Evaluation of sorghum technologies for smallholders in a semi-arid region of Zimbabwe (Part II): Sorghum varieties against fertilizer trials

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Three on-farm experiments were conducted during 1984/85, 1985/86 and 1986/87 seasons in Siabuwa (Zimbabwe), to test early maturing sorghum varieties SV–2 and 321CR with fertilizer use as possible solutions to production problems faced by farmers growing Balala variety. Varieties SV–2 and 321CR produced higher yields than Balala (by an average of 62 per cent) in the three seasons at farmers' levels of inputs and management. Farmer evaluation of the taste of porridge from sorghum grain showed a high preference for SV–2 and 321CR compared to Balala. Fertilizer application at 50 kg nitrogen per ha and 12 kg phosphorus per ha appreciably raised the grain yield of Balala sorghum and SV–2 and 321CR varieties on vertisols, siallitic clays and sandy loam soils in average and above average rainfall years (1984/85 by 37 per cent and 1985/86 by 60 per cent) but not in1986/87, a dry year. However, fertilizer use was not economic in the three seasons. It was concluded that SV–2 and 321CR are useful additions to the range of sorghum varieties available to farmers in Siabuwa.

Based on sorghum (*Sorghum bicolor* L., Moench) production problems identified in Siabuwa Communal Area (north-western Zimbabwe) in 1984, trials were designed to attempt to provide solutions (Chiduza *et al.*, 1995). This paper describes the trials started in the 1984/85 season, to examine early-maturing varieties and fertilizer as solutions, including the porridge taste tests administered.

Materials and methods

Interactions of sorghum varieties and fertilizer
The sorghum variety against fertilizer trial was planted to determine possible yields with the new, short-season, white grain sorghum varieties SV-2 and 321CR and to compare their yield potential with Balala, a local long-season sorghum variety. The trial was planted in Siabuwa at six sites in 1984/85 and 1985/86 seasons. A randomized complete block design (RCBD) with a factorial combination of five varieties and two fertilizer levels was used and replicated three times at each site. The five varieties were; Balala, two improved intermediate-maturity varieties Serena (red grain) and M36172 (white grain), and two improved short-season, white grain varieties SV-2 and 321CR. Fertilizer was applied at the following rates; no fertilizer applied, 16 kg nitrogen per ha, 12 kg phosphorus per ha, and 7,6 kg potassium per ha applied as an initial dressing of compound fertilizer at planting combined with 34,5 kg nitrogen per ha as ammonium nitrate top-dressing, six weeks after planting. The plot size was 5 m by 4,5 m with 1 m between plots. Row width was 75 m one plant per 20 cm of row.

Soil fertility levels in Siabuwa vary greatly with soil type (Hungwe, 1985) and sites were selected to cover the three main soil types in the area, the vertisols, the siallitic clays and the sandy loams. The trial was established at two sites of each soil type during both seasons, but a different location within the same field was selected during the second season.

The trial was dry planted, reflecting communal farmer practice, at all sites on 16 November during 1984/85 and 28 November during 1985/86. The researcher planted, thinned, applied fertilizer treatments and harvested the sorghum. Other non-experimental inputs and practices were managed by the communal farmers. In particular, communal farmers were responsible for weeding (generally two hoe weedings) and bird scaring.

At harvest two crop rows were discarded on each side of an individual plot, together with plants in the 50 cm zone at both ends of every row. The number of plants, number of panicles and fresh weight of panicles were recorded for the remaining 4 m by 1,5 m nett plot.

A sub-sample of ten per cent by weight of the nett plot fresh weight was collected from each plot and dried at 80°C to constant weight at 12,5 per cent moisture for 72 hours. Yield per ha was calculated from the sub-samples of threshed grain and recorded.

An analysis of variance was first done for each site in each year, then across sites and across years, and was followed by means separation tests. An economic partial budget (CIMMYT, 1988) was performed for Balala, SV-2 and 321CR with and without fertilizer. The grain yields from the trial plots were reduced by 20 per cent in the partial budget to reflect yields that farmers would expect to get in their sorghum fields (CIMMYT, 1988). The 1986 Grain Marketing Board price of Z$180 per tonne was used to value sorghum grain and farm gate costs were used to value fertilizer and labour for applying the fertilizer and harvesting the extra yield.

Fertilizer levels trial
The fertilizer levels trial was planted in 1985/86 and 1986/87 to examine the response of SV-2 to a range of low levels of inorganic fertilizer. The experimental design was a split plot. Levels of initial topdressing of compound fertilizer was applied to the main plots, and levels of topdressing of ammonium nitrate to the sub-plots. There were three replicates. A total of 16 experimental treatments were included as a factorial of the following: (1) Initial fertilizer; 0:0:0, 10:7.3:4.6, 20:14.6:9.2, and 30:21.9:13.8 kg nitrogen: phosphorus: potassium per ha. (2) Topdressing fertilizer; 0, 28, 56 and 84 kg nitrogen per ha. Gross plot sizes were 20 m by 3 m for the main plot and 5 m by 3 m for the sub-plot.

Three sites, one on each of the three main soil types, were selected for 1985/86 and 1986/87, but different farms were used each year. The trial was planted on 30 November 1985. Two sites were planted on 28 November 1986 and the third site on 10 December 1986. Management of these trials, including planting, thinning, weeding and harvesting, was done by the researcher. Harvesting methods and data collection were similar to that described earlier.

Data from one site was available for the 1985/86 season (crops at two sites were destroyed by drought) and three sites from the 1986/87 season. A grouping of sites by soil type resulted in homogeneous variances for data from sites located on sandy loam soils and for sites on clay or sandy-clay loam soils. An analysis of variance was carried out on the two sets of data.

Partial budgets, as previously described were calculated from the combined data from the sandy loam sites. No economic analysis was done for sites on the clays and sandy-clay loams because fertilizer effect on grain yield was not significant.

The variety trial
This trial examined whether shorter-season sorghum varieties had yield advantages over other types currently grown by farmers in Siabuwa.

The experimental design was a RCBD replicated three times. Ten sorghum varieties were used: MR 730, SV-1, SV-2, Segaolane,

Chisumbanje, MR748, MR726, MR703, Serena and the local variety Balala.

The trial was planted during 1986/87 at seven sites across all soil types in Siabuwa. Plot size and management responsibilities were similar to those in the variety against fertilizer trial. Since most farmers do not use fertilizer on sorghum, fertilizer was not applied in this trial. The data gathered and methods used at harvest were also similar to the variety against fertilizer trial.

Farmer and site selection for the experiments
In 1984/85 farmers were selected largely on their willingness to co-operate, but many farmers offered land for the next season of trials and so it was possible to choose farmers with representative resource levels and soil types for the 1985/86 and 1986/87 seasons.

With several farmers it was not possible to obtain a sufficiently large piece of land with a similar cropping history on which to place a trial. Where necessary, trials were blocked so that each owner managed one replicate.

Some difficulties were experienced during the trial programme. Trials at several sites showed high coefficients of variation. Results from those sites have been reported because they reflect variations that occurred in farmers' fields. Some of the varieties tested, especially M36172 and to a lesser extent 321CR and SV-2, had approximately 77 per cent of the numbers of plants per square metre that were present for Balala and Serena. Plant population density was in part reduced by birds, particularly partridges (*Perdix perdix*) which dug up seeds and seedlings.

Farmer evaluation of taste of thick porridge from sorghum grain
Two tests, a multiple comparison test and a hedonic test (Larmond, 1982), to evaluate the taste of thick porridge (the main food prepared from sorghum), were administered during the 1986/87 season to 21 panelists randomly selected from a gathering of farmers. Hot thick porridge from four sorghum varieties, Balala, SV-2, 321CR and M36172, was served to farmers. Balala, the second most preferred local variety by farmers, was used as the standard because grain of Maila Tonga, the most preferred local sorghum variety, was not available when the tests were conducted. The detailed conduct of these tests followed the guidelines given by Larmond (1982).

In the multiple comparison test, farmers were asked to decide whether each coded sample of SV-2, 321CR and M36172 had a better taste, comparable to, or poorer than the standard Balala. Farmers were then asked the amount of difference that existed between each of the coded samples and the standard. Scores were assigned to the responses. A score of nine indicated a very high preference and one an extreme dislike.

The multiple comparison test can only tell if one sample is better than the other and cannot show whether both samples have a high preference or not. Accordingly, the hedonic test was carried out to ascertain how much people really like the samples. The standard and test varieties were recorded for this test. Again a scale of one to nine was used for the responses.

An analysis of variance of results from the tests was carried out and Tukeys test used to determine which varieties were significantly different from each other.

Results

Rainfall during the three seasons of the trials in Siabuwa was 775 mm in 1984/85, 720 mm in 1985/86 and 355 mm in 1986/87 seasons (Fig. 1, Part I of the article). The first two seasons, 1984/85 and 1985/86, were among the 47 per cent of the years with rainfall above the mean of 676 mm whilst 1986/87 had the third lowest rainfall total in the 34-year record. Responses to experimental treatment, particularly fertilizer, in the trials was dependent on the pattern and amount of rainfall in each season.

Variety against fertilizer trial
Interactions variety against seasons ($p = 0.01$), variety against location (soil) ($p = 0.05$) and fertilizer against season against location (soil) ($p = 0.05$) for grain yield were significant and are examined separately.

The grain yield of all varieties was lower during 1985/86 compared to 1984/85 (Table 1, part one of the article), but in both seasons all the introduced shorter-season varieties outyielded the local long-season variety, Balala.

Response of variety against season depended on the cropping season's rainfall pattern and the number of days needed for a particular variety to reach physiological maturity. Although rainfall totals for both 1984/85 and 1985/86 seasons were above the 36-year average (775 mm and 720 mm respectively) the distribution of rainfall in relation to planting date favoured the 1984/85 season. In particular, in 1985/86 there was less rainfall shortly after planting and in March during grain filling. The low number of shoots and panicles per ha achieved by all varieties in 1985/86 (Table 1) is attributed to the low rainfall received just before and soon after planting. The interaction arose because the two intermediate-maturity varieties Serena and M3617 (126 and 121 days to physiological maturity respectively) and the long-season local variety (around 131 days to physiological maturity) experienced a longer period of water deficit during grain filling than did 321CR and SV-2 (106 and 94 days to physiological maturity respectively) in 1985/86 and consequently achieved lower grain yields (Table 1, Fig. 1).

Relative performance of varieties were different with site but there was no consistent link with either the type of soil or tillage at a site (Fig. 2). For example, at the two sites on the sandy-clay loam soil, variety SV–2 shifted from being the highest yielding at one site to being the lowest yielding at the other. Except for one site on the clay soil, Serena (the intermediate variety) was consistently the highest yielder at all sites. Varieties 321CR

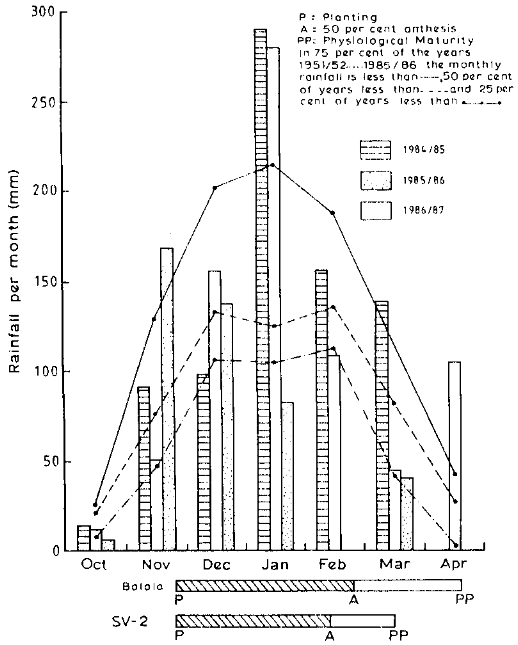

Fig 1: The development cycle of sorghum varieties, Balala and SV-2 and rainfall in Siabuwa

Table 1: Grain yield and plant population (populaton density) for sorghum (at maturity) in Siabuwa (Variety/fertilizer trial for 1984/85 and 1985/86 seasons)

Variety	Grain yield (kg per ha)	No. of plants per ha	No. of panicles per ha
1984/85			
M36172	2 583	128 600	127 400
321CR	2 499	125 700	131 500
SV-2	2 511	100 400	108 600
Serena	3 640	160 300	132 800
Balala*	2 223	160 000	141 800
1985/86			
M36172	892	49 000	41 100
31CR	1 636	73 800	69 000
SV-2	1 824	69 100	66 700
Serena	1 244	77 400	70 200
Balala*	702	77 400	70 200
SED (Season x Variety	123	6 420	7 770

*Local long-season variety

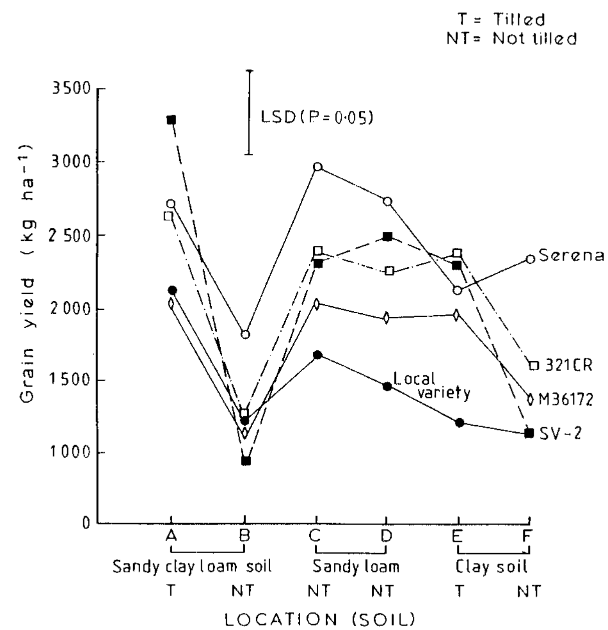

Fig. 2: Variety x Location (soil) Interaction in the Variety x Fertilizer trial, Siabuwa 1984/85 and 1985/86

and M36172 were also consistently higher yielding than Balala, while SV-2 was less consistent but generally yielded more than Balala. Tillage appeared important for high yield among the new short-season varieties at sites where the soil can cap (sandy clay loam) and on the clay soils (Fig. 2).

All varieties, including Balala, responded to fertilizer, but the level of response depended on the rainfall distribution and soil type (Fig. 3). On average the local variety gave a higher percentage grain yield increase with fertilizer (70 per cent) than did the improved materials (average of 40 per cent). Grain yield of Balala with fertilizer was generally less than the yield of the improved varieties without fertilizer, especially in 1985/86 when Balala was affected by a water deficit during grain filling and so could not benefit from the fertilizer applied (Fig. 3). In 1985/86 there was a consistently higher grain yield (approximately 60 per cent increase) with fertilizer across all soil types compared to approximately 37 per cent in 1984/85. For the new varieties, fertilizer effects on the sandy-clay loams and sandy loams tended to be greater at sites that had been tilled (Fig. 3), which reflects the similar N and P status of the soils (Chiduza *et al.*, 1990).

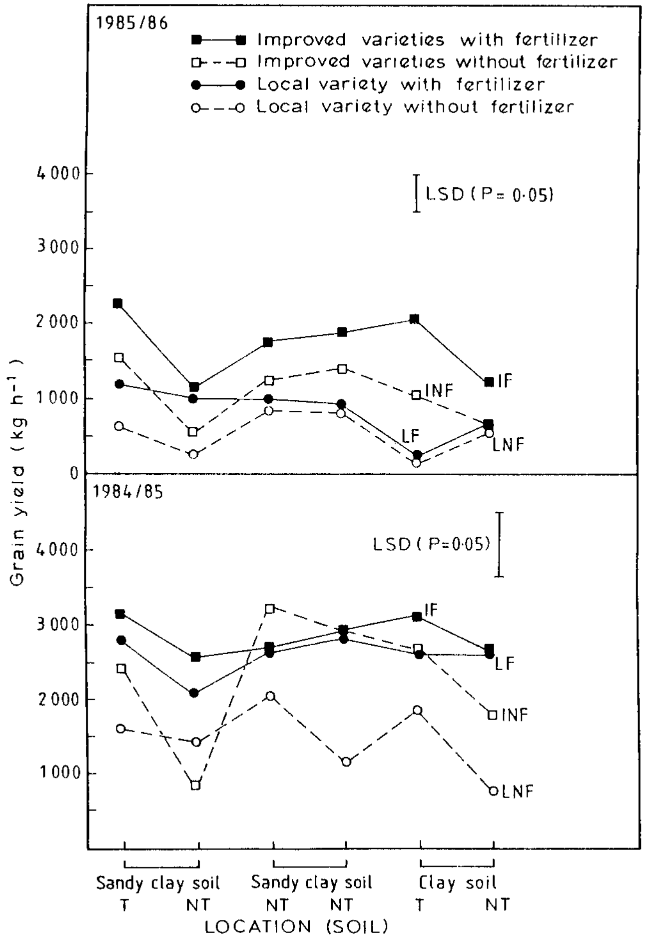

Fig. 3: Season x Fertilizer x Location (soil) Interaction in the Variety x Fertilizer Trial, Siabuwa 1984/85 and 1985/86

Table 2: Grain yield at seven sites in Siabuwa and length of growing season at Chiredzi (under irrigation)

Variety	Grain yield per site (kg per ha) 1	2	3	4	5	6	7	Variety mean over sites	Length of growing season (days): emergence to 50% anthesis	emergence to Physiological maturity[1]
MR730	825	859	523	741	333	288	327	557	76	91
SV-2	1 313	1 763	1 626	1 276	755	150	884	1 081	76	94
Segaolane	1 031	1 444	769	718	774	768	359	838	73	100
SV-1	1 077	1 195	839	789	822	213	908	835	75	103
MR703	947	939	946	645	360	224	294	622	73	121
MR726	517	728	120	323	0	324	268	326	75	122
MR748	731	731	305	646	780	115	522	547	74	123
Serena	0	0	0	0	0	19	0	3	84	126
Chisumbanje	0	0	0	0	0	9	0	1	84	128
Balala (local)	4444	0	0	0	0	156	0	86	90	131
SE	63.4	99.8	354.0	216.1	202.7	221.4	187.5	90.2	n.a.	n.a.

[1]Physiological maturity determined by appearance of dark helium.

Variety trial

Rainfall was very low during 1986/87 season (third lowest rainfall in the 34-year record) with little rain in January and none in February (Fig. 1) and the resulting grain yield of the varieties examined was low (Table 2). Farmers did not harvest any grain from most of their longer-season sorghum crops in Siabuwa in 1986/87. Serena (intermediate) and two later maturing varieties, Chisumbanje and Balala, did not reach physiological maturity because of the short growing season, and gave no grain yield at almost all sites. The earlier maturing varieties, SV-1, SV-2, Segaolane, MR748, MR703 and MR726, gave grain in the 1986/87 season. The number of days from emergence to 50 per cent anthesis explain the grain yield obtained. Serena, Chisumbanje and Balala reached 50 per cent anthesis 10-18 days later than the other varieties and this meant that the early part of the grain filling phase coincided with the period of low rainfall (Fig. 1).

Segaolane produced above average yields at all sites while SV-1 was above average at six of the seven sites. The varieties MR730 and MR748 had above average yields at some sites but below average at others. Variety SV-2, which yielded well in the previous cropping seasons, again yielded well above average at six of the seven sites (Table 2).

Fertilizer levels trial

There was no effect on grain yield of either the initial dressing or the topdressing of fertilizer on the sandy-clay soils (Table 3). Relatively high levels of NPK present in these soils and insufficient moisture (third lowest rainfall in the 34-year record for 1986/87) accounted for the low response to fertilizer.

At the two sites with sandy loam soils, the response to fertilizer was inconsistent (Table 4). Site 2 showed significant yield increases with increasing levels of both topdressing and the initial dressing up to 20:15:9 kg NPK per ha topdress, but little response was seen at the other site.

The different response to fertilizer at the two sandy-loam sites was probably due to the differences in planting date and in the rainfall distribution following establishment of the trial at the two sites. A prolonged dry spell was experienced soon after establishment at the non-responsive site and resulted in little effect of fertilizer on grain yeild.

Farmer evaluation of taste of porridge from sorghum grain

The multiple comparison test showed the taste of thick porridge prepared from the grain of SV-2, 321CR and M36172 was significantly preferred (p = 0.5) by farmers to the taste of Balala. Variety 321CR was the most preferred, followed by SV-2 and then M36172, compared to Balala.

In the hedonic test there were significant differences (p = 0.01) in the preference for the thick porridges prepared from SV-2, 321CR, M36172 and Balala. Preferences were in agreement with those from the multiple comparison test. Variety 321CR had the highest preference score of 8,3 out of a possible score of 9 (it was liked very much). Variety SV-2 was the second favourite (score 7,8) while farmers had a 'moderate preference' for M36172 (score 7,2). Balala received a neutral score of 5,0; it was neither liked nor disliked. Preference for M36172, the least preferred of the three introduced sorghum varieties, was significantly higher (p = 0,05) than that of Balala. Thus all three,

Table 3: Effect of fertilizer on sorghum grain yield (kg per ha) for clay and sandy loam soils, Siabuwa in two seasons 1985/86 and 1986/87

	Topdress N (kg per ha)			
Initial dress NPK (kg per ha)	0	28	56	84
Clay Soil				
0:0:0	2 831	2 961	2 024	2 936
10:7:5	2 431	3 236	3 635	3 417
20:15:9	3 447	3 423	2 795	3 887
30:22:14	2 704	3 556	3 690	3 462
Sandy Loam Soil				
0:0:0	695	958	1 150	1 167
10:7:5	793	1 034	1 125	1 571
20:15:9	1 163	1 231	1 856	2 200
30:22:14	1 158	1 454	1 833	1 473

Table 4: Effect of fertilizer on sorghum grain yield (kg per ha) on sandy loam soils, Siabuwa 1986/87

	Site	
Fertilizer (kg per ha)	**1**	**2**
Initial Dress, NPK (kg per ha)		
0:0:0	732	1 253
10:7:5	553	1 709
20:15:9	574	2 651
30:22:14	532	2 427
SE	124	220
Top Dress, N (kg per ha)		
0	427	1 478
28	617	1 722
56	670	2 313
84	677	2 528
SE	105	151

new, white, early-maturing sorghum varities were preferred more or equally to the varieties currently grown by the farmers for thick porridge.

Discussion

Grain yield of short season sorghum varieties

The data presented showed that introduced pearly-white grain sorghum varieties with a short plant development cycle, consistently outyielded (by an average of 62 per cent) local long-season varieties in the three years of an average and a poor rainfall season in Siabuwa. Varieties SV-2 and 321CR performed well in all the seasons in which they were tested while M36172 showed a greater potential to take advantage of a good rainfall season. Given the highly variable rainfall pattern in Siabuwa the stability of the yield improvement offered by the new, short-season sorghum varieties over the different types of season experienced in Siabuwa is important. A season with good rainfall occurred about one in three years in Siabuwa.

Serena, an intermediate-maturing improved variety, outyielded the short season varieties SV-2 and 321CR in 1984/85 (the season with a good amount and distribution of rainfall) but in 1985/86 and 1986/87 most short-season varieties outyielded Serena. The variety trial conducted during 1986/87, when just 365 mm of rainfall was recorded, highlights the advantage that farmers can derive by growing short-season sorghum varieties. Seeded long-season sorghum varieties yielded 86 kg per ha compared with 514 kg per ha for the same long-season ratoon crop (in adjacent fields) and 828 kg per ha for seeded introduced short-season varieties under farmer management in that extremely dry year (Table 2).

Thus, any of the three improved short-season varieties SV-2, M36172 and 321CR would be preferable to the local longer-season varieties under present farmer management, in almost all seasons in Siabuwa.

Table 5: Costs that vary and net benefits from the use of fertilizer with farmer's local sorghum variety, 321CR and SV-2 for the seasons 1984/85 and 1985/86

Treatment	(a) Total costs that vary (Z$/ha)	(b) Net benefits (Z$/ha)		(c) Marginal rate of return
Farmer's variety, no fertilizer	0	156.10		
321CR, no fertilizer	6.70	229.68	1232%	75%
SV-2, no fertilizer	6.99	242.21		
Farmer's variety, with fertilizer	145.38	265.10		
321CR, with fertilizer	152.70	365.76	96%	
SV-2, with fertilizer	153.07	382.18		

(a) The cost 0 given to the farmer's variety biases the MRR in favour of this variety. If a seed cost were attached to the farmer's variety, the MRR in moving to the improved variety would be much higher.
(b) Yields discounted by 20% to approximate farmer's yields.
(c) Marginal rate of return calculated only in moving to highest performing improved variety SV-2.

Farmer food preference for short-season sorghum varieties

The priority for most farmers in Siabuwa is the production of subsistence food. The crops and varieties of those crops they produce are dictated by, amongst other things, food preferences. At the moment one of the main reasons why farmers grow long-season sorghum varieties is because they like the taste of the thick porridge. However, results from the food evaluation tests indicated that farmers preferred the taste of thick porridge from the new, short-season sorghum varieties when compared with current, long-season varieties. Taste preference has been shown to be important in the adoption of sorghum by subsistence farmers, for example, in West Africa (ICRISAT, 1980/83).

If data on grain yield are considered, in the wetter years then the intermediate variety Serena had a higher yield than Balala compared to other varieties. However, no farmer was observed to grow Serena even though it had been available in Siabuwa since the early 1980s. A few farmers were observed to be growing three other improved shorter-season sorghum varieties; SV-2, 321CR and M36172 in 1985/86 and 1986/87, straight after their release. The difference between Serena and the other varieties, apart from length of growing period, is grain colour and taste. Serena is a red-grained, brewing-type sorghum, whilst the other three are pearly-white grained and are specifically bred as food sorghums. Unsuitability for porridge may explain the low adoption of brewing sorghum varieties reported by Reid (1982) in Kariba district.

Adoption of short-season sorghum

The combination of higher, more stable grain yield with a preferred taste should lead to the new, short-season sorghums being adopted quickly by Siabuwa farmers. The new, short-season sorghums are open-polinated. Seed was made available free to farmers who expressed interest in growing it during the 1987/88 and 1988/89 seasons, so that they had little extra cost associated with the use of these new varieties. Even if seed had been purchased the change would have been extremely economical with an estimated marginal rate of return of 1 232 per cent in moving from Balala to SV-2 (Table 5).

Nevertheless, it is anticipated that farmers will continue to plant a proportion of their sorghum area to Balala, especially as a ratoon crop on the vertisols, for two main reasons. Firstly, long- or intermediate-season sorghums with acceptable grain taste for making porridge and higher yield potential may have a role in the system to take full advantage of good rainfall years. However, these sorghum varieties had still to be developed. Secondly, a shortcoming of the new, short-season varieties appeared to be their greater difficulty in establishing a good plant stand on the vertisols. This was observed at trial sites especially in 1985/86 when rainfall was low just after planting, and the resulting yield reduction required further study in relation to land preparation. Serena and Balala had good stand establishment on all soil types, whether tilled or not. It seems that the short-season varieties were more responsive to land preparation and would therefore establish themselves better as land preparation improves in Siabuwa.

Fertilizer use

Because of the small number of sites and seasons sampled, the conclusions on fertilizer use require further investigation.

Indications are that during very dry seasons, similar to 1986/87, applying fertilizer does not increase yield and so an economic disadvantage would accrue from applying fertilizer. Similar dry seasons with less than 450 mm of rainfall, in which little or no response to fertilizer is likely, occur about once in every seven years in Siabuwa.

During 1984/85 and 1985/86 seasons, use of 50 kg nitrogen, 12 kg phosphorus and 7,6 kg potassium per ha produced a yield increase of about 44 per cent across all soil types, compared to no fertilizer. Although in these trials Balala produced the highest percentage response to fertilizer, the absolute grain yield for Balala with fertilizer was only slightly higher than that of the new short-season varieties without fertilizer.

Table 5 shows the marginal rate of return of applying fertilizer to Balala, 321CR and SV-2 sorghum during 1984/85 and 1985/86, the years when fertilizer consistently raised grain yield. Marginal rates of return in moving from no fertilizer to 50 kg nitrogen, 16 kg phosphorus and 7,6 kg potassium per ha were 75 per cent for Balala and 96 per cent for SV-2. Farmers in Siabuwa do not take risks by purchasing high levels of inputs. Also farmers do not make an investment unless the average rate of return is at least 199 per cent per crop per season (Perrin *et al.*, 1976; CIMMYT, 1988). Consequently, the cash return is at least 100 per cent per crop per season (Perrin *et al.*, 1976; CIMMYT, 1988). The cash returns to fertilizer use are probably unattractive to farmers in Siabuwa even in above-average rainfall seasons.

Preliminary results showed that applying fertilizer to either Balala or improved short-season sorghum varieties in Siabuwa is risky and uneconomical. These findings support current farmer practice. However, fertilizer use needs further investigation. Lower levels of nitrogen fertilizer (20-40 kg nitrogen per ha) applied as a cheaper straight nitrogen source rather than mixture of compound and straight nitrogen topdress shortly after emergence may be economic in average and better-than-average rainfall years, especially on tilled land.

In conclusion, results from Siabuwa experiments indicated that:

a) Use of short-season varieties SV-2 and 321CR increased grain yield of sorghum per ha (and yield stability) over almost all rainfall seasons under farmer management practice without use of fertilizer in the short term. Short-season sorghum varieties are useful additions to existing local, long-season varieties in Siabuwa.

b) Use of fertilizer (50 kg nitrogen and 7.6 kg potassium per ha) was uneconomical for most seasons on all the main soil types in Siabuwa with either long- or the new, short-season sorghum varieties.

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Recent developments in standardisation of steelwork analysis and design: state-of-the-art and trends

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Zimbabwe has great technical potential in the area of civil engineering constructions. Building investments are supported by a number of well-organized design offices and contractors. However, particularly during the last few years, engineers have been raising the issue of the lack of Zimbabwean building codes which reflect the specific conditions of the local market and achievements in local research. The common design procedure in Zimbabwe is to follow the requirements of the British Standards when designing building structures. The last three symposia on Science and Technology, held in Harare in 1988, 1990 and 1992, have shown that there is, in Zimbabwe, sufficient input data of design-based technical information and human resources, in terms of active researchers and engineers, to create design codes of practice, based on Zimbabwean experience in material technologies, market products and design philosophy concepts. The process of standardization of structural codes has been initiated by the Standards Association of Zimbabwe and the first structural timber codes have been established. Research was undertaken at the University of Zimbabwe to assess the state-of-the-art and directions of future development in structural steelwork design. This paper is of a review nature, presenting recent developments in the analysis and design of steel structures, which are important from the point of view of their application to the on-going standardization process in Zimbabwe.

The behaviour of steel-framed structures is complicated by a variety of failure modes, such as the following:

- local instability of sectional plate segments
- overall out-of-plane buckling
- large in-plane displacements resulting from the influence of axial forces on the sway deflections of storeys (identified as the so-called P-D effect) and the flexural stiffness of individual members (referred to here as the P-L effect)
- plastic and strain-hardening deformations
- semi-rigid action of the joints.

Furthermore, structural imperfections, such as geometrical imperfections and residual stresses, generally degrade the performance of the whole system. Because of the interaction of different factors in structural performance, the analysis and design of steel frames cannot treat different modes of failure independently, even if they affect the design criteria of individual elements only.

In the past it was convenient to use simple behavioural models to trace different modes of failure separately, on the basis of element-oriented design concepts. Individual system elements were therefore required to satisfy a series of design criteria. Progress in computer analysis, the availability of personal computers (PCs) and powerful main frame units stimulated research towards new, more system-oriented design concepts, and towards the standardization of the behavioural models used in the various design situations in the area of steel structures.

The emphasis in structural design is