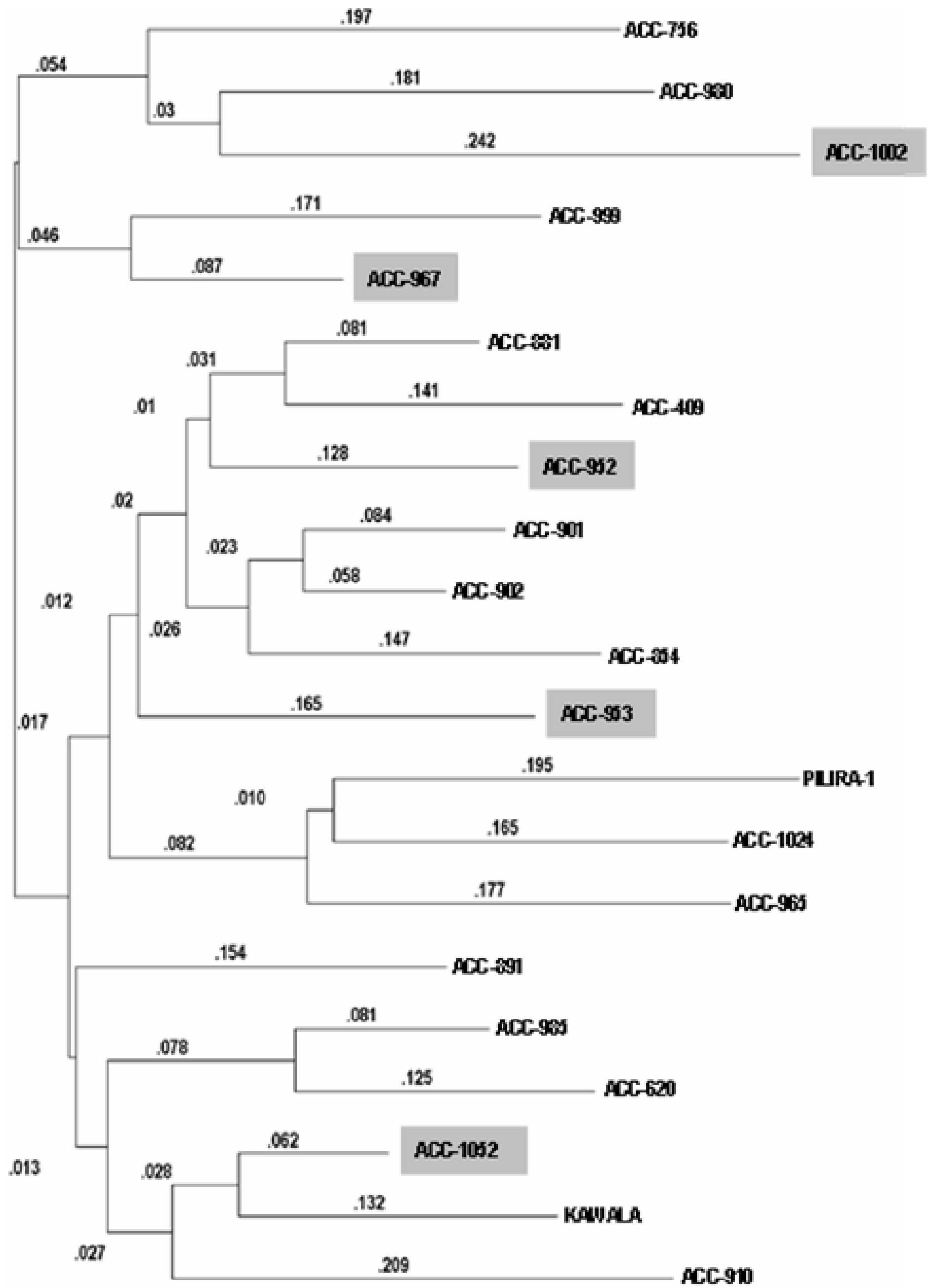

Figure 2. Dendrogram of the genetic relationships among 21 elite *Sorghum* accessions based on the Jaccard similarity matrix. The numbers above a branch indicate patristic distances as inferred by neighbour-joining (NJ) analysis. The genetically diverse accessions selected by farmers and breeders for release is highlighted (Acc-1052, Acc – 953, Acc - 952, Acc- 967, and Acc- 1002).

roles and responsibilities within the household, in farming, and in society, yet the operational implications are often obscured, not least by gender bias, however unwitting, on the part of plant breeders (Franworth and Jiggins 2003). The analysis of differentiated gender roles and responsibilities along the food chain and in gene flow management, can help plant breeders to avoid bias and accommodate diversity, and thereby make their work more relevant and effective. For example, during this study, it was obvious that women put more emphasis than men on poundability and cooking time (reflecting women's role as grain processors and cooks). Both men and women considered early maturity, plant height, grain colour and size, along with resistance to insects and birds, as key selection criteria. In a farmer–participatory breedng project on pearl millet in India, women's main consideration in selection were grain yield, early availability (related to their role as food managers), and the ease of hand-harvesting, lower panicle number and lower plant height (related to their role as harvesters). For the men, yield and quality were of greater concern (Welzien et al., 1996).

There is an abundance of knowledge that farmers have and when integrated in breeding scheme, it will increase the adoption rate of new varieties. This indigenous knowledge will enrich the scientific knowledge that breeders and curator have in the selection, crossing, multiplication, and conservation of sorghum landraces

Participatory variety selection

The visits of farmers to the research stations proved to be useful, practical, and cost effective method for obtaining farmer input for the preliminary screening of the 101 sorghum accessions and for permitting farmers to decide which accessions they want to test in on-farm trials. Researchers learned which accessions farmers preferred and which they dislike and the reasons for these opinions. The in-depth analysis of farmers' preferences for the accessions grown on their own community farms confirms the findings from the station visits and defined clearly their selection criteria. The use of PRA and focus group interviews prior to variety selection was very useful in the planning of field-testing activities. There was a high degree of concurrence between the results of focus groups and the information gathered during PVS.

The 20 accessions that were selected by farmers at two experimental stations in 1998-1999 were evaluated in community plots at six sites in 1999 –2000 and at eight sites in 2000 – 20001 in both agroecological regions (high and low lands). In 1999 - 2000 growing season, four accessions Acc 1052, Acc 952, Acc 953, and Acc 1002 were selected at all sites in both ecological regions. Acc 967 was selected at all the sites in low land region (Salima ADD) and at one site in high land region (Shire Valley ADD) while acc 965 was selected at all the sites in the high land area and at one site in the low land region. These top six accessions along with Pilira 1 variety and Kawala were subjected to several quality tests by farmers and during open days. After these rounds of assessment, acc. 965 received the worst score in both ADDs for quality traits and was then discarded from the final list for release even though it received a perfect score for maturity, height, drought tolerance, field insect resistance, and despite also its average grain yield. This accession was kept as a promising alternative in years to come. Likewise the accession 756 was not released based on its poor performance in quality tests despite a good rating for maturity, height, drought tolerance, insect resistance, and grain yield.

The genetic data revealed no presence of redundant accessions in the pool that was selected. This indicates than even though farmers share or exchange seeds, they are able to maintain individual genotypes through selection. The data also provide information on how well the sorghum collection has been managed by the Malawi National Gene Bank.

The evidence strongly indicates that the introduction of a participatory approach to agricultural research has allowed sorghum landraces that have out-performed breeder developed lines on more than one criterion to be selected. The underlying rationale and empirical evidence presented here argue strongly for a wider implementation of this approach in other crops. A similar selection scheme that was applied to cowpea was equally successful (Nkongolo et al., 2001). By comparison with many other participatory methods (Farrington and Martin, 1987) the approach also represents a cost-effective use of scientists' time: the role is that of building up a portfolio of varietal material broadly compatible with what farmers are known to prefer and then allowing farmers to make the selection under their own conditions. Farmers will likely adopt accessions identified through such a decentralized and participative approach for many years. Decentralized breeding, zonal trials and farmer participation would better define cultivar domains.

A most important variable is the range of diversity that farmers can be offered. The range of choices is likely to be larger when there are decentralized breeding programmes with coordinated multilocational trials designed to produce cultivars with wide adaptation. The more variability there is for quality traits, and the better the adaptation of the cultivars to the local environments, the more likely that several accessions will be adopted (Witcombe et al., 1996). In the present case, five accessions have been adopted. When farmers in an area are exposed to new cultivars in a PVS programme, the outcome may be an increase or a reduction in biodiver-sity in that area. Changes in biodiversity depend on the existing variability in farmers' fields, the genetic dissimilarities among the new cultivars offered to farmers, and the number they adopt (Witcome et al., 1996).

The present study showed that farmers' characterization of several accessions combined with statistical, nutritional, and genetic analyses performed by the breeders were useful in selecting the best elite accessions that have been adopted by the farmers at large. This multidisciplinary approach ensured the selection of accessions with acceptable digestible protein without redundancy of the materials released.

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