EFFECTS OF POST-HARVEST PRACTICES ON THE PRODUCTION AND NUTRITIVE VALUE OF MAIZE RESIDUES IN ZIMBABWE

Livestock Production Programme project R6993
(NRI project A0730)

1 October 1997 - 30 September 2000

Final Technical Report

J Morton, C Wood, S Ncube, R Coker, N Nyoni,
D Thomas and M Nagler

Acknowledgements

We would like to thank our colleagues at NRI and the Matopos Research Station, as well as colleagues on other LPP-funded projects in Zimbabwe and other participants in LPP's Inter-Project Workshops for their support and assistance in this project. Most of all we would like to thank the farmers of Bidi and Irisvale for participating so enthusiastically in this project.

This project was completed under the leadership of John Morton, who is responsible for the final form of this report. However, he would like to make a personal acknowledgement of the role of Chris Wood in identifying and designing the project, and leading it from its inception until August 2001.

This publication is an output from a research project funded by the United Kingdom Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID. R6993 Livestock Production Research Programme.

EXECUTIVE SUMMARY

This report concerns a project implemented by NRI and the Matopos Research Station between 1997 to 2002 to research improved methods of storing stover (maize residues) in Zimbabwe's communal areas, given the heavy reliance on stover as a livestock feed in the dry season, and observations that stover stored traditionally risked both loss of nutritive value and mycotoxin contamination.

Having chosen a suitable site at Bidi, about 130 km south of Bulawayo in Natural Region V, the project used both participatory and structured research methods to understand the role of stover storage in farming systems, and confirmed its comparing traditional unroofed stores with roofed stores. Because of a large knowledge gap on the variance of nutritional and mycotoxicological parameters between and within stores, and on apprpriate methods of sampling, the project moved to on-farm but researcher-managed trials using stores built of durable but relatively expensive materials. During the second year, volunteer farmers designed and built their own stores of more appropriate materials, with minimal help from the project.

Results from the natural science components of the project were inconclusive. There was no consistent pattern of the roofed stores conserving nutritive value better than unroofed stores. While the presence of various mycotoxins was reported, this was not at levels in excess of any current regulations or guidelines for livestock feed, nor was there any indication that carry-over of mycotoxins into milk for human consumption was a concern.

Results from farmer interviews suggested that farmers' reasons for wanting improved storage were complex, but principally revolved around the desire to prevent large-scale losses of stover to relatively major dry-season rainstorms, which can rapidly cause the entire store to become unpalatable and unusable. At the same time, monitoring of farmers using trial stores in Bidi, and farmers constructing roofed stores as a result of contacts with the project but without project assistance in the Irisvale Resettlement Area (and to a lesser extent in other areas) suggested that the technology was in fact far more likely to be adopted in slightly better-off and more market-oriented communities of livestock keepers.

CONTENTS

ANNEXES

Tables and Figures

I BACKGROUND

This report concerns a research project originally entitled "The Effect of Harvest and Post-Harvest Practices on Production and Nutritive Value of Maize and Sorghum Residues", which was implemented by NRI and the Matopos Research Station between October 1997 to May 2002. The project was founded on:

- the fact that smallholders practising mixed crop-livestock farming in Zimbabwe's Communal Areas rely heavily on residues from human food crops for fodder in the dry season, and
- observations that these residues were stored exposed to sun and rain, with a risk of both loss of nutritive value and of mycotoxin contamination.

In Zimbabwe, native pasture is the main source of nutrients for livestock in the wet season, whilst residues from crops grown for human food, of which maize stover is the most plentiful, are used in the dry season (Smith *et al.* 1990, see also Mupunga and Dube 1993). Wolmer *et al.* show that over 80% of cattle owners in each of four sites across Zimbabwe's Natural Regions IIA to V use crop residues as dry season feed. Crop residues can be stored and fed to animals (principally cattle) in the kraal, or grazed *in situ* in the fields once the harvest is in. Ndlovu and Sibanda (1990) report that in 1987, Communal Area farmers harvested two million tonnes of maize residues and 80,000 tonnes of sorghum residues. Utilisation of crop residues as feed is conventionally seen as a key part (together with draught animal power and management of manure for soil fertility) of a mixed farming model that is the natural end-point of a process of crop-livestock integration that is driven by growing human population densities (see Scoones and Wolmer 2002 for a critical discussion of this view). By this view, the use of crop residues can compensate for the loss of the grazing resource as a result of increased cultivation, and help reduce the overstocking of native pasture that can cause land degradation (Thomas and Barton, 1995). In fact, as Wolmer *et al.* (2002) point out, there is no simple relation in Zimbabwe of management of crop residues either with the agricultural "potential" of the area or with relative resource scarcities: residue storage and other "intensive" fodder management strategies are used seasonally in the drought-prone Chikombedzi area of Natural Region V.

The situation in Zimbabwe is mirrored elsewhere in dryland Africa: up to 80% of the feed consumed by cattle during the peak months of the dry season in sub-Saharan Africa can be derived from the residues of crops (Sandford 1989), with some 60-100% of leaves utilised compared to 40% of the stalks.

Although levels of crude protein and phosphorus in the residues of fertilised crops can be two or three times higher than those available from native pasture in the dry season (Thomas and Barton,1995), crude protein contents are still low and crude fibre levels high in relation to animal requirements (Smith *et al.*, 1990). In addition, crop residues are often wasted or inefficiently used in smallholder farming systems. Harvesting practices can reduce the availability of leaf material, whilst there is scope to improve the traditional methods of storage of crop residues. During the wet season, crops may be attacked by termites and by fungi capable of producing mycotoxins, whilst out-of-season rainfall can cause leaching of the soluble components, reducing the nutritive value still further. Mycotoxins can seriously affect animal performance and human health as they pass into the food chain through the milk. Previous studies in

Zimbabwe, conducted by Wareing and Medlock (1992) at the Natural Resources Institute (NRI), identified a number of potentially mycotic, allergenic and mycotoxigenic species of *Aspergillus, Penicillium, Fusarium, Alternaria, Phoma* and *Cryptococcus* in maize and sorghum stovers. However, detailed mycotoxin analysis was not undertaken.

The objective of this project was to evaluate the effects of harvest and post-harvest practices on the production and quality of maize and sorghum stover, and develop methods to improve its availability, nutritional value and safety as an animal feed. Harvest management (e.g. methods of harvesting and cutting height) and post-harvest storage methods (e.g. *in situ* versus removal and storage under cover) will affect the yield, nutritive value and safety of crop residues. Existing agronomic practices at harvest and storage methods were to be surveyed; losses in nutritive value estimated using the *in vitro* gas production method (Prasad *et al*.,1994); and fungal and mycotoxin contamination of crop residues and milk assayed. The gas production method was preferred to alternative methods as it measures the degradation of soluble carbohydrate as well as the fibre fraction. It was anticipated that losses in quality will be mainly due to changes in the soluble fraction of the stover. Cost-effective interventions to reduce the decline in nutritive value and prevent fungal contamination were to be identified and tested on-farm in the semi-arid Matobo region of Zimbabwe.

Rainfall and possible damage to stover quality

The benefits of covered stover stores will depend on the extent of losses which they are preventing, which in turn depends to some extent on rainfall. Rain followed by mould attack when stover is being stored, normally the June to August "winter" period (although this does vary from farm to farm and from year to year), can cause severe damage to the stover and should be largely prevented by using roofed stores. Monthly rainfall data from Matopos Research Station was obtained for the 37 years prior to the project (1961 to 1997) to indicate the frequency and extent of winter rainfall and hence give some basis for estimating the benefits of using roofed stores.

The rainfall data is given in Table 1 below. Rainfall was recorded in 18 of the 37 years over the June to August period, there being no obvious pattern to the distribution of years with wet winter seasons. However, rainfall in this period is clearly common. Over the 37 year period June to August rainfall averaged 3.7 mm (standard deviation 6.48 mm). Above average rainfall fell in 12 of the 37 years, the highest being recorded at 30.6 mm in 1982 (a year with a strong El Niño phenomenon). It is unknown what the relationship is between rainfall and extent of stover damage. Mists can occur which could facilitate mould attack even though recorded rainfall may be low. However, it appeared reasonable to conclude that the stover is exposed to rain-related damage in one in every two or three years. Protection from the sun and increasing the storage period into the start of the wet season are additional advantages which would occur every year.

Table 1 Rainfall at Matopos Research Station, July 1960 to June 1997
(above average values in **bold**)

Year (July to June)	Total rainfall (mm)	June + July rainfall (mm)	June to August rainfall (mm)
1960-61	839.1	**7.7**	**11.7**
1961-62	495.4	0	0
1962-63	704.5	**7.2**	**7.2**
1963-64	339.9	0	0
1964-65	412.0	0	0
1965-66	483.6	**4.3**	**4.3**
1966-67	629.2	0	1.2
1967-68	364.5	0	0
1968-69	606.9	0	0
1969-70	336.3	**4**	**4**
1970-71	492.1	0	0
1971-72	676.1	0	0
1972-73	394.6	1.2	1.2
1973-74	974.6	3.2	**6.2**
1974-75	832.1	0.6	0.6
1975-76	686.7	0	0
1976-77	696.6	0	**14.6**
1977-78	986.0	1.9	1.9
1978-79	416.0	0.3	0.3
1979-80	568.2	**3.3**	3.3
1980-81	753.7	0	0
1981-82	380.9	**21.1**	**30.6**
1982-83	382.5	**11.3**	**15.5**
1983-84	344.4	**4.5**	**4.5**
1984-85	546.5	0	0
1985-86	504.8	0	0
1986-87	325.2	0	0
1987-88	778.2	2.1	**8.4**
1988-89	415.3	0	0
1989-90	445.7	0	0
1990-91	547.1	0	0
1991-92	241.0	0	0
1992-93	519.5	**9.2**	**9.2**
1993-94	439.9	0	0
1994-95	475.6	0	0
1995-96	830.6	**13.6**	**13.6**
1996-97	617.7	0	0
Average	***552.1***	***2.6***	***3.7***

II PROJECT PURPOSE

The project purpose was to identify losses in nutrients of stovers harvested and stored under existing conditions and develop improved harvesting and storage practices which reduce these losses.

The three main developmental problems identified were:

(i) Shortage of roughage for cattle in smallholder systems in the dry season resulting in low productivity.

(ii) Low nutritive value of maize and sorghum stovers and contamination with mycotoxins, a potential health hazard.

(iii) Need for improved harvesting and post-harvest storage methods to reduce losses and fungal contamination on-farm.

The project was then intended to disseminate improved methods to local farmers and facilitate their dissemination more widely.

III PROJECT STRATEGY

In the Project Memorandum a strategy of identifying current practices and improvements was planned for year 1 of the project, followed by on-farm trials in years 2 and 3, operating in two communities.

It became apparent early on in the project that harvesting patterns were complex and varied between households, and the project's greatest chance of successful interventions lay in post-harvest storage. It was also decided to limit experimental work to maize residues as they are used much more than sorghum residues. Further discussions and field familiarisation stimulated a reconsideration of the experimental design. Loss measurement during storage would be facilitated by direct comparison between existing practices and improved stores. The lack of any comparable previous experience in sampling stored stover, and a fundamental lack of knowledge on what levels of variance (of nutritional and toxicological parameters) to expect meant that these comparative trials would need to be researcher-managed. For the further development and introduction of improved storage structures, a farmer participatory approach was considered most appropriate.

A revised strategy evolved during the project whereby one community was selected initially for researcher-managed trials on maize stover storage in Year 1. Due to time constraints the trial stores had to be constructed by the project using materials which would almost certainly be too expensive for local smallholder farmers. Year 2 would develop and construct lower cost structures using farmer participatory methods. Years 1 and 2 would be used for a technical evaluation of the impact of improved stores on feed quality. Improved techniques would than be extended to a second community in year 3 using a farmer participatory approach, with level of uptake being an indicator of the appropriateness of the intervention. Because of drought conditions during the project, resulting in stover not being exposed to any significant dry-season rains, a low-cost project extension of a fourth year was granted to allow additional collection of nutritional and mycotoxicological data.

In order to present a complex interdisciplinary project, this report does not present all project activities followed by all project results, nor the activities taken chronologically. Instead it is structured according to four broad components of the research, with research activities and results/outputs being reported under each component. The four components are:

- Surveys to identify field sites, explore the applicability of improved stover stores at the primary field site (Bidi) and identify trial farmers
- Construction of trial stores, sampling and laboratory evaluation of stored stover for nutritional quality and mycotoxins
- Participatory trials and qualitative monitoring in Bidi
- Dissemination of results to a second community (Irisvale) and qualitative monitoring of uptake.

IV PREPARATORY SURVEYS

Initial survey to identify field sites (Activity 1)

Gulati Communal Area, northwest of Matopos National Park, is relatively near Matopos Research Station (MRS), and has had good links with MRS in the past, so appeared to be a convenient field site for the work. After an introductory meeting, a series of individual semi-structured interviews were conducted with selected farmers. Interviews covered:

- The calendar of crop production and other agricultural activities
- Varieties of maize and sorghum planted
- Acreages of different crops planted
- Calendar of animal feed sources
- Calendar of labour demand
- Harvesting and storage of stover
- Condition and management of veld grazing
- Seasonal changes in animal conditions
- Livestock production objectives
- Social differentiation

A single group interview in Halale (southwest of the Park) covered most of the above topics, as did individual interviews with one farmer each in Sigangatsha and Bidi further south. This survey is described in more detail in Technical Annex 1A.

It was concluded that while it might be possible to carry out the research project as planned in Gulati, it was very likely that better sites could be found, still within a reasonable distance of MRS. The main reason for rejecting Gulati was lack of perceived interest in better storage of stover. This in turn related to:

- relatively low pressure on grazing because of de facto use of nearby commercial farms
- soil and water table conditions that give high returns to soil fertility management, so that stover is valued as much for incorporation (in a trampled but uneaten state) as for feed
- and probably to a relatively commercialised economy, that allows some farmers to purchase concentrates and commercial feeds during the dry season.

The following criteria for selecting a site or sites were proposed:

- reasonable availability of maize and sorghum stover
- average or worse than average grazing pressure
- perceived farmer interest in better/longer storage of stover
- relative ease of access from MRS.

It was recommended that rapid appraisals be carried out as soon as possible in several further sites. These comprised Bidi, 130km south of Bulawayo, Silozwi Communal Area southeast of the National Park, and Irisvale, 85km southeast of Bulawayo.

Second survey of sites, conducted in Bidi, Irisvale and Silozwi (Activity 2)

In response to the recommendation from the initial survey, rapid supplementary surveys were conducted of nine to ten farms in each of three districts considered to be likely candidates for the trial introduction and evaluation of improved stores for stover. More detailed results are given in Technical Annex 1B. The original intention was to sample a range of farmers with livestock holdings and areas planted to cereals above and below a local average, but given the need also to focus on farmers with some interest in storing stover, in practice farmers surveyed were above average in both respects. Based on these data with all their limitations, labour availability and crop residue production appear to be similar in the three districts, although farm to farm differences within districts could be large.

Farm to farm differences in livestock holdings could be large, but there tended to be more goats in Bidi, more cattle in Irisvale while livestock appeared to be generally less important in Silozwi. These conclusions were also supported by the regional livestock data and general overviews of the three districts. Again the preference for goats in Bidi may be indicative of its more marginal nature, goats generally being preferred where there are problems in feeding cattle.

There was good agreement between all the farmers surveyed that the August to November period was when grazing was most restricted, and hence when stored stover may be particularly useful. Stover may be grazed in fields in August and September and taken from storage from September to November. Since the 1992 drought had led to the deaths of much livestock, particularly cattle, farmers also appeared to be interested in storing feed as a hedge against future droughts.

Eight of nine farmers surveyed at Bidi stored stover, nine of ten at Irisvale and nine of ten at Silozwi (although it was said that stover storage was not so common here). Raised platforms (*ingalani*) in kraals are used for storage in Bidi, in Irisvale storage methods include storage in bags, as silage and in an old water tank, while in Silwozwi rocks are widely used as bases for storage. Practices between farms are quite variable.

Without exception, all the farmers interviewed expressed an interest in improved and extended stover storage. The increased storage periods on interest ranged from one month to one year. At all three sites at least one farmer expressed interest in storing stover for as long as one year as a hedge against drought. Early/dry season rains and the effects of the sun were seen as the major storage problems by nearly all farmers. Late rains also caused some spoilage. Lack of labour was a commonly given reason for not improving stores, lack of money, know-how and not thinking about it were other reasons given.

From these surveys, we concluded that sites where improved and possibly extended storage of stover is most likely to be of use to farmers, and hence is most likely to be adopted, would be where:

- livestock, particularly cattle, are important;
- cereals are grown on a sufficient scale to generate enough stover for storage;
- alternative dry season feeds are in limited supply;
- where droughts could lead to losses of livestock.

All three of the sites surveyed appeared to have the desired characteristics to some extent. Bidi was the most marginal of the three sites, and appeared to be the most suitable of the three for introducing improved stores for stover. Although cattle numbers were currently fairly low due to losses in the 1992 drought, they were said to be increasing due increasing calving rates and purchases. Irisvale also appeared suitable, but its status as a Resettlement Area was a complicating factor.[1] Silozwi is perhaps the least suitable as livestock appears to be a less important element of the mixed farming here, although it was said that cattle numbers are set to increase as more grazing land is being made available. Although most crop residues were said to be currently used for manure/compost this situation could change in the future, and indeed this survey indicated considerable interest in the storage of at least some of the stover.

Therefore Bidi was chosen as the site for the initial trials, with Irisvale chosen for later farmer participatory trials.

Identification of farms for initial trials (Activity 3)

Further survey work was undertaken in April 1998 to identify 10 farms in Bidi which would be suitable and willing to collaborate with the first round of trials. This is further discussed under Section V, Activity V.

Wider surveys of farmers in Bidi and Irisvale (Activity 4)

The initial surveys of Bidi (Activity 2) were undertaken rapidly, and although intended to capture a range of farmer-types had in practice been directed towards households with an interest in storing stover. The farmers that would be chosen for the Mark 1 (and the later Mark 2) trials were self-selected and (it emerged) well above local averages for livestock holdings and area planted. It was therefore decided to carry out a wider and more rigorously sampled survey in Bidi in mid-1998, to investigate the representativeness of the trial farmers, to obtain a broader picture of harvesting practices and to assess the likelihood of wider uptake.

A list of farm households, used by extension workers for the distribution of free seeds etc., proved to be unreliable when used as a basis for identifying farmers to survey. Alternative, nearby householders were surveyed when the named household was not appropriate (e.g. absentees or destitute old people who did not constitute an agricultural household). Ten further households for collaborating with the introduction of lower cost, Mark 2, roofed stover stores were identified as a by-product of the survey. However, due to extreme drought conditions, only very limited information on stover storage was obtained.

In November 1999, by which time the project had initiated contacts with Irisvale Resettlement Area, a simplified questionnaire was administered to 41 farmers in Irisvale and 31 in Bidi. Full results are given in Technical Annex 1C.

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[1] Irisvale was formed from a group of white-owned ranches that were acquired in a willing-seller, willing-buyer basis by the government during the early 1980s and used for resettlement on a mixed crop-livestock basis.

Table 2: Summary and Comparison of Key Findings, Bidi and Irisvale

	Bidi (n=31)	**Irisvale** (n=41)
Average number of adults available for work on farm	4.1	3.4
Households keeping cattle	26%	100%
Average cattle holding	12.50 (cattle-owning hhs) 3.23 (all hhs)	18.06(cattle-owning hhs) 15.85 (all hhs)
Average goat holding	10.74	5.34
Average donkey holding	3.29	1.85
Households purchasing livestock feed	0%	34%
Households purchasing livestock salt	19%	7%
Planting choices - cereals	97% planting maize, sorghum, pearl millet. 16% households planting finger millet.	100% planting maize. 13% planting sorghum, 5% planting pearl millet
Planting choices- other	94% bambara nut, 84% groundnut. Cowpea, sunflower	82% bambara nut, 72% groundnut. Cowpea, sweet potato, sunflower, sugar peas, coffee
Average area - maize	1.66 acre	5.85 acres
Average area - sorghum	1.85 acres	n/a*
Average area - groundnut	0.72 acres	0.6 acres
Average area - bambara nut	0.73 acres	0.80 acres
Average total planted area	6.97 acres	7.59 acres
Major cultivation problems - maize	1. drought/poor rainfall 2. too much rain/waterlogging 2. poor fertility/lack of fertiliser/manure	1. drought/poor rainfall 2. stalkborer 2. poor fertility/lack of fertiliser/manure
Households using traditional ingalanis - maize	26%	21%
Households using traditional ingalanis - sorghum	19%	0%
Households using traditional ingalanis - groundnut	29%	1%
Households who had heard of roofed stores	84%	49%
Households who had seen roofed stores	71%	39%
Households building or planning to build roofed stores	23%	15%

Table 2 (contd.)

	Bidi (n=31)	**Irisvale** (n=41)
Reasons for not having built roofed stores	1. shortage of time/labour 1. shortage of grass 3. no animals	1. Shortage of time/labour 2. Shortage of grass 3. Lack of info./confidence
Households storing green stover/stover from green maize	1%	0%
Households reporting spending time or money building/repairing stores	13%	24%
Households salting, chopping or mixing stover	19%	27%
Households recording losses of stored stover	26%	1%
Months stover most likely to be fed from store	1. September 2. October 3. August	1. September 1. October 3. August
Months stover most likely to be named as most important feed	1. September 1. October 3. August	1. September 2. October 3. August
Households who would like to feed stover into November	16%	7%

NB: all Bidi data expressed as percentages uses n=31. Irisvale data expressed as percentages uses n=39 for questions relating to 1998 crop planting and 1999 residue storage specifically, and n=41 for other questions.
* Only 5 farmers in Irisvale, cultivated sorghum with a total area of 3.5 acres, a negligible amount when averaged across 39 farmers.

As could be expected from Irisvale's relatively privileged status as a Resettlement Area, there are major differences between the two sites. Bidi farmers, still apparently not recovered from cattle losses in 1991-92, had also suffered heavy losses of goats to disease and parasites. Average livestock holdings in Irisvale are far higher, and much more concentrated on cattle (11 households own cattle but not goats, which is virtually unheard of in Communal Areas). Over a third of Irisvale households, and no households in Bidi purchase livestock feed (excluding salt). This supports what we already knew about the more commercial orientation of at least some livestock producers in Irisvale. In both sites, there appears to be free grazing, at least within villages or neighbourhoods, of harvested fields. Although a number of farmers regard this state of affairs as a problem, it seems unlikely to change (e.g. through fencing). In the long run this favours the adoption of stover harvesting and storage.

Perhaps surprisingly, total cultivated area was not on average very different in the two sites, although it was more unequally distributed in Bidi. The Bidi farming system gives equal importance to maize, sorghum and pearl millet, while the Irisvale farming system is very heavily centred on maize to the exclusion of other cereals. Bambara nut and groundnut are important minor crops in both. In Irisvale, there is a greater range of minor crops cultivated by one or two farmers in the sample.

Both areas had been afflicted by drought in the 1998-99 growing season, though not it would seem as badly as in 1997-98 or 1991-92. In both areas some farmers also reported soil fertility problems, and/or shortages of manure and fertiliser. A great range of crop weeds, pests and diseases were reported, most notably *striga* in Irisvale. Some Bidi farmers reported waterlogging problems when rain did come.

As regards storage practices, the surveys demonstrated that only a minority, although a significant minority, in either area, invested effort in building and maintaining crop residue storage structures. In Bidi, around one-quarter of farmers have traditional *ingalanis*. In Irisvale, farmers are less likely to have traditional ingalanis, but more likely to store stover ad hoc in huts, kraals or around the courtyard. However, Irisvale farmers are more likely to experiment with salting stover or mixing it with more nutritious feed (27% compared with 19%), and in spending time or money building or maintaining residue storage structures (24% compared with 13%). Expressed concern about storage losses, and expressed desire to extend residue storage time, were very low in both sites. The area of maize and sorghum planted per livestock unit[2] is 0.46 acre in Bidi and 0.32 acre in Irisvale, but it is possible that higher yields in Irisvale would more than compensate for such a difference, and it would be hard to know how to interpret a difference anyway (more stover per livestock unit could make stover storage less or more likely).

Within each community, it was hard to identify easy indicators for readiness to adopt improved storage. Average cattle holding was not significantly higher than average for those reporting spending time or money on storage structures in either community, and in Bidi a number of those maintaining storage structures were cattle-less. Households investing in storage tended to have more adults available than the average (5.4 against 4.1 in Bidi, and 4.7 against 3.4 in Irisvale), though with small sub-samples these figures are of dubious significance. But other answers did suggest the importance of labour shortage and difficulties in obtaining thatching grass in deterring improved storage. Dissemination efforts based on the project must bear this in mind, and there should be a continued search for low labour input storage methods, and methods which use alternatives to hard-to-obtain thatching grass.

In both areas, enthusiasm for stover storage has probably been diminished by drought and poor harvest, but these are facts of life in Southern Zimbabwe. In the longer term, population and grazing pressure, allied to the social difficulties of preventing others' cattle from grazing in harvested fields, is likely to favour adoption of improved storage. In the medium-term, even in better years, the surveys taught the project that improved stover storage is likely to remain the concern of a minority in both sites.

[2] Using a rule of thumb for current purposes of bovine=1, shoat =0.2, donkey =0.5

V. CONSTRUCTION OF TRIAL STORES, SAMPLING AND ANALYSIS OF STOVER

Research Activities

Construction of trial stores (Activity 5)

As the initial surveys to identify sites had taken longer than expected, and an early end to the rains meant that the harvest would have to be early, there was a need to store stover within a matter of weeks of identifying the collaborating farms. There was also a specific problem of experimental design. In researching the effects of stover storage on both nutritional value and mycotoxin levels, the researchers were faced with a lack of knowledge on the variance of nutritional and mycotoxicological parameters within and between stores, and therefore what sample sizes would be appropriate. Maize stover is relatively large and heterogeneous compared to materials such as grains or maize cobs. Maize stover stores are haphazard piles of loose stalks, many up to 1.5 metres long. All of the biological processes under investigation will have different effects on stover, depending whether it is at the bottom, middle or top of the heap, and in the middle or towards the outside: many individual stalks run from the middle to the outer edges of the heap. Representative sampling was therefore of critical importance, but there was no scientific evidence to produce a suitable sampling protocol. A major aim of the first year's trial was to provide data on which the first year's protocol could be evaluated and improved upon, if necessary.

Because of these problems, it was necessary to run researcher-managed trials in Year 1, in order to have the necessary methodological foundation for more participatory trials in subsequent years. One aspect of these trials had to be the clearest possible difference between the improved stores and traditional unroofed storage. For all these reasons the first round of trials used store designs and materials too expensive for farmers to afford unassisted.

The ten farms collaborating with the on-farm storage trial were identified and visited to take the initial stover sample and review existing storage facilities. The list of farms is given in Table 3. In all cases the harvest was much further advanced than is usual at this time of year. This is because the rains stopped early, effectively ending in January instead of March or April. This may have been due to the "El Niño" climatic phenomenon which was particularly strong in 1998. As a result, the late sown maize had largely dried early in the fields, making the harvest early and poor. This has several implications. The harvest was earlier than usual limiting the time available for the planning and construction of improved stores. The stover was going into storage much drier than usual making the leaf material much more likely to fragment and be lost. Risk of mould attack and mycotoxin accumulation were conversely probably greatly reduced for this initial period. Stover (as well as grain) production was appreciably reduced compared to more average conditions. Green grazing was already starting to dry out, earlier than usual, indicating that stover will have to be used earlier than usual. Therefore particular pressure on feed resources such as stover was anticipated during the 1998 dry season.

Table 3: Farmers included in on-farm trial

Farm No	Place	Farmer
1	Bidi	Mrs Ndiweni
2	Bidi	Mrs S Ndiweni
3	Bidi	Mr R Dube
4	Matshina	Mrs P Phuthi
5	Matshina	Mrs P Moyo
6	Matshina	Mr M Ndhlovu
7	Tshipisani	Mrs M Ndhlovu
8	Tshipisani	Mrs Maphosa
9	Lingwe	Mr R Nyati
10	Lingwe	Mr M Ndebele

Existing storage facilities are summarised in Table 4. More details can be found in the relevant visit report in Technical Annex 2A.

Table 4: Existing storage facilities at farms included in on-farm trials

Farm number	Size of store enclosure	Size of storage platform	Height of platform above ground
1	large enclosed field	platform to be built	
2	will put wire fence around store	planned 6 x 4m	planned 1m
3	store in large home compound	platform to be built	
4	small 7 x 7m	3 x 3 m	0.3m
5	18 x 18 m	6 x 2.5m	1m
6	very large	4 x 4 m	0.6m
7	30 x 30m	platform to be built	
8	round, 16 m diameter	3 x 2m	1m
9	10 x 10m	7 x 3m	1m
10	small, 7 x 7m	2 x 2m	0.3m

Farms 4 and 10 had only restricted space to build an improved store, the other eight farms appeared to have adequate space. Two of the ten farmers were already taking action to build their own roofed stores, stimulated by earlier contacts with the project. Also roof-like structures are quite commonly used to shade animals. This was very encouraging as if the roofed stores were found to be a worthwhile improvement on open platforms, farmers appeared to be able to have suitable structures constructed using locally available resources.

Outline designs were prepared for 5 x 4 m stores (for eight of the collaborating farms where space was not restricted) and for 3 x 3 m stores (for farms 4 and 10). The designs consisted of a corrugated asbestos sheeting roof supported by treated gum tree poles, materials which were puchased locally but which are probably too expensive for farmers to use themselves for this purpose (although they are used for house construction). The larger design of store cost about Z$7,000 in materials (about £256 at the then prevailing exchange rate).

Stover leaves are generally the most nutritious part of the stover. However, this material can be lost during handling and storage reducing the nutritive value of the stover as a whole. All 10 participating farmers were asked whether leaf loss from stover was seen as a problem and what steps they took to reduce it. Leaf loss was widely seen as a problem. Fragmented leaves were very much in evidence in the fields and farmers were aware of its value as a feed. This material is grazed in the fields, so it is not necessarily all lost if it does fragment from the stover. Farmers will also pick up the material if possible and feed it to cattle. Leaf loss was a particular problem in 1998 due to the exceptionally dry conditions. Normally the stover leaves are still a little moist when they are stored which reduces leaf loss. Stovers can also be handled after rain or early in the morning when there is a dew as the leaves are moistened to minimise losses. Fencing can be used to trap leaves, but collecting the material is laborious. None of the farmers could suggest a practical way of reducing leaf loss under such dry conditions. Indeed, it is difficult to see what can be done as the leaves dry out very much faster than the stover stems. As the stems must be dried sufficiently to prevent mould damage the leaves must inevitably be very well dried and liable to fragment. There was certainly awareness amongst the farmers that moist leaves were less likely to be lost by fragmentation.

Development of stover sampling protocol (Activity 6)

A sampling protocol, based on earlier experiences of other commodities, was developed by Prof. Coker for each of the ten participating farms for 1998.:

(a) In **April 1998** (*immediately after harvest)*: from throughout *the field*, collect a single 5kg (approximately) composite sample, composed of fifty stovers. The analysis of this sample will determine the nutritional and safety status of the stover immediately after harvest.
(From the ten participating farms: 10 x 5kg samples, in total)

(b) In **May 1998**: an *improved* storage method, developed by staff at Matopos Research Station in collaboration with selected farmers, should be introduced. An *existing* store, of similar capacity to the improved store, should also be selected. Stored stover should be equally distributed between the existing and improved stores, until the improved store is fully utilised.

(c) During **May-June 1998** (*at the beginning of the storage period)*:

from throughout the *existing* storage area, collect the equivalent of fifty complete stovers (each stover representing an approximately 100g incremental sample) and combine as 5 x 1kg subsamples;
(From the ten participating farms: 50 x 1kg subsamples, in total)

from throughout the newly developed *improved* store, collect a single 5kg (approximately) composite sample, composed of fifty stovers.
(From the ten participating farms: 10 x 5kg samples, in total)

(d) *Using the 50 x 1kg subsamples generated by the ten **existing** stores, evaluate the variability associated with sampling for mycotoxins in stored cereal stover, and the efficacy of a sampling plan involving 5kg composite samples:*

- *In the first instance, the mycotoxin content (and nutritional status) of 25 x 1kg subsamples (from five farms) should be determined, and the results of a statistical analysis of these data used to either confirm the suitability of a 5kg composite sample (or to design an alternative sampling plan)*
- *Additional 1kg subsamples should be analysed if the statistical data generated by the analysis of 25 x 1kg subsamples is insufficient to evaluate the efficacy of the proposed sampling plan*

(From the 5 - 10 participating farms; existing stores: 25 - 50 x 1kg subsamples)

(e) During **October-November 1998** (*at the end of the storage period)*: from both the *existing* and *improved* stores collect and analyse a single 5kg composite sample (if suitability confirmed; see paragraph 11(d), above).
(From the ten participating farms; existing stores: 10 x 5kg samples;
improved stores:10 x 5kg samples, in total)

An appropriate sample preparation procedure should be developed at Matopos Research Station, which will facilitate the conversion of composite samples into comminuted, representative subsamples. A process involving the combined chopping, comminution and mechnical division of stover stems is anticipated.

In the first instance, representative subsamples of the composite samples should be combined to produce a small number of 'combined samples' which should, in turn, be screened for a selection of mycotoxins (including aflatoxins B_1, B_2, G_1 and G_2; ochratoxin A; deoxynivalenol; T-2 toxin; fumonisin B_1; moniliformin; altenuene, alternariol, altertoxins and tenuazonic acid). Finally, the mycotoxin content of the individual composite samples should be determined, focusing upon those mycotoxins identified in the 'combined samples'.

The number of samples analysed annually, *per commodity,* may be summarised as follows (assuming a single population of ten farmers):

• in the field;	10 x 5kg samples
• at the beginning of storage;	25-50 x 1kg subsamples (existing stores)
	10 x 5kg sample (improved stores)
• at the end of storage;	10 x 5kg samples (existing stores)
	10 x 5kg samples (improved stores)
• *Total*	*40 x 5kg samples*
	25-50 x 1kg subsamples

The protocol described in paragraphs 11-13, above may be shown schematically **for each farm**:

Immediately after harvest; May 1998

In the field

50 x stovers

↓

5kg sample

At the beginning of storage: May - June 1998

Existing store	**Improved store**
50 x stovers	50 x stovers
↓	↓
5 x 1kg subsamples	**5kg sample**

At the end of storage: October - November 1998

Existing store	**Improved store**
50 x stovers	50 x stovers
↓	↓
5kg sample	**5kg sample**

Stover sampling 1998 (Activity 7)

Time 1 sampling, mid (16 - 20) April 1998

The ten farms were visited from 16 to 20 April for stover sampling, immediately after harvest when stover was still in the fields (standing or stooked). Sampling was intended to give a composite sample representative of the maize stover to be stored. Fifty stovers from each farm were taken for the sample (about 5kg). If the stovers were in stooks or stacks, which was mainly the case, an approximately uniform number of stovers was taken from each stook/stack. Stovers were taken from different parts of the stook/stack at random. Standing stover was sampled by taking stovers at regular intervals from different parts of the field. Where some stovers were in stacks and others still standing, a by-eye judgement was made on the proportion of stover in each category and the sampling adjusted to reflect this proportion. Cobs were removed from the stovers leaving the leaf sheath as is usual here. Failed plants which contained small poorly developed cobs were sampled with these cobs as it is usual practice to leave these with the stover. On returning to Matopos, the samples were sorted and well dried material replaced in plastic sacks, moist material was laid out to sun dry surrounded by netting intended to trap leaf material which may fragment and be lost. Clearly the maize stover was somewhat heterogeneous in terms of its state when sampled. Time of sowing was clearly an important factor as well as timing and management of the harvest and stover.

Time 2 sampling, early (1 - 5) June 1998

Sampling was completed during a visit by Prof. Coker to Zimbabwe, as outlined in the protocol, at the start of the storage period. Although the farmers had been asked to add equal quantities of stover to their traditional and new stores, some farmers had not achieved a uniform distribution of stover. Mr Ncube and Mr Nyoni were briefed on the sampling method, and participated in the time 2 sampling. The June sample from the open store was collected as ten samples of 5 stovers each, taken from different parts of the store in order to estimate the variability of the samples.

Time 3 sampling, mid (12 - 17) September 1998

The 10 collaborating farms (Farms 1 to 10) were sampled as per the protocol for the final time for the 1998 trial during Prof. Coker's September 1998 visit to Zimbabwe, towards the end of the storage period. The time 3 sample from the existing store was not available from farm 6. It was decided to use a new farm as an alternative (farm 11; Mr Ncube at Bidi), and construct a Mark 1 store there, as collaboration had been generally unsatisfactory on farm 6. The partial drought had meant that relatively limited quantities of stover had been available for storage, so that there was no extra stover available for storage into the start of the wet season.

The samples obtained were coarsely ground in Zimbabwe, after further drying as required. They were air freighted to the UK where they were subjected to riffle division, ground to1mm particle size, and stored in a chill store at 4^oC prior to analysis.

Lower cost (Mark 2) stores constructed in Bidi (Activity 8)

During this activity, farmers were asked to design their own stores using materials which were available to them. The project gave some assistance with the provision of some materials and labour if required, but the Mark 2 designs were intended to be suitable for adoption without external subsidies. The collaborating farmers were all aware of the Mark 1 improved stores. The availability of thatching grass for the roof and the 3 longer mopane poles for the central supports of the structure (for a ridge style roof) were seen as the major constraints. These materials were therefore supplied in part by the project to facilitate the construction of these stores. In the case of the thatching grass this was mainly because thatching grass would normally be cut in the dry season (from the Matobo Hills area) after the time for building stores, and trial participants had not been identified sufficiently far in advance to do this themselves.

Ten farms in Bidi Ward were selected for the construction of Mark 2 improved stores, during the harvest season 1999, and monitored during construction in May 1999.

Table 5: Farms for Mark 2 store construction

Farm No	Place	Farmer
21	Matshina	Mr B Ndebele
22	Bidi	Mrs J Ncube
23	Bidi	Mr and Mrs A Moyo
24	Matshina	Mrs D Ngwenya
25	Matshina	Mrs S Dube
26	Matshina	Gabriel Ndebele
27	Tshipisani	Mr J Ncube
28	Matshina	Mrs A Moyo
29	Matshina	Mrs E M Ndebele
30	Bidi	Mr and Mrs J Ndlovu

More details of the design and cost of these stores are given under Activity 12, Section V and in Technical Annex 1D.

Of 10 original Mark 2 farmers, two had joined the project for spurious reasons and never built stores.[3] One Mark 1 farmer (Farm 5) spontaneously built his own Mark 2 store, and by September 1999, on two of the collaborating farms identified for Mark 2 stores (Farms 21 and 25), a second Mark 2 store was also constructed on the farmers' initiative. These additional Mark 2 stores received no subsidies or materials from the project.

Stover sampling 1999 (Activity 9)

Based on data from the 1998 sampling, a revised sampling protocol was put into effect in 1999 (See Figure 1). A discussion of the sampling plan in given in the Technical Annex 2B. Three farms were selected from the ten with Mark 2 stores. Ten replicate 1kg samples were taken from each store (traditional open store and the Mark 2 roofed store) at each of two sampling times, at the beginning (26 - 30 July 1999) and towards the end of the storage period (from 13 November 1999).

In the first instance, a representative subsample was collected from each 1kg sample, and the samples combined to afford a composite sample, which was screened for mycotoxin contamination. The balance of each 1kg sample was further analysed if the composite sample contained significant levels of mycotoxin(s).

The 1998/99 wet season had seen good rainfall at Bidi, although as in the previous year it had ended early. There were good maize and sorghum harvests generally, and so there was plenty of stover, but a shortage of alternative feed. Encroachment of cattle into fields of standing stover had reduced its availability for storage in several cases. Time 1 sampling was conducted in late (26 - 30) July 1999, Time 2 sampling in mid (from 13) November 1999.

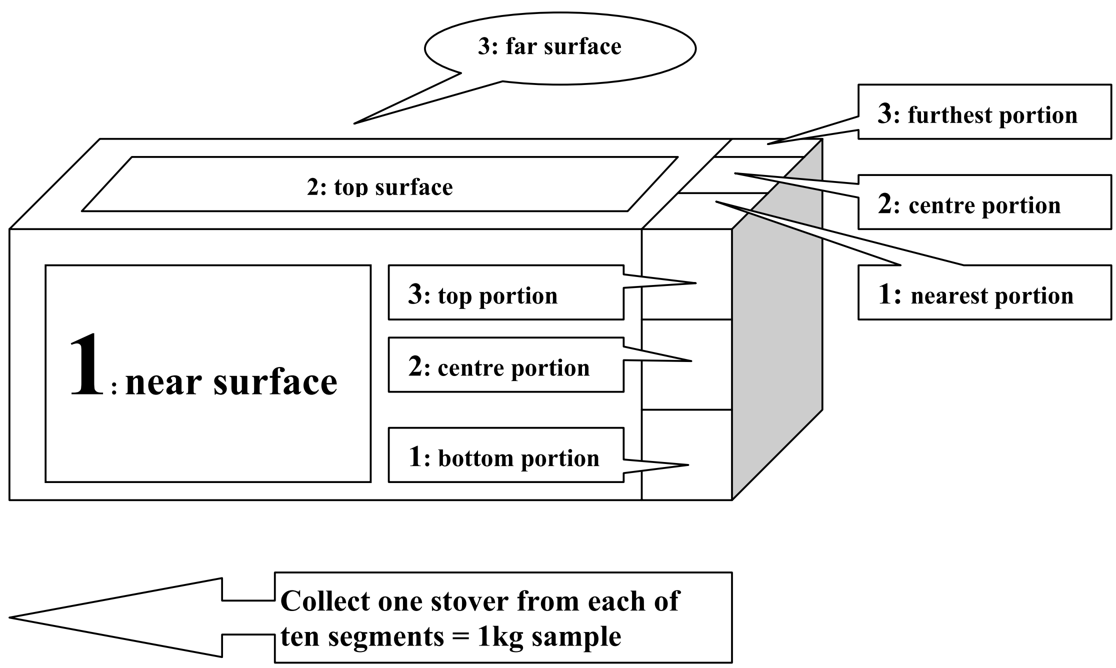
[3] Farms 26 and 29. The farmers had wished to gain access to free building materials and had threatened the extension worker with sorcery in order to get on the list.

Figure 1 Sampling plan for collection of samples of maize stover

Each store to be sampled as follows:

1. Each 1kg sample to be composed of 10 stovers collected randomly from throughout the store, as follows:
    - Divide the store, lengthwise, into *ten equal segments* using long canes as markers
    - Beginning at one end of the store, collect a single stover from the *first segment*, as follows:
        - Use three cards numbered 1, 2 and 3 to identify the sampling point within each segment
        - Firstly, randomly select **one** of the cards to identify the *surface (NB* samples are not collected from the two end surfaces):
            - Card numbered 1 = select near surface (to the person with the cards)
            - Card numbered 2 = select top surface
            - Card numbered 3 = select far surface
        - Secondly, randomly select **one** of the cards to identify the *portion* of the selected surface, assuming that each surface is divided into *three equal portions*:
            - Card numbered 1 = select bottom portion of near/far surface, or nearest portion of top surface (to the person with the cards)
            - Card numbered 2 = select centre portion of any surface
            - Card numbered 3 = select top portion of near/far surface, or furthest portion of top surface
        - Collect a **single stover**, from the identified *sampling point*, by removing the stover from any point within the selected portion

2. Repeat the process for each of the *ten segments*, in order to produce a **1kg sample**
3. Repeat the above steps, collecting a total of **10 x 1kg** samples from each store



Stover sampling 2000 (Activity 10)

Since there were little or no dry season rains during 1998 and 1999, further samples of stover were collected during 2000. Samples were collected at the beginning and end of the storage period (on 21 and 22 June and during November 2000). The experimental design, sampling, sample preparation and gas production methodology was the same as that used in 1999. However, because of a shortage of stover on farms possessing participatorily constructed Mark 2 stores, the project reverted to using sampling stover from Mark 1 stores with asbestos sheeting roofs, and open stores on the same farms: Farms 5, 9 and 10. The June samples had been exposed to rain (77.6 mm at Kezi) in early June, prior to sampling. There was no rain recorded in July, August or September, then 3.5mm in October, 65.3mm in November. June samples could not be regarded as truly representing stover at the start of storage as samples from the open stores may have already been subject to significant damage.

Laboratory evaluation of stover samples (Activity 11)

Stover samples were analysed for chemical composition, in vitro digestibility (by the gas production method) and for mycotoxins.

In vitro gas production

The gas production protocol was based on the Theodorou *et al*. (1994) method and is detailed in Technical Annex 2C. Samples were incubated in a nitrogen rich medium using a dilute inoculum as described by Wood *et al*. (1998). Gas production data was fitted to the France *et al*. (1993) model which estimates two rate constants, lag time and end point of gas production (gas pool A). Additionally, dry matter disappearance (DMD) at the end of the 96 h incubation period was estimated by filtration. Means were calculated and t-tests comparing parameters for the roofed and open stores on each farm were undertaken using Genstat (version 5, release 4.1, Lawes Agricultural Trust). Data for the DMD, cumulative gas production after 12, 27, 48 and 96h incubation (CG12, CG27 and so on), rate constant b and other parameters of the France et al. (1993) model were analysed to explore differences between the samples. Data for CG96, the longest incubation time, DMD, as an indicator of the extent of degradation, and for rate constant b, as indicator of the rate of degradation, are presented. Other parameters were explored for evidence of differences between samples.

For the year 2000 samples, initially the November samples only were analysed to see if there were significant differences between stover samples from roofed and open stores at the end of the storage period. Where significant differences were found, July and November samples from the relevant farm were re-evaluated in a second gas production experiment to test if there were differences in the July samples from the open and roofed stores, and to examine changes during the four month storage period.

Analysis of composition

Beside the in vitro gas production analysis, stover samples were subjected, at Matopos Research Station, to conventional analysis of chemical composition. Ash and Crude

Protein were determined by Proximate Analysis and fibre (Acid Detergent Fibre and Neutral Detergent Fibre) by the detergent methods of Van Soest.

Mycotoxins

The following mycotoxins were determined using standard operating procedures, involving a combination of solid phase extraction clean-up and high performance thin layer chromatography (HPTLC) or high performance liquid chromatography (HPLC): aflatoxins B_1, B_2, G_1 and G_2, fumonisin B_1, deoxynivalenol, T-2 toxin, zearalenone, and ochratoxin A. (Deoxynivalenol and T-2 toxin were determined from Time 2 collection, November 1999, onwards after the presence of zearalenone/*Fusarium* moulds in samples from farm 22 had been demonstrated at the beginning of the storage period.)

Research Results

Laboratory evaluation of stover samples 1998

The complete sample set was obtained from 8 of the collaborating farms. One farm was withdrawn from the experiment due to poor collaboration, all the stover in the open store was used at sampling time 3 for a second farm. Only data from the 8 complete data sets are reported here.

In vitro gas production

The means by farm and sampling time for roofed (Mark 1) and open (traditional) stores for selected gas production parameters are given below in Tables 6, 7 and 8 for CG96, DMD and rate constant b respectively. CG96 and DMD estimate the extent of digestibility of the stover, rate constant b its rate.

Table 6: Stover sampling 1998: cumulative gas production (CG96) (ml/g dry weight of feed)

Farm	Time 1, field	Time 2, roofed store	Time 2, open store	Time 3, roofed store	Time 3, open store
1	237	213	233	225	232
3	225	173	179	179	212
4	232	223	219	237	233
5	243	212	243	220	239
7	235	215	229	229	238
8	241	229	221	235	238
9	229	220	227	230	221
10	230	221	225	220	228
All farms	234	213	222	222	230

Standard errors of differences of means

	Farm	Treatment	Farm*treatment
s.e.d	1.53	1.21	3.42

Table 7: Stover sampling 1998: DMD (proportional)

Farm	Time 1, field	Time 2, roofed store	Time 2, open store	Time 3, roofed store	Time 3, open store
1	0.704	0.652	0.693	0.694	0.701
3	0.677	0.603	0.601	0.625	0.651
4	0.684	0.680	0.654	0.703	0.698
5	0.749	0.675	0.742	0.713	0.749
7	0.687	0.648	0.678	0.693	0.702
8	0.714	0.671	0.667	0.705	0.711
9	0.690	0.655	0.682	0.693	0.690
10	0.680	0.659	0.672	0.671	0.699
All farms	0.698	0.655	0.674	0.687	0.700

Standard errors of differences of means

	Farm	Treatment	Farm*treatment
s.e.d	0.0026	0.0021	0.0058

Table 8: Stover sampling 1998: rate constant b (h^{-1})

Farm	Time 1, field	Time 2, roofed store	Time 2, open store	Time 3, roofed store	Time 3, open store
1	0.0312	0.0255	0.0271	0.0252	0.0254
3	0.0294	0.0151	0.0203	0.0185	0.0255
4	0.0262	0.0249	0.0260	0.0266	0.0257
5	0.0368	0.0314	0.0366	0.0323	0.0375
7	0.0278	0.0221	0.0264	0.0246	0.0265
8	0.0314	0.0266	0.0239	0.0268	0.0249
9	0.0312	0.0273	0.0294	0.0278	0.0292
10	0.0292	0.0261	0.0278	0.0261	0.0299
All farms	0.0304	0.0240	0.0272	0.0260	0.0281

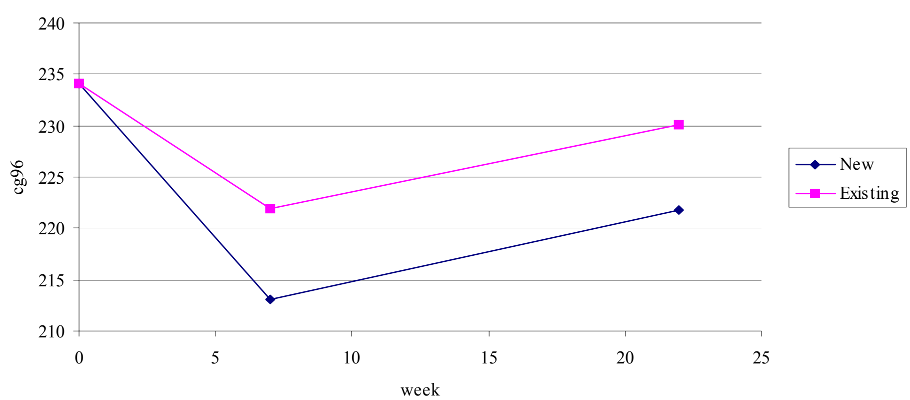
Standard errors of differences of means

	Farm	Treatment	Farm*treatment
s.e.d	0.00046	0.00036	0.00102

Differences between farms, between treatments and between sampling times, and interactions between them, were highly significant ($P<0.001$) for all three parameters.

Figure 2 shows the overall trend across farms for CG96, very similar patterns were observed for data for DMD and rate constant b. There was on average a decline in CG96 values from sampling time 1 to time 2, from the field to the start of storage, then an increase during storage which was similar for both stores.

Figure 2: Plot of mean values across farms for roofed and open stores at the 3 sampling times



Differences between the stores at time 2 indicate that either there were differences in the quality of the stover going into the two stores, or else there were very rapid changes when the stover entered the stores which were affected by the store design. If the latter was the case, the open store appeared to preserve stover quality better than the roofed store under the prevailing weather conditions found during the trial (no measurable rain between April and August inclusive). Farm 3 was atypical, with particularly low values for CG96, DMD and b at time 2 for both stores, and for the roofed store at time 3. The upward trend in values for all three parameters from time 2 to time 3 is difficult to explain as a gradual reduction due to declining digestibility might have been expected. However, the trends were very similar for both covered and open stores, so there was no evidence that the store designs were having an effect on stover quality between times 2 and 3 as gauged by the in vitro gas production technique.

Stover composition

Table 9: Chemical composition of stover, averaged over farms (g kg^{-1})

Store/time	Ash	Crude Protein	NDF	ADF
Time 1/in field	93	56	768	473
Time 2/open	101	38	783	488
Time 2/covered	114	42	800	513
Time 3/open	109	35	759	472
Time 3/covered	132	35	774	488
Time 2 both stores	108	40	791	500
Time 3 both stores	121	35	767	480

The composition data indicated that there was a trend for Crude Protein content to decrease with time, and ash content to increase. This was consistent with the loss of leaf material with time leading to a reduction in CP, and dust blown onto the stover could account for the rising ash content. There were no apparent trends in either measure of fibre.

T-tests conducted on the composition data on samples from the two stores indicated no significant differences ($P>0.05$) between stovers in the open and covered stores at either sampling times 2 or 3 in respect of their ash, CP or NDF content. Differences in ADF contents achieved statistical significance ($P<0.05$) at both times 2 and 3, with the ADF of the sample from the covered store being greater than that from the open store at both times. This may represent differences in the stover going into the two stores. There was no evidence that the stores themselves were affecting the composition of the stover during storage between times 2 and 3.

Mycotoxins

All samples collected during April, July and September 1998 contained insignificant levels of mycotoxins.

Laboratory evaluation of stover samples 1999

Due to the large differences between farms found in 1998, subsequent experiments were designed to compare roofed and open stores on individual farms. Farms were not used as a replicate due to the probable confounding effect of farm-treatment interaction.

In vitro gas production

Mean values for CG96, DMD and rate constant b for each farm, open and covered stores and for both times of sampling are given in Table 10. Gas production parameters CG96 and rate constant b indicated that there were no significant differences between the stovers in the two stores at the first sampling time. DMD data indicated that stover in the roofed store had significantly ($P<0.05$) higher values than that in the open store in Farms 28 and 30, but there were no differences in Farm 22. This is in contrast to the 1998 data which indicated higher digestibilities of stover in the open store initially.

Table 10: Separate comparisons at beginning and end between new and existing stores: in vitro gas production

Variable	Farm	Mean of open store		Mean of roofed store		Sig difference at 5% between open and roofed stores at:	
		July	November	July	November	July	November
CG96 (ml g^{-1})	Farm 22	205.0	208.6	205.8	211.6	no	no
	Farm 28	234.9	234.7	242.0	240.7	no	yes
	Farm 30	224.5	237.5	232.7	239.4	no	no
DMD (proportional)	Farm 22	0.653	0.664	0.645	0.670	no	no
	Farm 28	0.698	0.703	0.711	0.699	yes	no
	Farm 30	0.662	0.696	0.695	0.714	yes	yes
b (h^{-1})	Farm 22	0.030	0.031	0.028	0.031	no	no
	Farm 28	0.027	0.031	0.028	0.028	no	yes
	Farm 30	0.031	0.029	0.032	0.032	no	yes

The DMD variable for Farm 30 shows significant differences at both July and November. When the July values were used as a covariate there are still significant differences at the 5% level in November with the open store appearing to give a better performance than the covered store. Looking at the responses of Farms 22 and 28, Farm 28 shows a trend of moving from no significant difference between stores to a significant difference at the end of the experiment, with stover in the covered store giving an increased gas production. However, this trend was not apparent in the DMD data which indicated higher initial DMD for the stover in the open store but no differences at the end of storage. Farm 22 shows a trend of no significant difference at the beginning and the end of the stores.

For none of the parameters analysed were there consistent improvements in digestibility associated with storage in either the covered store or the open store. Differences observed in all cases were relatively small, and probably of little or no practical consequence even when statistical significance was achieved. From the 1999 gas production data it was concluded that, under the weather conditions prevailing at the time of the trial (again, no measurable rain from April to August inclusive), there were no demonstrable differences between the performance of the open and covered stores.

Stover composition

Mean values for the chemical components of the stovers sampled in 1999 are given in Table 11, together with the statistical significance of the differences between stovers from open and roofed stores at the beginning and end of the storage periods.

Table 11: Separate comparisons at beginning and end between new and existing stores: chemical composition (g kg^{-1})

Variable	Farm[a]	Mean of open store		Mean of roofed store		Sig difference at 5% between open and roofed stores at:	
		begin	end	begin	end	begin	end
CP	28	21.9	22.9	24.4	22.3	no	no
	30	20.6	19.8	27.5	22.9	yes	yes
	22	37.6	35.6	38.6	34.8	no	no
ADF	28	468	495	456	476	no	yes
	30	522	507	490	484	yes	yes
	22	538	553	525	530	no	no
ash	28	110.2	141.8	90.6	106.6	yes	yes
	30	154.5	115.7	126.7	117.9	yes	no
	22	193.8	177.5	172.8	160.7	no	no

Different trends were observed in the three farms. Samples from Farm 22 had no statistically significant (P>0.05) differences between stores at either the beginning nor end of storage, neither were there differences (P>0.05) between stovers from the same store sampled at different times. On Farm 28, similarly, no differences (P>0.05) were observed in CP. For ADF, values rose during storage (P<0.05) in both stores. Ash content fell in both stores. There were large differences in CP, ADF and ash for the stovers in the open and covered stores at the start of the storage period (all differences significant, P<0.01) for Farm 30. However, there was little evidence for changes during storage, only the differences in ash content for samples from the open store achieving statistical significance (P<0.05).

As with the in vitro gas production data, there was no consistent evidence that the covered store performed differently to the open store from the composition data. There was a lack of homogeneity in the stover samples, particularly from Farm 30, which probably accounts for the differences observed between samples from the two stores from this farm.

Mycotoxins

The mycotoxin contents of the composite and individual 1kg samples of comminuted stover, collected in 1999, are described in Tables 12 and 13 below.

Table 12: Mycotoxin analysis of composite samples collected at Time 1 (July 1999)

Mycotoxin	Mycotoxin Level (µg/kg)					
	Farm/Store Type					
	Farm 28 Traditional (Open)	Farm 28 Mark 2 (Covered)	Farm 30 Traditional (Open)	Farm 30 Mark 2 (Covered)	Farm 22 Traditional (Open)	Farm 30 Mark 2 (Covered)
Aflatoxin B_1	0	0	0	0	0.8	1.6
Aflatoxin B_2	0	0	0	0	0	0
Aflatoxin G_1	0	0	0	0	0	0
Aflatoxin G_2	0	0	0	0	0	0
Fumonisin B_1	109	267	129	116	199	752
Zearalenone	0	0	0	0	65	73

The interpretation of these data is based upon the assumption that each of the participating farmers evenly distributed their stover between their traditional and Mark 2 stores, as requested. Furthermore, since the stores were not dismantled during sampling, the samples collected during Visit 1 were, unavoidably, collected from the exterior of the stack. However, given the freshness of the stack it may be assumed that the samples collected were reasonably representative of the whole store. Moreover, a significant proportion of the individual stovers collected extended into the heart of the store.

The Time 2 composite samples contained low levels of ochratoxin A and aflatoxin B_1, and higher levels of fumonisin B_1 (Farms A & C). Zearalenone occurred at the highest concentration (especially the traditional store at Farm C). The balance of the 1kg samples collected from the traditional store at Farm C were also additionally analysed for zearalenone. The contamination range was 40 to 609 µg/kg, with a mean of 279 µg/kg, which corresponded closely to the zearalenone content of the composite sample (268 µg/kg).

Given the results for Time 2, and the relative potencies of the toxins, the composite samples generated by the Time 1 sampling visit were analysed for the aflatoxins, fumonisin B_1 and zearalenone. The samples from both stores at Farm C contained low levels of aflatoxin B_1 and higher levels of zearalenone, whereas all the farm stores were contaminated with fumonisin B_1. The highest level of the latter occurred within the Mark 2 store of Farm C.

Table 13: Mycotoxin analysis of composite and individual 1kg samples collected at Time 2 (November, 1999)

Mycotoxin	Mycotoxin Level (µg/kg)					
	Farm/Store Type					
	Farm 28 Traditional (Open)	**Farm 28 Mark 2 (Covered)**	**Farm 30 Traditional (Open)**	**Farm 30 Mark 2 (Covered)**	**Farm 22 Traditional (Open)**	**Farm 22 Mark 2 (Covered)**
Aflatoxin B_1	0.5	0.9	0.3	2.1	0	0.3
Aflatoxin B_2	0	0	0	0	0	0
Aflatoxin G_1	0	0	0	0	0	0
Aflatoxin G_2	0	0	0	0	0	0
Fumonisin B_1	32	24	0	0	11	38
Ochratoxin A	0	4.3	0	3.8	0	2.2
Deoxynivalenol	0	0	0	0	0	0
T-2 Toxin	0	0	0	0	0	0
Zearalenone						
a). Combined	135	0	47	10	**268**	73
b). Individual						
1					40	
2					609	
3					245	
4					539	
5					313	
6					182	
7					142	
8					224	
9					225	
10					268	
Mean					**278.7**	

'0' = Not detected

The following conclusions may be drawn:

- Aflatoxin B1, fumonisin B1, ochratoxin A and zearalenone were detected in the maize stover

- All farm stores were contaminated with low levels of aflatoxin B_1 and fumonisin B_1. However, the apparent reduction in fumonisin B_1 levels during storage could reflect the changes in the composition of the store (stover was continously removed for feeding purposes) that occurred between the two sampling visits, rather than toxin degradation.

- All farm stores, apart from the Mark 2 store at Farm A were contaminated with zearalenone. It appears that the zearalenone content of the traditional stores at each of the participating farms increased significantly between visits. However, the increased levels could reflect changes in the composition of the store that occurred between the two sampling visits rather than a real increase in contamination.

- All levels of contamination were below those considered hazardous to livestock, or hazardous to humans consuming livestock products, as defined by national/international regulations and guidelines (see Table 14).

Table 14: Maximum permitted levels of mycotoxin contamination for livestock feeds

Toxin/Commodity	Animal	Country	Max. permitted level µg/kg
Aflatoxin B_1/ complete feed	Mature cattle, sheep, goats Mature pigs & poultry Immature animals Dairy cattle	EU	50 20 10 5
Ochratoxin A/Feed	Not specified Swine Poultry	Israel Sweden Sweden	300 100 1000
Zearalenone	No regulations specifically focused upon feed		
Total fumonisins 20% diet max. 50% diet max.	 Rabbits Breeding ruminants & poultry Poultry for slaughter	USA (FDA draft guidelines)	 5000 30,000 100,000

Laboratory evaluation of stover samples 2000

In vitro gas production

Average data for the samples from each farm, and presence of significant differences, are given in Table 15.

Table 15: Comparisons between maize stover sampled in November 2000 from roofed and open stores

Variable	**Farm**	**Mean of open store**	**Mean of roofed store**	**Sig difference at 5% between open and roofed stores**
CG96	Farm 5 Farm 9 Farm 10	201.5 181.1 215.0	213.7 192.7 217.6	yes yes no
DMD	Farm 5 Farm 9 Farm 10	0.661 0.696 0.658	0.702 0.700 0.678	yes no no
b	Farm 5 Farm 9 Farm 10	0.0183 0.0217 0.0150	0.0234 0.0242 0.0156	yes no no

The CG96 and DMD for stover from the roofed stores were in all cases higher than those from the corresponding open store. These differences achieved statistical significance for Farm 5 (both parameters) and Farm 9 (CG96 only). As with the

DMD, rate constant b was higher for stover from the roofed stores, but achieved significance only in Farm 5. Lag times were significantly shorter for stovers from the open store for all three farms (P<0.01).

For Farm 5 there was clear evidence that stovers kept in the open store were fermented more slowly and to a reduced extent compared to stovers kept in the covered store. Similar trends were seem on the other two farms, but generally did not achieve statistical significance in the parameters most likely to influence animal performance. Therefore, samples taken from Farm 5 in June and November 2000 were evaluated in a second gas production experiment to test whether these differences were due to the different stores. Data on CG96, DMD and rate constant b from the second experiment are given in Table 16.

Table 16: Cumulative gas production (CG96), Dry matter disappearance (DMD) after 96h incubation and Rate constant b of maize stover sampled from Farm 5 in July and November 2000 from roofed and open stores

Variable	Samples	Roofed store	Open store	Sig difference at 5% between open and roofed stores
CG96 (ml g^{-1})	June samples	239.6	234.7	no
	November samples	242.9	228.9	yes
	Sig difference at 5% between June and November samples	no	no	
DMD (proportional)	June samples	0.686	0.692	no
	November samples	0.689	0.665	yes
	Sig difference at 5% between June and November samples	no	yes	
b (h^{-1})	June samples	0.0263	0.0261	no
	November samples	0.0280	0.0246	yes
	Sig difference at 5% between June and November samples	yes	no	

The second experiment confirmed the highly significant (P<0.001) differences between the stovers from the two stores on Farm 5 observed in the first experiment. No significant differences were observed in CG96, DMD or rate constant b between the stovers in the two stores in June. Differences (P<0.05) were observed in CG12 and Gas Pool A, with gas produced from the stovers from the roofed stores being higher in both cases, but no other significant (P>0.05) differences were observed in the other parameters analysed. In contrast, significant (P<0.05) differences were observed in all parameters except CG12 between the November samples from the two stores.

There was evidence for changes in the quality of stovers during storage in both stores. In the roofed store the increased rate constant b ($P<0.05$) indicated an increased rate of degradation. Early gas production data CG12, CG27 and CG48 was higher for the November samples than the June samples ($P<0.05$). However, there were no changes in the extent of degradation as indicated by the DMD, CG96 or Gas Pool A ($P>0.05$). For the open store, there was a trend towards increased gas production at short incubation times (up to and including CG27), then reduced gas production at longer incubation times (CG48 and onwards). However, of the parameters examined, only differences in CG12 achieved statistical significance. DMD was significantly reduced on storage in the open store ($P<0.01$), but there were no differences in CG96 or Gas Pool A($P>0.05$).

Thus for one of the three farms there was clear evidence that storage in a roofed store gave a superior quality stover than storage in a traditional open store. On Farm 5 increases in CG96, DMD and rate constant b were 6%, 4% and 14% respectively. Given that these increases were no particularly great, were not found on two of the three farms during a wet year and were not found during dry years, there is clear evidence that improvements in digestibility due to the introduction of the roofed stores are unlikely to be of importance to livestock keepers. The avoidance of gross losses of feed will be far more important.

Stover composition

Stover samples taken from three stores in the 2000 storage season were submitted to chemical analysis as in previous years. However, results were inconclusive and as before, showed no consistent pattern of better conservation of nutritive value by improved stores.

Mycotoxins

The mycotoxin analysis results for year 2000 are shown in Tables 17 and 18, below.

Table 17: Mycotoxin analysis of combined and individual 1 kg samples, Time 1 (June 2000)

Mycotoxin	**Mycotoxin Level (µg/kg)**					
	Farm/Store Type					
	Farm 5 Traditional (Open)	**Farm 5 Mark 1 (Covered)**	**Farm 9 Traditional (Open)**	**Farm 9 Mark 1 (Covered)**	**Farm 10 Traditional (Open)**	**Farm 10 Mark 1 (Covered)**
Aflatoxin B_1	No aflatoxin was detected					
Aflatoxin B_2						
Aflatoxin G_1						
Aflatoxin G_2						
Fumonisin B_1	88	102	85	55	59	132
Ochratoxin A	No ochratoxin A was detected					
Deoxynivalenol	No deoxynivalenol was detected					
T-2 Toxin	0	235	680	483	0	0
Zearalenone	100	371	461	90	453	151

'0' = Not detected

Table 18: Mycotoxin analysis of combined and individual 1 kg samples, Time 2 (November 2000)

Mycotoxin	Mycotoxin Level (µg/kg)					
	Farm/Store Type					
	Farm 5 Traditional (Open)	Farm 5 Mark 1 (Covered)	Farm 9 Traditional (Open)	Farm 9 Mark 1 (Covered)	Farm 10 Traditional (Open)	Farm 10 Mark 1 (Covered)
Aflatoxin B_1	No aflatoxin was detected					
Aflatoxin B_2						
Aflatoxin G_1						
Aflatoxin G_2						
Fumonisin B_1	430	40	34	89	13	50
Ochratoxin A	No ochratoxin A was detected					
Deoxynivalenol	No deoxynivalenol was detected					
T-2 Toxin	705	717	0	0	0	0
Zearalenone	1140	0	644	97	379	104

'0' = Not detected

The results may be summarised as follows:

- No significant levels of the aflatoxins, deoxynivalenol, or ochratoxin A were detected
- Fumonisin B_1 occurred at both collection times. Since there was no clear relationship between the concentrations of toxin and storage period, it is probable that the variations in concentration resulted from changes in store composition, rather than changes occurring as a result of storage conditions and time
- T-2 toxin occurred at both collection times in Farms 28 and 30, but was not detected in Farm 22. For Farm 28, the toxin concentration increased significantly between the two sample collection periods, for both the traditional and Mark 2 stores. However, the levels of T-2 toxin decreased significantly, with storage, for Farm 30. As before, it is probable that the variations in concentration resulted from changes in store composition, rather than changes occurring as a result of storage conditions
- Zearalenone occurred on all farms at both sample collection times. Although the concentration of toxin appeared to increase dramatically, with storage, in the traditional store of farm 28, there was no clear relationship between storage conditions/time and toxin level
- The highest concentration of toxins found in the stover were 430 (fumonisin B_1), 717 (T-2 toxin) and 1,140 (zearalenone) µg/kg.
- The levels of fumonisin are low and of no significance.
- The level of T-2 toxin in the stores on farms 28 & 30 is the cause of some concern. Although there are no widespread regulations for T-2 toxin in livestock feeds, experimental studies have indicated that T-2 toxin can cause impaired immunocompetence, and haemorrhagic syndrome in cattle. For example, dairy cattle exhibited the latter when fed mouldy corn containing 1000 µg/kg T-2 toxin. Experimental studies with calves have shown that concentrations of around 600 µg/kg T-2 toxin in the diet compromised their immunocompetence.
- The result for T-2 toxin is based upon our standard procedure (High Performance Thin Layer Chromatography) for the determination of this toxin. However, given

the high level, and its implications, the result should be confirmed by, for example, liquid chromatography/mass spectrometry. (Confirmation activities were outside the remit of this project.)

- The level of zearalenone (1,140 μg/kg) found on farm 28 is also a cause of some concern. Although zearalenone itself is not considered to be an important factor in dairy cow productivity, levels as low as 1.5 μg/kg in combination with *Fusarium* trichothecenes (e.g. T-2 toxin) have been reported to have a serious impact on fertility and productivity. Swine are considerably sensitive to zearalenone, and it has been reported that noticeable effects on reproductive efficiency begin to occur in young gilts at around 1μg/kg dietary toxin

Discussion and Conclusions

Rainfall in 1998, 1999 and 2000

Rainfall data for Kezi, the District administrative centre for Bidi, are given below for 1998, 1999 and 2000.

Table 19: Monthly rainfall (mm) at Kezi for 1998, 1999 and 2000

Year	1998	1999	2000
Jan	165.3	108.1	n/a
Feb	14	60.2	n/a
Mar	25.6	48	n/a
Apr	0	0	12.9
May	0	0	13.7
June	0	0	77.6
July	0	0	0
Aug	0	0	0
Sep	1	1.3	0
Oct	29	16.5	3.5
Nov	65.3	107	65.3
Dec	137.8	93.8	68.1
Total	438	434.9	n/a

For 1998 and 1999 there was no rain at all in the April to August period. Rainfall in September was very low, in October there were some heavy rains (>10mm in a day). In 1998, the stover sampled at the latest sampling time had not been rained on at all during storage, while in 1999 the stover had been exposed to one heavy day's rain (13.5 mm on 27 October 1999) and light rain (3 mm of rain or less) on a total of six days from late September to the mid November 1999 sampling. In contrast, in 2000 there were heavy rains in June, after the stover had been harvested and stored. The 2000 season was therefore a test of the stores under adverse weather conditions, unlike the two preceding years.

Nutritive value

Despite the interesting result from Farm 5 in 2000, in vitro gas production and chemical composition analysis for the three years of the project failed to show any significant pattern of roofed stores conserving the nutritive value of stover better than traditional unroofed stores.

Mycotoxin analysis

The following final conclusions may be drawn regarding the contamination of maize stover with mycotoxins, and the impact of improved storage conditions on mycotoxin levels:

- Maize stover may be contaminated with a variety of mycotoxins (the aflatoxins, ochratoxin A, fumonisin B_1, T-2 toxin and zearalenone
- The highest reported levels of T-2 toxin and zearalenone are a cause of some concern. Furthermore, the co-occurrence of three different mycotoxins in stover (e.g. on farm 28) may cause synergistic effects. However, the impact of these mycotoxins on the health and productivity of livestock, compared with other constraining factors, is unknown
- Current knowledge indicates that the carry-over of the fumonisins and zearalenone into milk is not a problem.
- There was no clear relationship between levels of mycotoxin contamination and storage conditions or period. It is possible that contamination levels were partly effected, at least, by mould infestation occurring before harvest and/or storage, and the time required for the stover to reach a 'safe' moisture level. It is also possible that stover in an open, traditional store (with direct access to sunlight) would dry more rapidly than when contained in a roofed store. However, it is important that stored stover is also protected from further rain damage.

VI PARTICIPATORY TRIALS AND QUALITATIVE MONITORING IN BIDI

Qualitative monitoring of Mark 2 stores (Activity 12)

The 9 collaborating farmers were interviewed by the NRI-based social scientist during or soon after construction in May 1999 (see Technical Annex 1D) and again during September 1999, and 8 of them were interviewed by Ndabazinhle Nyoni during February 2000, using a checklist drafted at NRI. This round of monitoring is the primary source for the paragraphs below. The 9 farmers were also interviewed in the questionnaire survey of November 1999 (though not used as part of the sample for analysis of that survey).

As a result, it is possible to compare the 8 Mark 2 farmers interviewed against the Bidi averages from the questionnaire survey (1998 planting figures in acres):

Table 20: Comparison of farmers in Mark 2 participatory trials with Bidi averages

	Bidi average	Mk2 farmers average
number of adults available for work on farm	4.1	4.4
1998 planted areas (acres)		
maize	1.7	2.5
sorghum	1.9	1.4
finger millet	-	0.4
pearl millet	1.7	1.7
groundnut	0.7	1.4
bambara nut	0.7	1.4
total area	7.0	9
household livestock holdings		
cattle	3.2	9.5
goats	10.7	21
sheep	2.7	9.4
donkeys	3.3	5

The Mark 2 farmers are slightly above the Bidi average in areas planted to maize, groundnut and bambara nut, and slightly (possibly not significantly) in total planted area. They are *well above* Bidi averages for holdings of all livestock species. All the Mark 2 farmers are cattle-owners. They are however below the average cattle-holding for farmers reporting cattle (12.5 in questionnaire survey).

Like the larger sample, all but one of the farmers were grazing their animals on other people's fields after harvest, and having other animals graze on their fields. Only one said his fields were fenced. One of the farmers referred to neighbours agreeing dates, the others gave the impression of unregulated grazing.

Store Design and Construction

Stores were of various dimensions, with platform sizes from around 3m x 4m up to 7m x 5m. Most farmers had adopted a design pitched on all four sides of the roof, rather than gable-ended like the Mark 1 stores, and some had designed stores that did not need a central pillar. Mopane was the wood most commonly used, especially for the platform and roof. Some farmers also used other woods, especially for uprights: *tswiri, mukuyu, singa* (acacia), *mkhya, vikani*. The farmer who also had a Mark 1 store used contour grass and pearl millet and finger millet stover instead of thatching grass. Termites are a major problem, both to stored stover and to the stores themselves. One farmer poured commercial antkiller into the postholes, one used Jeyes Fluid, and one charred his timbers before use.

Stores were constructed by various combinations of male family members, friends and hired labour; in two cases the project had provided station hands for building. Cash outlays varied from the minimal to Z$2540 for a single store. One farmer had built two separate Mark 2 stores for Z$1430 and Z$1800. Even with MRS supplying some thatching grass, several farmers complained that it was insufficient and that they had problems in finding more. Some farmers encountered problems in finding poles, (which can be collected subject to sometimes difficult negotiations) or building materials on the market, or in finding labour.

Three farmers had no other store: the rest had one or more unroofed stores. Stores were constructed in various locations, in granary enclosures, in feeding enclosures, with other stover stores or in separate enclosures, at various distances of up to 300m from the homestead.

Pre-Harvest Problems

Mk2 farmers had experienced a range of problems with growing crops:

- *maize:* shortage of rain, sun, stalk borer and other insect pests, striga and other weeds
- *sorghum:* quelea, striga and other weeds, rain shortage and *ingumane* smut
- *groundnut:* rain shortage and diseases

In terms of perceived problems with the quality of stover entering the store, the farmers were generally satisfied, apart from two reports of animal damage and one of termite damage. Some described the maize stover as “dry but in good condition”. Seven (of nine) farmers had stooked their maize, for periods of between one week and one month. Three farmers stored maize stover in their roofed store to the exclusion of sorghum stover, and three farmers stored groundnut hay alongside cereal stovers.

Feeding of Stover

Stover was fed on average for a period of 3.5 months (though farmer recall seemed hazy, starting late July in one case, late August or September in most cases. Most farmers finished feeding in November, one carried on December and one into January. The farmers stopped feeding stover when it had all been eaten, except for one who had stover spoilt because of a leak in the roof (and dumped it in the kraal) and one who noted that animals would not eat stover when grazing became available.

Farmers were asked in which months they considered stover to be more important than any other feed: October was the most cited month, followed by September and November. Farmers were also asked in which months the store had enabled them to feed stover they could not otherwise have done. On average each named a period of just over two months, between September and January. October and November each received six mentions.

Stover is seen mainly as a cattle feed, but six farmers also gave stover to donkeys more or less equally with cattle and four mentioned giving it to goats, or not stopping goats feeding when stover was given to cattle. Among cattle, cows with calves were mentioned twice as receiving preferential treatment, heifers and draught animals once each. Feeding was daily in some cases, or as seldom as twice a week, and in relatively small amounts, 3-5 bundles of stover per feed, or in one case, six drums (200 litre fuel drums cut in half) four times a week.

Two farmers specifically mentioned using the feeding of stover "to let animals know there is feed at home" or to keep them near the homestead. One other farmer fed after animals had returned from watering, when they needed it.

Two farmers mentioned feeding sorghum stover early in the dry season and reserving maize stover for later. One mentioned that when the two stovers are fed mixed, animals select maize over sorghum.

Six of the farmers sprayed salt (coarse NaCl sold for animal use) water on crop residues, one using this method only on groundnut hay. One mentioned learning this technique from an extension worker, one that it controlled excess bile (*einyonyo*) in animals. Interestingly, only 3 of the 31 households in the questionnaire survey used salt on crop residues.

Problems

At the February monitoring, five farmers reported no storage problems and no losses. One reported the loss of a cartload when the store roof leaked (this may have occurred after the main storage season, or during dry-season rails that fell on Bidi but not at the Kezi weather station), one reported minor termite problems, controllable with ash, and one reported problems of straying animals eating about half the stover. This farmer also reported that the store had collapsed; it is not clear whether before or after the losses to animals.

In September, when interviewing was more detailed and memories fresher, four farmers referred to stover keeping, or even improving its colour, especially in comparison with traditional unroofed stores. One saw this as particularly important for green mealie stover, which the animals prefer. Four farmers noted that stover in the Mk2 stores was dry, but in at least three of these cases, this was probably because the stover had entered the store dry.

Evaluation

Farmers had found a number of other uses for the stores, in particular storing grain/seed of various crops (particularly important as unseasonal rains led to a risk of premature germination, storing thatching grass, and as a shelter (from the rain) for goats and sheep.

Farmers were asked to agree or disagree with a number of statements on stover storage. The very high levels of agreement on all statements suggest this method was fairly flawed, so results should be treated with caution. All agreed that the stores preserved stover from rain and sun (one had had rain damage, but from a store not properly built). Six agreed that the stores preserve stover from termites: two noted that this depends on what farmers do to control termites.

All agreed that the stores: encouraged them to store stover they would otherwise have left in the field; prevented stored stover becoming useless; allowed them to store stover before longer; allowed them to feed more stover each day. These can perhaps be interpreted as expressions of general agreement with the principle of storing stover, rather than reflections of each farmer's own advantages from storing stover.

All but one farmer agreed that the stores allowed them to feed animals they would not otherwise have fed, and five farmers specified; donkeys, goats, sheep and cattle other than draught animals.

All agreed that the stores meant that the stover was more attractive to animals; seven specified, mentioning that it was not sunburnt or rain-damaged, that it was kept "fresh and new", still had the greenish colour normally lost to sun, was more nutritious than stover stored in-field etc. One farmer mentioned protection against termites. All agreed that the stores kept stover moist. All but one agreed that the store kept stover green, and that they meant you could store green stover you would otherwise not have stored. However, these two answers must be treated with great caution. In the November questionnaire survey, only three of the farmers said that they "brought a significant amount of stover into store while still green" and one of these was talking about a failed, late-planted crop.

Farmers were asked the two main benefits to them of the store, but some appeared to think they could not repeat statements on the above list. It may (or may not) be for this reason that five mentioned storing grain or thatch grass as the most important reason, and four mentioned sheltering goats and sheep from the rain. Reasons more closely connected with feeding stover included: having enough stover for cows that calved in the dry season; being able to sell cattle because they were well-fed; being able to afford to feed animals when need arose; putting animals in good condition for ploughing' and making stover more attractive to animals.

Six farmers thought the store would stand for five or six years, in two cases with the caveats; as long as it is not attacked by termites, or as he long as he was able to repair it. One store had collapsed, and one other farmer gave a more cautious response of two years. This farmer had already reported a termite problem in September but taken no action.

All but one of the farmers felt the benefits received from the store in the current season made it worthwhile. The other (who had expected the store to stand only for two years) gave no response to this question or a similar one on expected future benefits.

All but the farmer whose store had collapsed were intending to use the store again next season. One said he would use it only for late-planted maize, as the early crop had (by February) already been "drenched". All but one farmer stated or implied that they were prepared to invest time and money on the store next season, and one specified a readiness to invest time. Two were cautious about investing money, noting it would be difficult to find, and would only be spent if major repairs were necessary. One farmer implied she might roof her traditional store.

Two farmers did not intend to change their harvest and storage practices for the next season, and one was not sure. Two expressed doubts about whether they would store stover next season because of the heavy rains: one because grazing would be abundant, the other possibly because stover would be in poor condition before storage. Three would change their practices; to harvest early and store stover green, to harvest more stover, and to change feeding practices respectively.

Six of the farmers had had friends, neighbours and relatives expressing interest in the store, but much of this was connected with neighbours' perceptions that the project was handing out free benefits. Three had given out positive messages that a store could be built without project support and that it brought benefits (storage of stover and shelter for smallstock). The eight farmers mentioned five individuals who were likely to build, but in two cases our informants were not themselves clear that project benefits were ending, so three (all identified by the same farmer) could be regarded as the maximum realistic estimate of those likely to build.

Subsequent monitoring (Activity 13)

The farmers with Mk1 and Mk2 stores in Bidi were subsequently visited in August 2001, September 2001 and May 2002, and interviewed, primarily in qualitative terms, on their use of the stores and on prospects for further adoption. Despite poor harvests due to drought in 2001 and 2002, the majority of project farmers were continuing to use their stores: mainly for stover, but also for veld hay and other fodders, as winter shelters for smallstock and for miscellaneous farm purposes. Despite some problems with termites, farmers generally felt the stores would stand for several years and felt they were a worthwhile investment. Some were actively repairing or extending the stores, and most indicated that they would at least invest further time in store maintenance.

However, it became increasingly clear during these monitoring rounds that the project farmers were firmly at the upper end of the scale of livestock (particularly cattle) ownership in Bidi, and that the project had more or less exhausted the pool of farmers for whom roofed stores represented a worthwhile investment. Old age, and sickness of household heads and others were reducing the number of farmers maintaining their existing stores.

At the same time, no spontaneous adoption was occurring, and other farmers who had expressed an interest in stover storage, and even some of the Mk2 farmers themselves, concentrated very much on the supposed possibilities of free assistance from the project, and not on the stores as a technology that farmers could adopt unassisted. The very limited assistance the project had offered, with good reason at the time (thatching grass to all farmers and building assistance to a few) has acquired a much greater importance in farmers' eyes, and may not have helped the chances of uptake in the long-term.

Conclusion

The Mk 2 stores can be judged to have been technically successful. One allowed rain damage to stover, and one collapsed, though apparently after all the stover was used. The trial farmers felt the benefits received in one season had made the stores worthwhile, they intended to use them, and they intended to invest time and money in maintaining them during the following year. Most farmers saw their stores as lasting for 5 or 6 years, subject to some maintenance. Several gave specific reasons why they valued them: they made stover more attractive to animals, and allowed special feeding for particular animals: draught oxen and cows with calves.

These advantages should also be seen in the context of information given during the September 1999 visits on the frequency and seriousness of damage to traditionally-stored stover from dry season rains. Some farmers were suggesting that they lost up to 70% of stover to dry-season rains averaged over a run of years. This information and the February 2000 monitoring data pointed to the stores being successful and a worthwhile investment for farmers.

However the lack of spontaneous adoption directed the team's attention back to a consideration of the differences of Bidi project farmers to sampled Bidi averages pointed to improved stover storage being The Mk2 farmers were slightly better off in terms of area planted, and significantly better off in terms of livestock holdings. Only 4 of the 31 farmers sampled in the questionnaire survey had spent time or money building or repairing stores that season. The project team concluded that investment in roofed stover stores under the conditions of low cattle numbers, skewed cattle ownership and poor harvests prevailing in Bidi (and probably other Communal Areas in Natural Regions 4 and 5) was a solution virtually exclusively for better-off farmers.

VII DISSEMINATION OF RESULTS TO IRISVALE, PARTICIPATORY TRIALS AND QUALITATIVE MONITORING

Dissemination of results to Irisvale (Activity 14)

As part of the project design, it was planned to disseminate the roofed storage technology to a second community, with the project providing technical advice but not subsidising any inputs of either materials or labour. The Irisvale resettlement area (see Section V) was chosen for this purpose. It had been planned to start extension activity in Irisvale in August 1999 with a field day in Bidi to introduce the covered stores to Irisvale farmers and to allow farmer to farmer contact. In the event, a familiarisation visit to Irisvale in May 1999 found that one Mark 2 style roofed store was already at an advanced state of construction (at the farm of Mrs Mabel Ncube, in Irisvale village 8) following early contacts with project staff.

The field day in Bidi was organised for 25 August 1999, with 211 people attending. These were mainly farmers from Irisvale, but included collaborating farmers from Bidi, Agritex extension staff, Natural Resources Board staff and chief's representatives. Three farms were visited, those of Alphonso Moyo (Farm 23) and Sister Dube (Farm 25) which had Mark 2 roofed stores, and Philimon Moyo's farm (Farm 5) with a Mark 1 store. The 3 farmers described their experiences with the stores. Additionally, Mrs Ncube, the farmer from Irisvale who had constructed a roofed store, was asked to talk on her experiences with it. Presentations described the benefits of stover storage, the benefits of using roofed stores and methods of constructing them. There was opportunity for farmers to discuss the stores after the presentations and over lunch, provided at one of the collaborating farms. The Irisvale farmers were very happy with the field day and about 30 farmers said that they were planning to construct a Mark 2 type of stover store in 2000. Extension workers were similarly happy with the field day.

A randomly sampled and structured survey was conducted in Irisvale in December 1999, as described in Section IV above. This was designed to quantify some of the variables the researchers felt would influence uptake, as well as allowing comparability with Bidi.

Discussions on costs and benefits in Irisvale (Activity 15)

During September 1999, interviews were conducted in Irisvale (and to a lesser extent in Bidi) to obtain a rough quantification of the costs and benefits of stover stores. The one Irisvale farmer who had already built a store similar to those in Bidi gave the following cost figures.

Cost of constructing store (Mabel Ncube) - Zimbabwe Dollars	
Labour of roofing	2500
Labour of cutting poles	700
Labour constructing roof	300
Materials for roof	400
Total cash	3900
Value of labour collecting thatch/market value of thatch not included	

The farmer estimated that this particular store would last six or seven years because the poles had been treated against termites – another farmer talked of her store lasting five years. The individual farmers all considered the cost of building the store to be worthwhile, and felt they would find the money somehow. In terms of obtaining materials, poles are not seen as a problem, but thatching grass is. Contour grass rather than the high-quality thatching grass gathered from the National Park is used, but opinions differ as to how durable it is against rain or termites and it is also scarce, particularly in some villages. Labour was not seen as a major problem, although it might slow down store building. Several farmers talked of hiring casual labourers: Nswazi people seek casual work in Irisvale.

The costs of building a store depend on the size of the store, the choice of materials, and the cost of those materials either on the market or in terms of the labour necessary to collect them. When quantifying costs, a decision will have to be taken as to whether, and at what rate, to impute the costs of the household's own labour. Any calculation of costs and benefits should ideally use the incremental cost of building an improved store over costs of current storage practices, but from open *ingalanis* we have seen these are likely to be minimal.

The benefit of a store can be formulated as the value of stover successfully stored that would otherwise be lost to visible damage by sun and dry-season rain. This formulation currently holds fairly well for Irisvale, where, from interviews, saving stover from this sort of damage is the most important motivation for improving storage. It might underestimate benefits if building an appropriate store encourages farmers to store more stover and to store stover while green (see below), which would otherwise be grazed in the fields at (presumably) less overall benefit to the farmer's animals.

It holds less well in Bidi, where farmers consider it important to bridge the feeding gap at the end of the dry season and during the first, undesirable, green flush of browse. For Bidi, some premium on the imputed value of stover above the valuation methods mentioned below might be appropriate. The current formulation also does not take into account any non-visible loss in nutritional value or any loss of value associated with mycotoxin contamination. We have seen from Section V that scientific results for both processes were highly inconclusive. But by and large it seems useful to examine the benefits of improved storage, and the variation in those benefits across households.

The benefit of a store, therefore, is crudely speaking a function of:

- The amount of stover stored, in turn a function of:
  - the size of the store, which determines the maximum amount of stover to be stored
  - the actual amount of stover available in the fields
  - the existence of sufficient labour to bring it to store
- The life expectancy of a store, which is in turn a function of:
  - the materials used
  - the risk of serious attack by termites (or other natural damage)
  - the measures taken to control termites
- The proportion of stover that would be lost on average each year in an unroofed store, which is in turn a function of:
  - the proportion lost in a year in which serious dry-season rains occur
  - the frequency of such years
- An imputed financial value for stover, which could be obtained either:
- from a calculation involving the value of each nutritional component based on the value of specific commercially available feeds,
- or from a calculation involving the amount of stover a cow would eat ad lib, made equivalent to one day's ration of stockfeed

As an example, the cost of building Mabel Ncube's store is given above as \$Z3900, exclusive of the labour involved in collecting thatch. The benefits of the store can be crudely estimated as follows:

- The store contains 70m^3

- Miss Ncube's 31 cows, if allowed, would eat the entire store in 3-4 days
- One cow in one day will eat $70 \div 3.5 \div 30 = 0.67$ m^3
- Approximate value of one day's ration of stover = cost of 10 kg stockfeed = Z\$50 (50kg feed = Z\$250)
- Value of 1m^3 stover = $50 \div 0.67$ = Z\$75

- If store were not roofed c.25% would be lost each year. The store will last 6 years
- Stover saved = $70 \div 4 \times 6 = 105$ m^3
- Value of stover saved (1999 prices) = 105 x 75 = **Z\$7875**

On such a calculation, even imputing a high cost for the labour of collecting thatch, the return on the store is likely to be high. Some factors discussed above might raise or lower the calculated benefit.

The figure of 25% stover losses per year in an unroofed store was given by Mrs Ncube in a pile-sorting exercise as an answer to a question on the proportion odf stover lost overall to dry-season rains during the last ten years. Most (but not all) farmers we discussed the topic with, gave higher values for the proportion of stover lost each year, in the region of 50% to 70%, but intuitively and given the incidence of dry-season rainfall, these figures would seem high, and it may be that even Mrs Ncube's needs treating cautiously.

Additionally, the majority of stores are smaller, building costs are not proportional to volume, and some farmers only expected their stores to last for two to three years.

There should also be a small reduction in benefit from the fertiliser value of spoilt stover trampled in the kraal and incorporated with manure, but this is likely to be minimal.

The calculation of the value of stover, currently based on $0.67m^3$ of stover = 10kg of stockfeed, clearly needs more examination. A different figure based on a nutritional evaluation of stover could be used in future, which would neccessitate a conversion factor for weight into volume of stover.

Overall, we can conclude that, on current estimates of the value of stover:

- Benefits of improved stores to farmers storing large quantities of stover, in stores with relatively long life expectancies, are probably high, at least if spoilage of stover stored in unroofed stores (over a run of years) is 25% or higher
- Benefits to other farmers need more careful calculation.

Monitoring of uptake in Irisvale (Activity 16)

At the end of May and beginning of June 2000 a short checklist was administered[4] to all those farmers in Irisvale who, to the project's knowledge, were actually building stores, a total of 16. Farmers building came from all but one of Irisvale's nine villages. Two stores were completed, two complete except for thatching (the owner of one of these already had a roofed store but was building a second one), two complete except for roof construction, three farmers had started cutting poles to build, six were still gathering raw materials and one had yet to start gathering (but was clearly going to). Another seven farmers who had considered building stores but abandoned the idea, were also interviewed with a modified checklist. Of these, three had abandoned their plans during or before January 2000, and two in April-May 2000; for the others it was unclear

Some comparisons with data from the structured survey of Irisvale in November 1999 are possible.

Table 21: Comparison of adopting farmers with Irisvale averages

	adopting farmers	Irisvale average
no. of adults available to work on farm	4.0	3.4
household livestock holdings:		
cattle	27.3	15.9
cattle (adjusted)*	18.8	-
goats	4.5	5.3
sheep	1.3	0.2
donkeys	4.0	1.9

*One of the farmers had 154 cattle. The adjusted average is for the other 15.

[4] by Ndabazinhle Nyoni. Assistance with data entry was given by Becky Silverside

The adopting farmers have a slightly higher number of workers per farm, and more sheep and donkeys. Once adjusted for one outlier, their average cattle-holding is remarkably similar to the Irisvale average *for cattle-keeping households*. Three of the four farmers most advanced in store construction gave information on the acres of maize they had planted: 3, 5 and 6 acres respectively, consistent with the 41-farmer average of 5.9.

The adopters were asked to name three reasons for building. These have been grouped and ranked in three different ways: by the number of times a reason was named as primary, by the number of times a reason was named, and by a simple scoring system (1^{st}=3, 2^{nd}=2, 3^{rd}=1).

Table 22: Ranking of most frequently cited reasons for building improved stores, Irisvale

Most important reason only	All reasons (unweighted)	All reasons (weighted)
To keep feed from rain damage	To keep feed from rain damage	To keep feed from rain damage
= To keep feed properly (non-specific)	To keep feed properly (non-specific)	To keep feed properly (non-specific)
To feed animals in dry season	To feed animals in dry season	To feed animals in dry season
To keep stover from the sun	To keep stover from the sun	To keep stover from the sun
= to keep stover green/fresh	= to keep stover green/fresh	To keep stover green/fresh
= to feed dairy animals/get milk in dry season	To feed dairy animals/get milk in dry season	To feed dairy animals/get milk in dry season
= to keep more animals	= to feed draught animals at ploughing time	To feed draught animals at ploughing time
= farmer envied Bidi farmers	To keep more animals	= to keep more animals
	= farmer envied Bidi farmers	= farmer envied Bidi farmers
	= to get a calf each year from cows	To get a calf each year from cows
	= to keep feed for drought	To keep feed for drought
	= to protect against termites	= to protect against termites

Obviously even with grouping, there is a lot of overlap between these reasons, but the main reasons are clear: to protect stover from rain and sun, in order to feed animals during the dry season. Among farmers failing to build, the most important reasons were a general desire to store stover properly, and to keep it green and nutritious.

The four farmers most advanced in store construction, and apparently no others, had all used hired labour for gathering poles. Two of these were also buying thatching grass. One farmer was planning to use old corrugated iron for roofing, the only clear example of a material other than thatching grass being used. One farmer specified that he was helped by Dairy Group members in collecting poles.

Roughly measured areas of the stover platforms varied between 5 and 33 m^2, with an average of 16.3 m^2, and the height of the platforms varied between 0.3 m and 1.4m, with an average of 0.85 m.

Three farmers gave information on the cost of stores, varying from Z$400 to Z$1500, with hired labour the chief or only item for all three.

Farmers were asked to name up to three problems encountered in building stores. Responses have been grouped and are ranked below by three methods, the most important constraints at the top:

Table 23: Ranking of most frequently cited problems encountered in building improved stores, Irisvale

Most important problem only	All problems (unweighted)	All problems (weighted
shortage of labour/time	shortage of labour/time	shortage of labour/time
lack of transport	shortage of thatching grass	shortage of thatching grass
shortage of poles	shortage of cash	lack of transport
shortage of thatching grass	lack of transport	shortage of cash
	shortage of poles	shortage of poles

Shortage of labour is clearly the most important constraint, followed by shortage of thatching grass. Of course, most of the constraints are interdependent: shortage of labour could be circumvented with cash, and the scarcity of the gathered materials mean that the labour demands of gathering them are felt more acutely.

Among those who had failed to build, the reasons were mainly (9 out of 12 total responses) to do with lack of labour/time, demands from other activities, old age or ill-health, although one farmer included lack of stover as a secondary reason. It also appears that some of these farmers (and the farmer yet to start building included among the adopters) were under the misapprehension that only Dairy Group members and/or those visited by the project were "allowed" to build stores. Five of those failing to build still wished or planned to build next season. One was unable to build because of her responsibility for looking after orphans.

Subsequent monitoring in Irisvale (Activity 17)

Further qualitative monitoring was carried out in August 2001 and May 2002. By August 2001, five farmers had completed a total of six stores, and three farmers were clearly in the process of completing stores. As in Bidi, farmers were using stores for miscellaneous farm purposes as well as stover storage. Farmers envisaged investing either money or time or both in maintaining their stores. By May 2002 15 farmers in Irisvale were reported to be in various stages of construction, presumably including the five who had completed by 2001. There was a cluster of adopters in Village 8, the village of the original Irisvale adopter, Mrs Mabel Ncube. There was an increasing sense that roofed stores for stover (and veld hay) was a necessary part of small-scale dairying. Farmers were particularly concerned to store stover because of the likelihood of drought and sever feed shortages in the late dry season 2002.

Monitoring of spontaneous adoption in other communities (Activity 18)

In August 2001, project staff interviewed four farmers who had built roofed stover stores in Gulati, the Communal Area first contacted by the project (see Section IV). Another nine farmers were thought to be seriously considering building stores. These farmers were generally associated with the nascent dairy group at Gulati, and also with the LPP-funded sister project, implemented by Matopos Research Station and University of Zimbabwe, on small-scale silage production. In addition, two farmers on a small-scale commercial farming area near Gwanda, also built roofed stores. This anecdotal evidence further suggest that there is scope for roofed stover stores, primarily in communities beginning to engage in small-scale dairying, and in conjunction with storage methods for higher value foods (silage, urea treatment).

In addition, contacts between the project team and a former employee of MRS working in Namibia resulted in strong interest by a pilot group of ten farmers in building stover stores, followed by an exchange visit by 22 Namibian farmers in October 2000, to look at the Bidi stores and discuss them with their owners.

Conclusion

By the beginning of the third dry season after project work started, at least 15 households in Irisvale, 6% of the total, had adopted roofed stover stores with no material assistance from the project. This is not rapid, but suggests that the technology is likely to be appropriate to at least some Irisvale farmers. There is a strong contrast to Bidi Ward, where despite the building of roofed stores, spontaneous adoption appears to be virtually non-existent. Higher livestock holdings per household and the higher availability of cash seem to be the explanations, as well as the activities of the Dairy Group, which was obviously closely associated with the intervention in the minds of farmers. It does not appear that the need to invest specifically in dairy feeds (purchased or silage) makes conservation of a roughage like stover less attractive.

The major constraints on building stores appear to be labour-related. This is consistent with one factor that appears to distinguish likely adopters within Irisvale: availability of labour (which does *not* explain differences between Irisvale and Bidi).

Finally, the adoption in Irisvale seems to support the utility of field days and community-to community visits as a means of dissemination.

VIII PROJECT OUTPUTS AND CONTRIBUTION OF OUTPUTS

Extension outputs

The project produced an article for the LPP/AHP Newsletter *Livestock Talk* (Issue 3, March 2000) to inform livestock scientists of the project, and an extension pamphlet aimed at encouraging farmers to construct roofed stores (Technical Annex 3).

Technical outputs

Wood, C., Ncube, S., Nyoni, N., Morton, J., and Coker R. "Effects of Harvest and Post-Harvest Practices on the Production and Nutritive Value of Maize and Sorghum Residues in Zimbabwe" in Proceedings of the Second Workshop on Livestock Production Programme Projects in Zimbabwe, held at the Ingwe Lodge, Matobo, Zimbabwe 22-23 February 1999 Livestock Production Programme (2000).

Wood, C., Ncube, S., Morton, J., Coker R., and Nyoni, N. "Effects of Harvest and Post-Harvest Practices on the Production and Nutritive Value of Maize and Sorghum Residues in Zimbabwe" in T Smith and S H Godfrey (eds.) Sustaining Livestock in Challenging Dry Season Environments: Strategies for Smallscale Livestock Farmers; Proceedings of the Third Workshop on Livestock Production Programme Projects in Zimbabwe, held at the Ingwe Lodge and ICRISAT, Matobo, Zimbabwe 26-28 September 2000 Livestock Production Programme (2001).

A journal paper is in preparation, focussing on the methodological questions of combining scientific with participatory research, particularly given the knowledge gap on variance and sampling that existed at the beginning of the project.

Contribution of Outputs

The project outputs have contributed at four linked levels: understanding of processes of degradation in stored stover; direct impact on farmers; improved understanding of farming systems, and particularly feed storage, in Matabeleland South, and improved understanding of the methodological problems of participatory research on feed storage.

The natural science components of the project, investigations of loss of nutritive value of stover and investigations of mycotoxin contamination, can broadly be said to have had negative or inconclusive results. The research on *nutritive value* has, however, suggested new agendas for future research. Firstly, there could be more research on harvesting techniques themselves, incuding maturity at harvest and length of stooking. This problem proved too elusive for the project to tackle while simultaneously dealing with storage, but there is a suggestion that maize is cut at a stage too late to warrant stooking, and resulting in low CP levels.[5]

Secondly and relatedly, there is a research agenda around *palatability* of stored stover, which would not have been measured by any of the experimental methods used. Farmers in Bidi stated that the stores kept stover moist and green and considered it more "nutritious": they also stated, though the finding needs to be treated with caution, that the stores enabled the storage of green stover that could not otherwise have been stored. In Irisvale the desire to store stover cut green and more palatable to cattle was reported as a medium-priority reason for constucting stores. However, this immediately raises the issue of whether, by changing harvesting practices to bring stover to store more moist, the potential for mycotoxin contamination might be increased.

The presence of *mycotoxins* in stored stover in the Matabeleland South had previously been reported (Wareing and Medlock 1992). Because mycotoxins in feed can present a serious health risk to cattle, and under some circumstances to people, and cannot be seen, tasted or smelt by farmers, the presence of mycotoxins presented a genuine risk that justified further research. In the event, the project did not find any mycotoxins at anything near levels recognised as harmful to human health. While not conclusive, especially not with widely varying practices of utilisation of stored stover, this is a reassuring finding in that it largely removes one possible source of concern about the health risks of smallholder milk at a time when its market share in Zimbabwe is likely to increase. This data will be presented as an ad-hoc report to the Dairy Development Project and/or submitted for publication in a journal or conference regionally.

The absence of clear evidence for either loss of nutritive value or mycotoxin contamination is linked to our improved knowledge, obtained from farmers, of how rain affects stover. Essentially, the risk to stored stover in Matabeleland South is one of relatively major rainstorms causing the entire quantity of stored stover to rapidly become completely unpalatable and unusable as anything except compost, rather than more insidious processes of degradation. Despite the run of dry years during the project lifetime, rainfall data suggest a high frequency of years (one in two or three)

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[5] We are grateful to Ndabazinhle Nyoni for raising this point. For background on effects of maturity at harvest and stooking see Topps and Oliver 1993, Tolera et al. 1998, Van Soest 1988, Tolera and Sundstol 1999.

with dry-season rains potentially damaging to stored stover, and farmer comments suggest that losses from open stores, averaged over long-runs of years with and without dry-season rains, can be very large indeed.

The solution to both the problems we thought we were dealing with when the project began and the problem we were in fact dealing with were more or less the same - a simple roofed store, which given the availability and affordability of building materials was most likely to be thatched. Direct uptake by farmers of this "technology" was by the time of project closure small, but significant. Disregarding the farmers in Bidi who received strong encouragement and material help from the project, the technology had been adopted by 15 farmers (6% of the population) in Irisvale within about two years, and had begun to spread to two other communities.

Commenting on this rate of adoption involves a consideration of what we have discovered about farming systems in Matabeleland South, and the role of feed storage within them. The communities where spontaneous adoption occurred were not precisely of the sort envisaged as targets at the beginning of the project. They were not "ordinary" mixed crop-livestock producers. In Natural Regions 4 and 5 of Matabeleland South it is increasingly the case that successive droughts have meant that only a minority of farmers in Communal Areas have cattle[6], and that yields are low and unreliable. Under these conditions, very few farmers are likely to invest the necessary labour, cash, or forward planning[7] for store construction.

Instead, the uptake that the project did achieve was concentrated in a Resettlement Area and a rather uncharacteristic Communal Area[8], in both of which farmers were starting to engage in small-scale commercial dairy production. One of the most interesting findings of the project was that storage of stover is seen very much as a complement to technologies for storage or production of higher value feeds, such as silage or urea treatment. Smallholder dairying, which demands high value feed for milk production, makes it more, not less, important to safeguard the dry-season base diet.

It could be argued that a 6% adoption rate is not high, and represents essentially a failure rather than success for the project. We would argue[9] that it is in the nature of livestock production in developing countries that there will be major differences between farmers within a community, and between communities, as to how they respond to wider trends of resource availability or market opportunities, and how they adopt technology. With such an understanding, rapid mass uptake of any livestock feed technology is very unlikely.

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[6] Both the inability and the unwillingness of farmers to reinvest in cattle, and therefore a proportional shift to smallstock and donkeys, were becoming apparent both to the project team and to other observers during the life of the project.
[7] the need to obtain thatch grass from the Matobo hills area, almost a year before the season for constructing stores, was a n important constraint on adoption.
[8] uncharacteristic because of good market access to Bulawayo, and easy availability of water.
[9] One member of the present team and colleagues made similar comments several years ago: "..the point at which investment of labour for the cultivation of fodder and construction of hay-barns and manure-pits etc. becomes worthwhile, will vary between households, even within one locality. Similarly, households may take up an opportunity for commercialising livestock production at different times." (Morton, Matthewman and Barton 1997).

It is important to note that the smallholder dairy producers in more favoured communal areas and resettlement areas, who are most likely to adopt and benefit from roofed stores, while not as poor as mixed crop-livestock producers in representative communal areas of Natural regions IV and V, are still fairly poor by international standards, and are a recognised target group for LPP.

Following up the project with further dissemination is problematic given the economic crisis and political uncertainty in Zimbabwe at the time this report is being finalised. It will however be followed up if possible by the lead author, the LPP Zimbabwe Co-ordinator, and others as part of a general strategy to disseminate LPP outputs in Zimbabwe, as a toolbox, or one of several "baskets of options" aimed at presenting different but complementary feeding strategies to various categories of livestock-producer. If such a strategy is to be implemented, the Dairy Development Project will be a key pathway for smallscale commercial dairy producers.

Finally, the project has contributed to a better understanding of the methodological problems of sampling and analysing maize (and other) stover. These materials are extremely important feeds in smallholder farming systems in Southern Africa and elsewhere, but there has been a basic knowledge gap concerning levels of variance and procedures for sampling, the filling of which has been necessary to the design of any meaningful scientific trials. In the present project, this knowledge gap exacerbated the generic difficulties of integrating “scientific” and participatory work in livestock production research (Morton *et al.* 2002). These methodological issues will be discussed in a journal paper that is under preparation.

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