CHAPTER 5

CHARACTERISATION AND EVALUATION OF TEN SWEET SORGHUM LANDRACES

5.1 ABSTRACT

Ten Botswana sweet sorghum landraces were grown at the experimental farm of the University of Pretoria for characterisation of morphological and agronomic characters. The objective was to characterise and describe differences observed in the ten landraces and thus establish the potential of local germplasm as source of material for future crop improvement. The results revealed the presence of late and early maturing types. Late maturing landraces had taller and thicker main stems with more internodes compared to the early maturing landraces. Consequently, the late maturing landraces had higher stem fresh mass, stem dry mass and leaf dry mass. There was a wide variation in the tillering ability of landraces. At harvesting the least tillering landrace produced 2.3 tillers per plant and the most tillering landrace produced 5.3 tillers per plant. Landraces differed in proness to lodging with the most sensitive landrace showing 100% lodging and the least prone showing 5% lodging. Great variation was demonstrated in head exsertion, inflorescences, shape and compactness, length of panicle, glume colour, grain size, grain colour and grain numbers per panicle. Glume cover of the grain varied between 25% and 75%. Heads with high grain cover percentages had a tendency of low shattering. However, there were no differences in grain plumpness and grain form among the landraces. All landraces were awnless except for landraces 2 and 5 which were awned. Landraces differed in juice characteristics except in purity. Early maturing landraces had low stalk fibre percentages and low sucrose and brix percentages as

compared to the late maturing landraces. Landraces 9 and 10 were superior in juice purity and sucrose content and they were the most preferred landraces by an informal testing panel. From these results it was evident that there is a range of genetic diversity in Botswana sweet sorghum landraces which can be used in future for crop improvement.

5.2 INTRODUCTION

Sweet sorghum is rated a minor crop in Botswana and little or no documented information is available. No local research has been undertaken to improve sweet sorghum production nor to develop new varieties. As a result local farmers use traditional landraces selected over generations. In most cases these landraces differ from one district to another and major differences were found in the stems, inflorescences, maturity period, seed size and seed colour characteristics.

Collection and characterisation of germplasm are important first steps in building a gene pool for an under researched crop, to enable scientists to evaluate and improve the crop. Collection and evaluation of sweet sorghum cultivars have been carried out elsewhere. In the USA Coleman & Stokes (1958) Johnson *et al*, (1961) and Cowley & Smith (1972) evaluated sweet sorghum varieties for their potential use in the manufacture of crystallized sugar and fermentable carbohydrates, disease resistance and juice quality potential. In Australia, Ferraris (1981a; 1981b; 1988; Ferraris & Charles-Edwards,1986a; 1986b & conducted studies comparing the response of sweet sorghum varieties to environment, in terms of photosynthetic efficiency, yield and fermentable carbohydrate content. In India, Maheshwari, Prasad, Singh & Sharma (1974) and Shih, Gascho & Rahi (1981) investigated factors influencing biomass, fermentable sugars and disease resistance. Inman-Bamber (1980) evaluated sweet sorghum varieties for potential as a sugar producing crop in the Republic of South Africa .

Large collections of grain sorghum germplasm are available in Botswana in the Department of Agricultural Research of the Ministry of Agriculture, which has a Plant Genetic Resources Unit. The Department of Agricultural Research liaises with SADCC/ICRISAT Sorghum and Pearl Millet Improvement Program in all matters relating to germplasm collection. A lot of work has been done on the characterisation and evaluation of grain sorghum accessions, but very little or none has been done on sweet sorghum in Botswana. About 146 grain sorghum germplasm accessions collected from various parts of Botswana were characterized for agronomic characteristics including days to flowering, plant height, head types and grain colour (Anoymous, 1987). Sweet sorghum landraces were collected during the 1996/97 growing season for characterisation and evaluation in this study. The collection area represented the principal sweet sorghum growing areas of Botswana, as shown in Fig 3.1. The objective of this study was to characterise and describe differences in the 10 selected sweet sorghum landraces and thus establish the potential of local germplasm as a source of material for future crop improvement.

5.3 MATERIALS AND METHODS

Due to difficulties in characterisation of many accessions at a time, of the 65 accessions collected (Chapter 3) 10 landraces were characterised for a number of readily identified traits which included maturity period, leaf and stems yield, juice quality, inflorescence and seed characteristics. The landraces were characterised according to the Sorghum

Descriptors (IBPGR & ICRISAT, 1993). Characterisation of the 10 sweet sorghum landraces was conducted during the 1997/98 growing season on the Experimental Farm of the University of Pretoria. Soil characteristics at the Experimental Farm is described in Table A5.1in the Appendix. Rainfall and temperature data for 1996/97 to 1998/99 growing seasons in the Experimental Farm are presented in Table A5.2 in the Appendix.

Before planting, two plots of 18 m long and 10 m wide, were disced and harrowed. The plots were established in a 'Wagon wheel' pattern. Each landrace occupied a single row of 8 m representing a spoke of the wheel. Planting was done with a hand planter at an intra row spacing of 25 cm in a well prepared seedbed. No fertilizers were added during planting. Thinning to one plant per hill was done after approximately 20 days when the plants were well established. After 60 days, plants were topdressed with limestone ammonium nitrate (LAN) at the rate of 120 kg N ha^{-1}. Plots were kept weed free and supplementary irrigation was applied during periods of low rainfall. Aphid infestation was fairly severe and the crop was sprayed with an aphicide on several occasions.

For data collection the rows were divided into three segments, i.e. inner, central and outer segments, to ascertain plant population effects. Intervals between phenological events were recorded. After heading a combination of high winds and heavy rains resulted in some lodging, allowing an opportunity to rate the landraces for proness to lodging. During final harvesting twenty stalks were harvested from each row segment, stripped, packed in polyethylene bags, sealed (see Fig.5.1) and sent to the South African Sugar Association (SASA) Mount Edgecombe, Kwazulu-Natal for juice analysis. The juice was tested for brix value (soluble solid content), pol percentage (sucrose content as measured by a polarimeter), juice purity (percentage ratio of pol to brix) and fibre content (non-solubles bagasse after washing with water for one hour according to standard sugar cane technology methods. Five typical plants from each row segment were harvested to determine final stem height, stem thickness, number of internodes, number of leaves and tillers per plant, fresh stem weight and dry mass of stem and leaves. Number of leaves included those of the main stem and its tillers.

The inflorescences and seed were also characterised according to the Sorghum Descriptors (IBPGR & ICRISAT,1993). The analysis of variance (ANOVA) was performed by the SAS programme package and statistical significant differences between means were estimated by Tukey's Test (Steel &Torrie, 1985).

Fig 5.1 Preparation of sweet sorghum samples sent to South African Sugar Association (SASA) for juice analysis. Sweet sorghum stems are stripped, packing in polyethylene bags and taken to the cool room.

5.4 RESULTS AND DISCUSSION

Phenology

Phenological data of the ten sweet sorghum landraces are shown in Table 5.1. The early emerging landraces were L1, L2, L4, L5 and L8 which attained 50% emergence 4 days after sowing (DAS), while L3, L6, L7 and L9 attained 50% emergence 5 DAS and the latest landrace to emerge was L10 at 6 DAS. The general trend indicated that the five early maturing landraces reached boot, flowering, milk and soft dough stages at the same time and they were all harvested 109 days after emergence (DAE), during the hard dough stage. While Landraces L3, L6 and L7 were harvested 17 days later than the first lot and landraces L9 and L10 reached the dough stage at 131 and 139 DAE, respectively. These results identified early maturing and late maturing types. The classification was consistent to Cowley & Smith (1972) and Ferraris & Stewart, (1979) who classified landraces that matured within 100 to 120 days after emergence as early maturing, and those that reached maturity after 120 days as late maturing. Differences in days to harvesting are beneficial in that it expands the sweet sorghum season.

Stem characteristics

There were significant differences in main stem height, thickness and number of internodes (Table 5.2). In the late maturing types, landrace L6 had the longest stem (354 cm) and landraces L10 and L3 the shortest (330 and 331 cm, respectively). In the early maturing types landrace L4 had the longest stem (324 cm) and landrace L2 had the shortest (288 cm). These results indicated longer stems in late maturing landraces compared to the early maturing types. This was due to the fact that stems of the late maturing types contained more internodes than the early maturing ones (Stoskopf, 1985). The same trend was observed in stem thickness. Late maturing landraces had thicker stems than the early maturing types (Table 5.2). The stem thickness for the late maturing landraces ranged from 2.6 to 2.8 cm. While in the early maturing types, the stem thickness ranged from 2.1 to 2.7 cm. Thick stalks are desirable because small diameter stalks have a great tendency to lodge in the field and consumers tend to prefer thick stems for reasons of juiciness. The number of internodes in the main stems ranged from 10 to 14.

Table 5.1 Phenological data and days to harvest of the ten sweet sorghum landraces

Landraces	Days to 50% emergence	Days to 50% boot stage	Days to 50% flowering	Days to 50% milk stage	Days to 50% soft dough	Days to final harvesting
L1 (B)	4	79	88	95	105	109
L2 (G1)	4	79	88	95	105	109
L3(Z)	5	84	93	105	113	126
L4 (X1)	4	79	88	95	105	109
L5 (C1)	4	79	88	95	105	109
L6 (J)	5	94	105	112	117	126
L7 (E)	5	89	105	112	117	126
L8 (D)	4	79	88	95	105	109
L9 (R1)	5	94	109	119	124	131
L10 (A11)	6	105	117	126	131	139

* B, G1, Z, X1, C1, J, E, D, R1, and A11 refer to original codes in Table A3.1in the Appendix

The late maturing landraces had more internodes than the early maturing types. These results are in agreement with Coleman's, observation that late maturing sweet sorghum cultivars usually have long, thick stems, with harder rinds and more internodes (Coleman, 1970).

Most of the landraces showed a tendency to lodge during a wet and windy period. Landraces L3, L4, L7, L5, L1 and L6 were severely affected by lodging (Table 5.2).

However, it is not possible to draw definite conclusions from these results because the wind direction could have affected some landraces more than others due to the varying row orientation. Landrace 10 lodged the least and this was attributed to better root development and thick stems. The 5% lodging observed in L10 was due to stem breakages, while for most of the other landraces lodging was due to root lodging with stalks remaining intact.

Table 5.2 Length, diameter and number of internodes of the main stem and lodging % of the ten sweet sorghum landraces

Landraces	Stem height (cm)	Stem thickness (cm)	Number of internodes	Lodging %
L1	293	2.7	10	75
L2	288	2.1	10	50
L3	331	2.8	12	100
L4	342	2.4	11	100
L5	310	2.4	10	80
L6	354	2.6	14	75
L7	320	2.7	13	90
L8	299	2.5	12	45
L9	344	2.7	13	50
L10	330	2.7	14	5
LSDt (p=0.05)	55.95	0.5	-	-
C.V. (%)	6.07	6.59	-	-

Leaf and stem characteristics

Data for leaf area, leaf dry mass, stem fresh and dry mass and moisture contents are shown in Table 5.3. There were significant differences between landraces in leaf area. The leaf area per plant ranged from 4584 cm^2 (landrace 8) to 16399 cm^2 (landraces 10). There was a tendency towards late maturing landraces (L10, L3, L9 and L6) having larger leaf areas than the early maturing landraces (L8, L1, and L5). It was observed that early maturing landraces had fewer and narrower leaves compared to late maturing landraces with numerous and broader leaves. Leaf dry mass directly correlated with leaf area. The differences in leaf area represented the cumulative effects of differences in morphology of the landraces. There were significant differences among landraces in fresh stem mass but not in a stem dry mass (Table 5.3).

Table 5.3 Leaf area, leaf dry mass, stems fresh mass, stem dry mass, number of tillers and moisture content per plant of the ten landraces

Landraces	Leaf area per plant (cm)	Leaf dry mass per plant (g)	Stems fresh mass per plant (g)	stem dry mass per plant (g)	Number of tillers per plant	stem moisture content (%)
L1	6373	67.3	2329	530	4.0	77.3
L2	7526	71.2	2487	502	4.7	78.6
L3	13237	121.8	3906	896	5.3	77.0
L4	9965	100.6	3049	593	4.0	80.9
L5	6953	69.1	2296	527	2.3	77.0
L6	9452	105.5	2418	524	3.3	78.1
L7	7982	83.7	2418	480	3.3	80.1
L8	4584	74.0	2080	490	2.3	76.5
L9	10848	101.7	2655	723	3.7	72.8
L10	16399	139.0	2927	787	4.7	73.1
LSDt (p=0.05)	9113	57.1	1152.8	458.8	N/S	-
C.V. (%)	33.3	20.9	14.8	25.9	42.84	-

In the late maturing landraces, total stem fresh mass per plant ranged from 2418g to 3906g while in the early maturing types total stem fresh mass ranged from 2080g to 3049g. Stem dry mass followed the same trend as the stem fresh mass. The results showed a tendency of late maturing types attaining higher stem weights than the early maturing types. Ferraris & Charles-Edwards (1986a) also observed that late maturing cultivars of sweet sorghum achieved a greater biomass compared to early maturing cultivars.

There were no significant differences between landraces in the number of tillers per plant at maturity, mainly due to the fact that from 60 days after emergence landraces lost tillers due to factors such as increased shading in the canopies (data not presented). However, there was a clear tendency for landraces L5 and L8 of having fewer tillers (2.3) compared to landrace L3 (5.3) and landrace L2 and L10 (4.7). Most tillers in landraces L3 and L10 were of marketable value (data not presented). This is an important characteristic affecting crop productivity and the inclusion of L10 in future breeding programmes is recommended.

Generally, there was no difference between landraces in stem moisture content (Table 5.3). Landrace 4 (80.9%) and L7 (80.1%) had the highest moisture content and this juiciness was confirmed when tasting matured stems. Landraces with more moisture in the stem would be more desirable, provided levels of sugar are high.

Panicle and grain yield characteristics

Data of the mean width and length of the panicle, mean peduncle length, 100-seed weight and the grain number per panicle of the landraces are presented in Table 5.4. The size of the inflorescence (width x length of a panicle) varied. Landraces L7 and L8 had the smallest and landraces L10, L3, L6, and L4 had the largest panicles. Early maturing landraces typically had smaller panicles than the late maturing types. Significant differences in the length of peduncles were observed among the landraces, and the peduncles of L2, L4, L5 and L1 and L9 were the longest and those of the L6, L10, and L8 were the shortest. The results show longer peduncles in the early maturing landraces than in the late maturing landraces. Short peduncles are a disadvantage in terms of pest and disease sensitivity because insects and fungi tend to develop around the sheath of the flag leaf and extend to the panicle attacking the seeds (Doggett, 1970).

Table 5. 4 Mean panicle length, width, peduncle length, numbers of seed per panicle and 100-weight of ten sweet sorghum landraces

Landraces	Length of panicle (cm)	Width of Panicle (cm)	Length peduncle (cm)	Number of seed per panicle	100-seed weight (g)
L1	31.3	8.3	50.0	2708	1.86
L2	27.8	8.0	59.3	2875	2.44
L3	36.0	8.7	49.3	3893	2.14
L4	36.2	8.5	59.3	1585	2.48
L5	27.3	9.7	57.0	1933	2.23
L6	29.0	9.3	40.3	3839	2.69
L7	23.5	6.7	48.0	1193	1.45
L8	23.5	7.3	44.7	1500	1.91
L9	27.7	6.8	50.0	3769	2.51
L10	32.7	10.0	41.3	3199	2.60
LSDt (p=0.05)	2.67	1.02	15.87	-	0.32
C. V. (%)	3.09	4.52	10.85	-	4.91

Wide variation was observed in the number of seed per panicle (Table 5.4). Landraces L7, L8, L4 and L5 had less than 2000 seeds per panicle whilst landraces L3, L6, L9 and L10 had more than 3000 seeds per panicle. The results indicated that some of the late maturing landraces have the potential for seed production and they compare well to grain sorghum with 800 to 3000 seeds per panicle (Stoskopf, 1985). Although landrace

L3 had the highest grain number per panicle amongst the late maturing landraces, its 100-seed weight was the lowest of the four. The number of seeds per panicle and the weight of seed are important in determining grain yield. Although seed yield is not a priority in sweet sorghum, during drought years sweet sorghum could alternatively be utilized for grain production (Farraris, 1981b). However, under normal conditions it is not recommended to encourage grain production in sweet sorghum grown for stem sales because tall plants with heavy panicles lodge easily due to the leverage forces on the stem brought about by the weight of grain at the apex (Ferraris, 1981b). Seed sizes varied greatly within and between landraces as seen in Table 5.4. This indicates that farmers have not been selecting for seed size whilst selecting for stem characteristics.

Juice quality

There were significant differences among landraces in all characters of juice quality except, in purity (Table 5.5). The fibre content in stems of the late maturing types typically ranged from 10 to 12%, and for the early maturing types between 7 and 9%, but only L10 (12.4%) and L4 (7.6%) differed significantly. These results suggests that early maturing landraces had lower stalk fibre percentages as compared to late maturing types. According to the classification of Bryan, Moroe & Bascho (1985) the fibre content of all ten landraces can be classified as low in fibre content. According to this classification, fibre contents between 15 and 18% is considered high in fibre. They also reported that a high fibre content results in more juice being retained in the stalk bagasse.

A wide variation in brix percentage (soluble solids in the juice) was observed as shown in Table 5.5. Late maturing landraces especially (L10, L9, L3) had higher brix percentages compared to the early maturing landraces (L1, L2, L4, L8). Though not statistically significant there was a clear trend for the purity percentage to be higher than 37% for some late maturity landraces, and lower than 30% for most of the early landraces (L1, L2, L4, L5). In sweet sorghum where stems are chewed, a high soluble solid content of the juice will be preferable therefore, brix is an important characteristic in identifying landraces with quality juice.

Table 5.5 Fibre, brix, purity, and pol percentages of the ten sweet sorghum landraces (Analysed by SASA)

Landraces	Fibre %	Brix %	Purity %	Pol %
L1	8.9	8.7	27.1	2.36
L2	8.6	8.2	23.0	2.63
L3	10.7	11.4	32.2	2.65
L4	7.6	9.3	16.6	1.55
L5	8.6	8.3	22.4	1.86
L6	11.3	10.4	33.7	3.56
L7	11.4	10.0	38.8	4.00
L8	10.4	8.2	28.2	2.46
L9	10.1	12.0	37.8	4.57
L10	12.4	15.1	38.8	5.82
LSDt (p=0.05)	3.14	2.40	N/S	2.96
C.V. (%)	10.71	8.04	26.48	32.1

Fibre = non-solubles after washing with water for one hour (bagasse); Brix = soluble solid content; Purity = percentage ratio of pol to brix; Pol = sucrose as measured by a polarimeter; Sucrose= estimated pure disaccharide

Pol values give an indication of the sucrose content and some of the late maturing landraces were significantly higher than those of the early maturing types (Table 5.5). Landraces L10 and L9 had the highest pol percentages of 5.82% and 4.57% with L5 being the lowest (1.86%). The lowest in both pol and sucrose were L4 and L5 with pol being1.55% and 1.86%, in sucrose, 6.13g and 5.74g, respectively. It is therefore evident from these results that late maturing landraces had better juice quality compared to the early maturing landraces. However, these landraces were lower in sucrose content compared to the varieties grown in the Natal Midlands by Inman-Bamber, (1980). This is in line with the observation of Ferraris, (1981a) who reported that high yields of sugar (sucrose) and solubles (brix%) are associated with a long growing period and tall thick stems. The results suggest that there are sweet and juicy landraces like L10 and L9 in Botswana which can be included in breeding programmes for juice quality.

Inflorescence characteristics

Inflorescence characteristics are summarized in Table 5.6 and illustrated in Figs 5.2(a-b). There was a wide variation in head exsertion among the landraces, with inflorescences that were well exserted, exserted and those which were slightly exserted. Head exsertion is related to the length of the peduncle, with short peduncles bearing slightly exserted inflorescences.

Sweet sorghum landraces demonstrated great variation in the shape and compactness of inflorescence as shown in Table 5.5 and Fig 5.2(a - b). Landraces L1, L3, L6 and L10 had compact elliptic inflorescences, whilst landraces L4 and L5 had typical broomcorn morphology. The inflorescence of L9 was loose erect and the rest were semi-loose erect.

Table 5.6 Inflorescence and grain characteristics of the ten sweet sorghum landraces

Landraces	Head exsertion	Compactness of panicle	Awn	Grain form	Grain plumpness	Glume colour	Grain colour	Grain cover (%)	Shattering
L1	well exserted	compact elliptic	0	S	P	grey	yellow	75	very low
L2	well exserted	semi-loose dropping	+	S	P	purple	orange	50	high
L3	exserted	compact elliptic	0	S	P	grey	yellow	75	inter-mediate
L4	well	broom-corn	0	S	P	black	red	50	high

Landraces	Head exsertion	Compactness of panicle	Awn	Grain form	Grain plumpness	Glume colour	Grain colour	Grain cover (%)	Shattering
	exserted								
L5	slightly exserted	half broomcorn	+	S	P	grey	red	25	high
L6	exserted	compact elliptic	0	S	P	red	red	75	very low
L7	exserted	semi-loose erect	0	S	P	white	yellow	50	inter-mediate
L8	slightly exserted	semi-loose erect	0	S	P	red	red	50	low
L9	slightly exserted	loose erect	0	S	P	red	yellow	25	high
L10	slightly exserted	compact elliptic	0	S	P	black	white	50	high

*Characterisation according to Sorghum Descriptors (IBGR & ICRISAT, 1993)

Differences in the shape of inflorescences are so clear that they can be used for selection purposes. All landraces were awnless except for landraces 2 and 5 and grains of all the landraces were smooth and plump.

The landraces had varying glume and grain colour (Table 5.6 & Fig 5.2(a - b). The prevailing glume colours were grey, red, black and white and these were not correlated to the colour of the seed in any way. Seed colours were yellow, orange, red and white. There was no variation of seed colour within a landrace. This suggests that during breeding programmes seed colour could be used as a marker for selection.

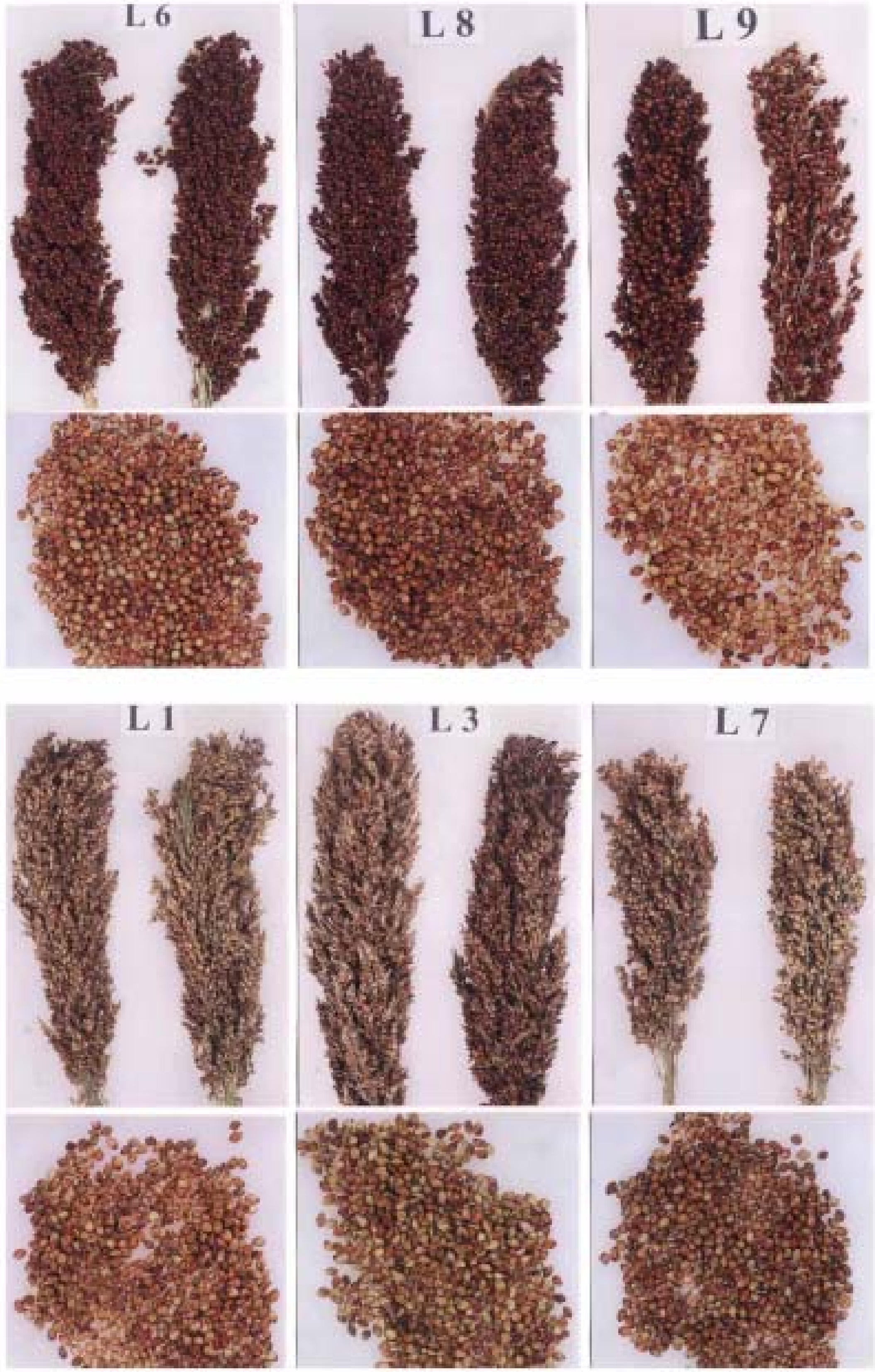

Fig 5.2 (a)

Fig 5.2 (a:b) Photographs illustrating differences in unflorescence development and seed charactaristics of the ten sweet sorghum landraces

Fig 5.2 (b)

There was a wide variation in grain cover and the range was between 5 and 75 percent (Table 5.6). Landraces with 25% and 50% grain cover were more prone to grain shattering compared to those with grain cover of 75%.

This study showed that Botswana landraces have a range of genetic diversity which can be used for crop improvement as well as adaptation in different regions. With data obtained from this chapter it has been possible to characterize individual landraces for phenology, date of maturity, morphology, yield per plant, juice characteristics and inflorescence characteristics. The most promising early (L2 and L4) and late (L9 and L10) landraces are characterised in Table 5.7.

In future the remaining 55 landraces ought to be characterized and there is need for inclusion of landraces from neighbouring countries for comparison purposes. However, the observations in the characterization exercise of the 10 landraces forms the bases for characterization of the genepool of sweet sorghum.

Table 5.7 Characters of the promising early and late maturing sweet sorghum landraces

Characteristics	Best early maturing landraces		Best late maturing landraces	
	Landrace 2	Landrace 4	Landrace 9	landrace 10
Days to 50% hard dough	109	109	131	139
Stem height (cm)	288	342	344	330
Stem thickness (cm)	2.1	2.4	2.7	2.7
Number of internodes	10	11	13	14
Number of tillers per plant	4.7	4.0	3.7	4.7
Stem fresh mass (g) per plant	2487	3049	2655	2927
Stem dry mass (g) per plant	502	593	722	786
Stem moisture content (%)	78.6	80.9	72.1	73.1
Stem fresh mass per stalk (g)	307.0	394.7	441.7	443.0
Fibre %	8.6	7.6	10.1	12.4
Brix %	8.2	9.3	12.0	15.1
Purity %	32.0	16.6	37.8	38.8
Pol %	2.63	1.55	4.57	5.82
Length of peduncle (cm)	59.3	59.3	50.0	41.3
Length of panicle (cm)	27.8	36.2	27.7	32.7
Width of panicle (cm)	8.0	8.5	6.8	10.0
head exsertion	well exserted	well exserted	slightly exserted	slightly exserted
compactness	semi-loose dropping	broom-corn	loose-erect	compact elliptic
awn	+	0	0	0
glume colour	purple	black	red	black
grain cover	50%	50%	25%	50%
grain colour	orange	red	yellow	white
number of seed per panicle	2875	1585	3769	3199
100-seed weight	2.44	2.48	2.51	2.60
shattering %	high	high	high	high
lodging %	50%	100%	50%	5%