Ensiling of tropical forages with Particular Reference to African Livestock Systems. Forage production and conservation for dry season feeding of smallholder dairy cattle in the semi-arid region of Southern Africa

TITTERTON M.,[1] MHERE O.,[2] MAASDORP B.,[3] KIPNIS T.,[4] ASHBELL G.,[5] SMITH T.[6] and WEINBERG Z.[5]

1. *Department of Animal Science, University of Zimbawe, P.O. Box MP 167, Mt. Pleasant, Harare, Zimbabwe.*
2. *Matopos Research Station, P.Bag K 5137, Bulawayo, Zimbabwe.*
3. *Department of Crop Science, University of Zimbabwe, P.O. Box MP 167, Mt. Pleasant, Harare*
4. *Agricultural Research Organization, Institute of Field and Garden Crops, The Volcani Centre, P. O. Box 6, Bet Dagan, Israel.*
5. *Agricultural Research Organization, Forage Preservation and By-products Research Unit, The Volcani Cenre, P.O. Box 6, Bet Dagan, Israel.*
6. *Natural Resources International Ltd., Park House, Bradbourne Lane, Aylesford, Kent, ME20, UK.*

[Paper presented at the XIIIth International Silage Conference, 11-13th September, 2002]

ABSTRACT

The ensilage of adapted forages and legumes in the semi-arid regions of Southern Africa can play an essential role in providing the opportunity for smallholder dairy farmers to maintain milk production and fertility in spite of poor and erratic rainfall and long dry seasons. Production of intercropped pennisetums and forage sorghums with legumes, on small plots with the use of low-cost and appropriate technology, has been developed and adopted after participatory farm trials in a dairy cooperative in a communal farming area.

However the use of agro-forestry, strategic irrigation, harvesting management for maximum digestibility, feeding strategy and farming system are important areas requiring further research and development before silage can assume full significance in smallholder dairy cow nutrition in this region.

INTRODUCTION

Livestock is recognized as being an integral component of the mixed farming systems that predominate in developing countries in the tropics, of which many are in Africa. Animal manure and traction make the land more productive than would be the case in their absence. Yet it has been recognized with equal force that livestock owned in the semi-arid regions, which predominate in much of Africa, are forced to barely subsist on poor and sparse vegetation in the dry season, leading to severe loss of body condition, productivity and fertility and on the land, the threat of desertification. In the smallholder farming system, the production of forage and fodder is often a sideline activity that is integrated with other areas of agricultural production (Nitis, 1999).Technologies aimed at achieving a balance, whereby livestock can increase in productivity, so enhancing wealth for the livestock owner, while resource degradation is minimized, must be developed (Steinfield, 1998). In the semi-arid regions of Africa, smallholder dairying generates a more regular income than any other rural enterprise and can lead to improved human nutrition and health, poverty alleviation and improvement of household food security (International Livestock Research Institute, 1997).

During the rainy season in Zimbabwe, despite erratic rains lasting in general from November through March (five months) the supply and quality of forage (normally as grazing on natural pasture or veld) are usually adequate for milk production from the indigenous and cross-bred cow (Nyoni et al., 2000). The remaining seven months, however, leave a large deficit in adequate nutrient supply for the productive animal. Small ruminants (goats, sheep and donkeys) are able to subsist on the poor winter grazing, crop residues (sorghum and maize stover) and browse, as are cattle herd "followers", such as weaners and young oxen. The dairy cow, the traction animal and the finishing steer, however, which are more productive, and which represent opportunity for wealth for the livestock owner, require a much higher plane of nutrition (Zerbini and Alemu, 1999).

Traditional smallholder dairy production is characterized by low levels of milk production, long calving intervals, of two years or more, and short lactations. Hence the availability of milk for local markets is erratic, as is income for the farmer. There are three major reasons for this: the high cost of commercially produced stockfeed, putting this source of feed beyond the reach of smallholders; the lack of adequate, good quality forage in the dry season; and the breed of cow (Dube, 1995; Henning, 1995; Gandiya, 1999).

Extensive research has been carried out to find technologies which would enable the farmer to plan ahead and strategically manage the feeding of their livestock.

One such technology is the conservation of forage produced during the wet season, for feeding to stallfed or partially zero-grazed livestock during the dry season. Other technologies include improving the nutritional value of crop residues through physical and chemical treatment, improved management of grazing and the use of by -products by the peri-urban farmer, all of which can contribute to the forage bank (Smith, 2001) The conservation of high quality forages, however, may be the only such technology that would satisfy the high demand for nutrients for such livestock operations as small-scale dairy farms in the semi-arid regions of the tropics (Dube, 1995) and for traction which commences in the dry season (Smith, 2001).

CURRENT ROLE AND IMPORTANCE OF SILAGE

In the semi-arid regions of the tropics, the conditions are harsh for conserved forage. High temperatures combine with short rainy seasons on largely poor soils to produce grasses and legumes which, while able to produce high yields under good management, still deteriorate rapidly in nutritional quality after only three months of growth, as lignification proceeds (Skerman, 1988).

The two ways of conserving forage are by hay making and by ensiling. Hay making of forages in Southern Africa is difficult because to conserve forage at its optimum yield, protein levels and digestibility, it should be cut in February or early March and this usually coincides with the wettest part of the rainy season (Topps and Oliver, 1993). It requires the use of mower-conditioners for rapid drying, hay balers and large sheds for protection from the rain, all suited to the commercial type of farming operation and not to the smallholder. For the smallholder, rain damage results in a loss of dry matter and quality due to leaching of nutrients by rotting. Thin -stemmed forages such as legumes can dry within two or three days (Cameron, 1988) but bulky forages such as napier, hybrid pennisetums and forage sorghum take too long to dry even when left out on racks (Mhere, 1997). If cutting is delayed to later in the season, there is a severe reduction in quality and excessive leaf shattering and loss, especially in legume forages (Maclaurin and Wood, 1987).

On the other hand, ensiling of adapted forage crops or grasses in March has a good chance of success because the procedure relies on a high moisture content of the crop and after sealing, protection from *leaching, rodents and insect damage. However, successful ensilage of forage depends on a number of principles, creating a major challenge to the smallholder:*

1. *The majority of smallholder livestock owners in Africa have an average of 2 to 10 hectares, in which they plant their own food crops and vegetables. The land on which their livestock graze is communal, so that the smallholder's arable land for forage cropping is very limited since priority has to be given to growing food for the family. Pasture improvement or grazing schemes have rarely succeeded because communal areas, by their definition, inherently allow no one farmer to take responsibility for management or fencing. Thus the only possible source of good forage is the forage crop grown by farmers on their own plots. The challenge, therefore, is to produce sufficient high quality forage from a small area, probably no more than 0.5 ha, to feed silage to an average of two cows for as much of the dry season as possible. The other option is to have land provided by the community for a forage centre under group management.*
2. *Time of harvesting is a complex matter involving not only maximum yield, nutrient and fermentation quality, but also family labour (often a major constraint) and integration with other farm activities. It is a question of determining which "trade-offs" to make to achieve the best result in terms of the smallholder animal's needs over the dry season and of the return to the farmer on his investment. Many farmers now own cows bred from Holstein or Jersey crossed with indigenous breeds such as the Mashona and Tuli in Zimbabwe. These cattle are often bought with the proceeds of the sale of indigenous cattle, hence the return on such an investment through providing adequate nutrition for maximum productivity has become more critical than ever.*
3. *Harvesting and chopping a crop to the ideal length is laborious and time consuming and hence specialized machinery is employed on the commercial farm to cut and chop the forage. The cost of such machinery is far beyond the resources of the smallholder and so the challenge here is to ensile forage chopped to the required length and compressed and sealed with appropriate low-cost technology.*
4. *The silo for a commercial farm in Zimbabwe would normally be a bunker or pit, sufficient to store up to 100 tons of silage and would require tractor compression. The challenge to the smallholder is to compress, seal and store silage of up to 5 tons without the benefit of a tractor. Small pits in which the silage has been compressed with water drums pulled by oxen have been tried and are still in use in some areas, but generally it has been found that spoilage is very high due to poor compression and over exposure of the silage upon removal for daily feeding (Chakoma, 2001). Drums have been used in other countries, mainly in Asia (Humphreys, 2000), but are scarce and expensive in many African countries.*

Even with a high yield of good quality forage, the quantity conserved would not be sufficient to feed dairy cows through both the dry season and during the rains, when the cow is lactating and may require higher levels of nutrition than can be supplied by grazing alone. This is of particular concern with regard to cross bred cows. Feeding strategy to maximize returns in the form of both milk yield and fertility from a limited amount of silage needs to be determined.

Our research was aimed at addressing all five of these constraints. However, participatory research on-farm, where there are one or two animals per farm and a wide range of soils and farmer attitudes, inherently produces large variation and experimental error, hence both formal and on-farm participatory experimentation have been undertaken concurrently.

1. PRODUCTION OF HIGH YIELDING, HIGH QUALITY FORAGE

In the high rainfall areas of Southern Africa, maize is the crop of choice for silage, because of its high yield, fermentation quality and energy content. It is suitable for intercropping with legumes (Maasdorp *and Titterton, 1997) or can be mixed with legume tree leaf forage (Mugweni et al., 2000) to improve protein content of the silage. However, maize is susceptible to moisture stress and consequently cannot be considered as a reliable crop for silage in the marginal and semi-arid areas, where dairy production offers the best means of improving livelihood for the smallholder livestock owner. In these areas, grain sorghum, forage sorghums and Pennisetum are more drought tolerant than maize and have a high yield potential as silage crops (Titterton and Bareeba, 1999; Mhere et al., 1999). However, it was concluded after an evaluation of grain and forage sorghums in semi-arid areas that sweet forage sorghums offer better potential as silage crops than grain sorghums (Cole et al., 1996). As with maize, however, these crops have a low crude protein content (7 and 9% for grain and forage sorghums respectively) and in order to produce a high quality ration to meet the nutrient requirements of dairy cows, protein-rich crops need to be introduced into the silage, either by growing them as sole crops and mixing them at ensilage with the forage crops, or intercropping them with the forage crops. A three-year study was carried out, using both formal trials and participatory trials on-farm, to determine the feasibility of intercropping forage sorghum and Pennisetum with legumes. Both cowpea (Vigna ungiculata) and dolichos bean (Lablab purpureus) were undersown using differing planting patterns and on two types of soil. Total biomass yields and protein content of silages from the mixed crops was significantly improved over that of the sole cereal crops. Pennisetum/legume crops produced between 5 and 10 tons dry matter on sandy and clay soils respectively while forage sorghum/legume crops produced between 8 and 13 tons dry matter (Table 2). Mhere et al. (1999) found, however, that soil type, planting pattern and weather had significant effects on the proportions of legume in both forage sorghum and forage pennisetum crops.*

Table 1. Crude protein and dry matter digestibility (g/kg) of hybrid Pennisetum and forage Sorghum intercrops with cowpeas and dolichos beans,grown over three seasons (1996-96, 1996-97, 1997-98) at Matopos Research Station (extracted from Mhere, 1999, Mhere et al., 1999).

Forage[1]	**Crude protein**	**Digestibilty[2]**
Pennisetum + cowpeas	121	596
Pennisetum + dolichos	124	590
Sorgum + cowpeas	119	591
Sorgum + dolichos	130	583
Pennisetum	81	594
Sorghum	69	601

[1]Forages harvested 14-17 weeks after planting.
[2]Digestibility derived from MADF (Clancy and Wilson, 1966; Linn and Martin, 1991) using the formula Digestibility = 99.43 -1.17 MADF.

Table 2. Dry matter yields (t/ha) on station and on-farm (Gulathi communal area) Extracted from Mhere (1999) and Mhere et al., 2000.

Crop combination	On-station	On-farm (32)

	Rain 750,600,4000		Rain 380,550
	Clay Sand approx. mean of 3 years		Farmer control mean of 2 years
PP 1:1			
	(Leg%)	(Leg%)	(dry-wet areas*)
FS/CP	12 (10)	9 (5)	2.8 (0.3-3.1)
FS/DB	13 (30)	7 (48)	2.9 (0.4 - 3.6)
PS/CP	9 (4)	7 (5)	2.2 (0.8 -3.0)
PS/DP	11 (10)	6 (20)	2.6 (0.7 - 4.7)
Average size of forage plot			0.3 (range 0.1 - 2.2)
Average no. bags per farm			180 (125 - 700)

FS= forage sorghum; CP = cowpea; PS= hybrid pennisetum; DB= dolichos bean
*Dry and wet areas of Gulathi communal area were distinguishable by the wet areas having sponge soils which retained water while the dry areas did not. One year experienced a severe drought while the other had higher than normal rains.

Elsewhere in Africa, high biomass yields from intercroppping forage sorghum with cowpea (Enyi, 1973), forage sorghum with dolichos bean (Kusekwa et al., 1992), hybrid Pennisetum with cowpeas (Maiti et al., 1988) and hybrid Pennisetum with Leucaena leucocephala (Gill and Tripathi, 1991) have also been reported.

Multi purpose leguminous trees are a good potential source of protein in conserved forages in the semi-arid areas. Fodder trees produce protein-rich forage and, being deep rooted, they generally withstand water stress well, possibly better than adapted annual legumes. The addition of wilted Amaranthus hybridus to maize (1:1) at the time of ensiling resulted in good fermentation and raised the crude protein content of the silage from 6.9% to 11.6%, while reducing the crude fibre content (Bareeba, 1977). In a study of four silages made from maize and forage legumes, Acacia boliviana, Calliandra calothyrsus, Gliricidia sepium and L.leucocephala, (mixed 1:1 on a w/w basis and ensiled in fertilizer bags) maize and tree fodder was shown to ensile well and to have high levels of crude protein (Table 3) but digestibility decreased substantially with the addition of A. boliviana and C. calothyrsus. Of interest was the effect of ensilage on protein binding by phenolic compounds (tannins) in which it was found that protein precipitation activity was reduced in ensiled tree fodder. However, the degree of reduction varied with type of tree (Mugweni, 2000; Mugweni, 2001). Milk yields were the same from Holstein

cows on the mixed silages as those from cows on maize silage and protein concentrate (Mugweni, 2001), suggesting that it would be worthwhile carrying out a similar study with forage sorghum and Pennisetums with tree fodder fed to cross-bred cows.

Table 3. Fermentation and nutritional quality of silages made from maize and legume forage trees. (Extracted from Mugweni, 2001).

Silage type	**Fermentation quality**		**Nutritional quality**	
	pH[1]	**NH3: N%[2]**	**CP% [3]**	**OMD %[4]**
Maize	4.0	7.7	9.4	56.0
M+*A.boliviana*	4.7	12.0	18.7	44.8
M+*C. Calothyrsus*	4.1	11.6	14.0	37.5
M+*G.sepium*	4.2	8.5	15.5	59.1
M+*L. Leucocephala*	4.6	12.8	17.2	49.3
Maize ± tree	***	**	***	***
A. boliviana	6.3	11.0	>24.0	40.9
C. calothyrsus	5.2	12.4	22.9	30.2
G. sepium	5.1	9.3	25.5	64.5
L. leucocephala	6.5	11.7	27.2	33.4
Tree ± maize	***	ns	***	***

[1] Acidity of < pH5 needed for good preservation
[2] Protein-N loss as ammonia of <15% is reasonable in legumes

[3] CP= Crude protein
[4] OMD- organic matter digestibility.

DETERMINATION OF APPROPRIATE HARVESTING STAGE USING NUTRIENT PROFILES ON THE CEREALS.

Nutrient profiles of cowpea and lablab showed that optimum protein and digestibility levels were reached at 12 to 14 weeks after planting, around mid February to mid- March in Zimbabwe, while forage sorghum has reached the soft dough stage of maturity by this time(Mhere, 2002). However, with other farming activities limiting the farm labour available for harvesting, cutting was mostly delayed to early April. The nutrient analysis of the two cereal crops at this stage showed a reasonable water soluble carbohydrate content in the dry matter but an unacceptably low digestibility (Table 4).

Table 4. Quality parameters of forage crops at 18 weeks post establishment.

Quality parameter	Forage sorgum	Pennisetum
	(g/kg DM)	(g/kg DM)
Dry matter (g/kg DM)	250-350	250-350
Crude protein content (g/kg DM)	75-85	95-105
Soluble sugars (g/kg DM)	70-90	125-155
Dry matter digestibility (g/kg)	520-570	550-565

Clearly more attention needs to be paid to achieving a better digestibility through earlier harvesting. Some farmers have tried cutting their hybrid pennisetums in January at one metre high and fed them fresh or, after wilting, ensiled them. The second cutting was then carried out in the last two weeks of March of both the Pennisetum and legume. These informal trials showed that by the time of the third cutting this strategy had allowed better growth of the legume and greater yields of total ensiled forage. With less forage to handle on each occasion, labour was less of a constraint. Formal experimentation needs to be carried out to verify these results, which look promising. Clearly the advantage with the use of wilting in semi-arid Southern Africa, is the dry, hot climate which facilitates rapid drying. Wilting was not found to be of any benefit in crops that were between 25 and 30% dry matter (Mhere, 1999), but when cut in January and February, the crops are less than 25% dry matter and should benefit from wilting. Wilting studies are recommended for this reason.

Either maize or a commercial additive (Sil-all) enhanced fermentation and quality of Pennisetum/ legume silage, while it was not found to be of any benefit in forage sorghum/legume silage (Mhere, 1999). However, most perennial tropical grasses require some form of additive at ensiling and, where it is available, molasses is suitable (Humphreys, 1999). Molasses in Zimbabwe is often scarce, but home grown additives (sweet-stem Sorghum stems) give similar fermentation patterns to maize meal and Sil-all (Alltech), but higher total nitrogen content when added at 10% fresh weight to hybrid Pennisetum/ legume silage (Mhere, 1999). This is probably due to the reduction in proteolysis.

3 AND 4. THE USE OF LOW-COST TECHNOLOGY TO PRODUCE SILAGE

The objectives of this study were to examine ways of overcoming the major constraints to smallholder farmers when ensiling forages, the use of high-cost machinery traditionally used in chopping and compressing forage on large-scale farms and unsuitable silos. Labour and gender issues were addressed as both are important in the smallholder dairy farming system.

Methodology

The treatments consisted of:

- ***Five forages (including two mixes): forage sorghum-dolichos bean; pennisetum-dolichos bean; forage sorghum; pennisetum; dolichos bean.***
- ***Two particle sizes (length of chop): coarse chop (mean 45 mm) from the use of large knives (pangas), fine chop (mean 18mm) from the use of a motor driven chaffer.***
- ***Two methods of compression: mechanical from the use of a manual tobacco press with a screw press driven down on a metal plate covering the bag followed by twisting the top of the bag for tying with twine; manual, with simply leaning on the bag accompanied by pushing out air pockets before twisting the top of the bag for tying with twine.***
- ***Two types of silos: recycled plastic garbage bags large enough to carry 50 kg (90-100 micron thickness); fertiliser/maize bags large enough to carry 50 kg of fertiliser (+ 125 micron thickness. The bags were, however, filled to carry 15 kg of silage, the amount estimated to comprise the daily total required to supplement an indigenous milking cow grazing natural pasture.***

Summary of results

There were differences in fermentation and nutritional quality of silages due to grass crop variety but none due to chop length, compression treatment or type of bag (Table 4). Therefore, on-farm silage can be made in non-permeable plastic bags with coarsely chopped crop material, which is compressed by hand if there is no mechanization available. Notwithstanding that, labour and time constraints led to the accepted use of the petrol-driven chopper on -farm. This type of chopper is available on hire to dairy farmers, whose cooperatives are members of the dairy development programme in Zimbabwe. Collaborative studies carried out in Israel (Ashbell et al., 1999; Kipnis et al., 2001) suggested that success of ensilage, despite the lack of fine chopping and partial compression, is due to effective sealing of the bags, preventing the loss of effluent containing lactic and volatile fatty acids, compared with pit or bunker silages, where loss of effluent is high, necessitating fine chopping and effective compression.

The technology is found to be ideal for smallholder farmers as losses are minimal, compared with silage pits, which have been used in smallholder dairy farms in the higher rainfall areas, where silage losses amount to as much as 30% of the dry matter due to poor compression and exposure losses in the remainder during removal for feeding. The bag technology has also been found to benefit women and children, as the bags can easily be stored and carried to the cows for feeding, thus there is minimum labour in feeding compared with daily digging out from pits. The nutrient requirements of a cross-bred Tuli/Jersey cow producing 8 litres a day are met from 5 kg silage dry matter per day, which equates to one bag of 15 kg of air-fresh silage per day (Nyoni et al., 2000).

The fertilizer bags, being thicker, could be used over two seasons. This makes their present cost (2002,

Zim$9.00) equivalent, when used over two seasons, to the cheaper bags (present cost around Zim $4.50). When no longer usable, the bags can be used for the manufacturing of wax for floor polish, a traditional practice in most smallholdings. Some losses (5%) in the cheaper bags were experienced due to poor packing of bags in the silage storeroom, a problem requiring attention.

Table 5. Fermentation quality of forage crops ensiled under differing conditions. (From Kipnis et al., 2001)

Crop material	Dry matter (DM) loss%	pH	NH3: N % DM	Lactic acid % DM	Butyric acid% DM	Acetic acid % DM	Ethanol %DM
All sorghum							
(FS)	9.36	3.7	6.07	5.63	0.05	2.04	2.12
All pennisetum							
(PS)	18.0	4.3	6.99	4.25	1.17	1.89	0.97
FS/DB	12.3	3.78	8.37	6.55	0.3	2.34	0.72
FS only	7.15	3.63	8.85	4.76	0.07	1.74	2.81
PS/DB	16.46	4.25	12.2	2.32	1.7	2.42	0.68
PS only	19.79	4.4	9.71	1.92	0.57	1.34	0.72
Making techniques (all materials)							
fine chopped	12.43	3.84	7.4	4.65	0.50	2.12	1.22
coarse chopped	15.31	4.20	9.7	4.62	0.72	1.8	1.6
tobacco press	15.04	4.05	7.5	4.18	0.5	1.74	1.38
hand press	12.88	4.01	8.2	3.59	0.67	2.13	1.45
garbage bags	11.56	4.34	8.8	4.26	0.45	1.43	0.95
fertilizer bags	9.11	4.04	7.3	4.77	0.22	1.66	1.21

STRATEGIC FEEDING OF SILAGE

During a severe drought in Gulathi communal area, it was found that cows fed on half a bag of silage a day (3 kg dry matter) for the months of August and September during the dry season, were in

reasonable body condition at calving (mean body condition score 2.0 on a scale of 0-5 (Mulvaney, 1978), compared with those cows not supplemented (mean body condition score 1.0) (Titterton, 1999). In a good year, cows fed on a bag of silage (6 kg dry matter) a day achieved body condition scores of 3.5 and 3.0 for indigenous and Tuli-Jersey cross-bred breeds respectively (Nyoni, 2000). While feeding in the dry season improved fertility, through reduced delay to conception and higher conception rates, there was no effect on milk yields in the following lactation (Nyoni, 2000). However, supplementation of a small amount of concentrate in the lactation period alone improved both yields and fertility (Garwe et al., 2000).

CONCLUSIONS AND RECOMMENDATIONS

- *Ensilage of forage crops is the preferred option over hay making for production of high quality forage for dry season feeding.*
- *Intercropping forage cereal crops with forage legumes produces a high yield of forage from a small area of land, sufficient to supplement two cows for the dry season in a normal year and up to two months in a drought year in the semi-arid areas. This is, however, subject to large variation brought about by soil type and weather. Strategic irrigation to ensure establishment of crops and alleviating the effects of mid-season drought should be developed for use by communities which have access to water. Harvesting management requires further study, in order to ensure optimum nutrient content while achieving high forage biomass yields. The use of forage tree legumes in an intercropping system with perennial tropical grasses or cereal crops needs to be explored as a viable alternative to annual legumes.*
- *It has been shown that fodder from forage legume trees can replace annual legumes in silage but so far this has only been proved with maize Their suitability for ensiling when mixed with forage sorghum and Pennisetums should be investigated.*
- *Escalating costs of fertilizer may threaten the viability of forage production and conservation for smallholder dairying in Africa. Manure can replace fertilizer to some extent if applied in sufficiently large quantities. This may require a collective form of animal management and forage production. Collective or cooperative farming systems need to be tested as socio-economically viable alternatives to individual farm production.*
- *Ensilage can be successfully carried out with low-cost small scale technology.*
- *It is feasible to achieve good productivity in dairy cows with dry season feeding of conserved high quality forage or with supplementary feeding in lactation (usually the wet season) but further studies on partitioning the supply of silage between the dry season and lactation to verify these results are required, particularly in a drought year. Cross-bred cows require special attention in terms of their nutrient requirements over the dry season.*

ACKNOWLEDGEMENTS

The authors and collaborators of the studies in producing and conserving forages for smallholder livestock owners in the semi-arid areas of Zimbabwe wish to thank the following for their contribution to the research:

- *Department for International Development, U.K.- research funding.*
- *German-Israeli Fund for International Development- research funding.*
- *Matopos Research Station, Department of Research and Specialist Services- facilities and staff*
- *University of Zimbabwe- facilities and staf*
- *Dairy cooperative of Gulathi communal farming area- participatory research.*

The views expressed are those of the authors.

REFERENCES

ASHBELL G., KIPNIS T., WEINBERG Z.G., HEN Y., AZRIELL A., KALLER S. and TITTERTON M. (1999) Developing a technology for ensiling forage crops for smallholder cattle owners in developing countries. In Proc. XIIth Int. Silage Conference on Silage Production in Relation to Animal Performance, Animal Health, Meat and Milk Quality. Uppsala, Sweden. July 5. 1999.

BAREEBA F.B. (1977) The ensilage characteristics and nutritive value of maize, amaranthus-enriched maize and sorghum silages preserved with either molasses or formaldehyde. M.Sc.(Agric). Makarere University, Uganda.

CAMERON D.G. (1988) Tropical and subtropical pasture legumes- lablab bean. Queensland Agricultural Journal. 114 (2): 110-113.

CHAKOMA C. (2001) Dairy Development Programme Forage Specialist. Personal communication.

DUBE D.M. (1995) The role of high quality dry season forage in the small holder dairy farming sector of Zimbabwe-Dairy Development Programme perspective. In Production and Conservation of Forages in Southern Africa. Rockefeller Forum on Agriculture Resource Husbandry Workshop, University of Zimbabwe, Harare.

ENYI B.A.C. (1973) Effects of intercropping maize or sorghum with cowpea, pigeon peas or beans. Experimental Agriculture, 9: 83-90.

GANDIYA F. (1999) Smallholder dairying in Zimbabwe- problems and opportunities. In (Eds. S. Dickin and D. Dickin) Zimbabwe Society of Animal Production Annual Journal. (Published in Farming World).

GARWE E.C., BALL P.H., HAMUDIKIWANDA H. and MUTISI C. (2000) Reproductive performance of indigenous and cross-bred cows developed for milk production in semi-arid regions and the effect of food supplementation. In In (Eds. T. Smith and S.H. Godfrey) Sustaining Livestock in Challenging Dry Season Environments: Strategies for Smallscale Livestock Farmers. Proceedings of 3rd workshop on Livestock Production Programme Projects. Matobo, Zimbabwe. 26-28 September, pp 82-89.

GILL A.S. and TRIPATHI S.N. (1991) Intercropping Leucaena with particular reference to hybrid Napier varieties. Range Management and Agroforestry. 12(2): 201-205.

HAQUE I. (1989) Annual Report, ILCA., Addis Ababa, Ethiopia. Pp 11-17.

HENNING P. (1995) The production of high quality dry season forage in the semi-arid areas of South Africa. In Production and Conservation of Forages in Southern Africa. Rockefeller Forum on Agriculture Resource Husbandry Workshop, University of Zimbabwe, Harare.

HUMPHREY L.R. (1999) Forage utilization. In (Eds.L.Falvey and C. Chantalakhana) Smallholder Dairying in the Tropics. ILRI, Nairobi, Kenya. pp 185-206.

International Livestock Centre for Africa (ILCA). 1994. Improving livestock production in Africa.

Evolution of ILCA's programme 1974-1994, ILCA, Addis Ababa, Ethiopia pp 102-103.

KIPNIS T., TITTERTON M., ASHBELL G., WEINBERG Z., HEN Y., AZRIELL A, MAASDORP B. and MHERE O. (2001) Development of ensiling technology and its use by small holder cattle owners in the semi-arid region of Zimbabwe. Final report submitted to the German-Israel Fund for Research and International Development (GIFRID). February. Pp.3-12.

KUSEKWA M.L., KYAMANYA R.S. and NGONI M.D. (1992) Fitting forage legumes into the cropping systems of semi-arid Tanzania. In Stares, J.E.S., Said, A.N. and Kategile, J.A. 1991. The complementarity of feed resources for animal production in Africa. ILCA.. Pp 215-222.

MAASDORP B.V. and TITTERTON M. (1997) Nutritional improvements of maize silage for dairying: mixed crop silages from sole and intercropped legumes and a long-season variety of maize. 1. Biomass yield and nutritive value. J. Animal Feed Science and Technology. 69: 241-261.

MAITI S., SAHU B.B., PAL S. and CHATTERJEE B.N. (1988) Effect of phosphate manuring on intercropping of hybrid Pennisetum. Environment and Ecology 6(2): 422-427.

MACLAURIN A.J. and WOOD A.M. (1987). Veld and pasture management. In (Ed. J. Oliver) Dairy Handbook. National Association of Dairy Farmers of Zimbabwe. p. 79.

MHERE O. (1997) The effect of hay quality of drying pennisetums on racks. Verbal communication.

MHERE O. (1999) Intercropping forage and legume crops. In (Titterton et al.) Forage Production and Conservation for Dry Season Feeding of Dairy Cows in the Semi-Arid Regions of Zimbabwe. In (Ed. T. Smith) Proc. DFID Workshop on Livestock Production in the Semi-Arid Regions of Zimbabwe. Matopos, Zimbabwe. Feb.1999 pp 53-59.

MHERE O., MAASDORP B.V. and TITTERTON M. (1999) The effect of intercropping on production and ensilage of sweet forage sorghum and pennisetum with cowpea and dolichos bean. In (Eds. T. Smith and W. Richards) Proceedings of Livestock Production Programme Workshop on Livestock Research in Zimbabwe. Department for International Development. Matopos, Zimbabwe.

MHERE O., MAASDORP B.V., TITTERTON M., DUBE S.M. and HEINDRICH G. (2000) On farm assessment of forage yields and silage quality of intercropped drought tolerant cereal and legume forages crops. In (Eds. T. Smith and S.H. Godfrey) Sustaining Livestock in Challenging Dry Season Environments: Strategies for Smallscale Livestock Farmers. Proceedings of 3rd workshop on Livestock Production Programme Projects. Matobo, Zimbabwe. 26-28 September, pp 76-81.

MUGWENI B.Z. (2000) The effect of feeding mixed maize-forage tree legume silages on milk production from lactating Holstein dairy cows. M.Sc. Animal Science. Thesis. University of Zimbabwe, Harare.

MUGWENI B.Z., TITTERTON M., MAASDORP B.V. and GANDIYA F. (2000) Effect of mixed-cereal-legume silages on milk production from lactating Holstein dairy cows. In (Eds. T. Smith and S. H. Godfrey) Sustaining Livestock in Challenging Dry Season Environments: Strategies for Smallscale Livestock Farmers. Proceedings of 3rd workshop on Livestock Production Programme Projects. Matobo, Zimbabwe. 26-28 September, pp 82-89.

NITIS I.M. (1999) Production of forage and fodder. In (Eds.L.Falvey and C. Chantalakhana) Smallholder Dairying in the Tropics. ILRI, Nairobi, Kenya. pp 157-184.

NYONI L., TITTERTON M., HAMUDIKIWANDA H. and MUTISI C. (2000) Body condition score and lactation responses in indigenous and cross-bred cows in smallholder dairying systems in a semi arid area of Zimbabwe. In (Eds.T. Smith and S.H. Godfrey) Sustaining Livestock in Challenging Dry Season Environments. Proceedings of the third workshop on Livestock Production Programme Projects. Matobo, Zimbabwe. 26-28 September, 2000. pp.

SKERMAN P.J. (1988) Tropical forage legumes. In 2nd ed. Plant Production and Protection Series, No. 2, FAO.

SMITH T. (2001) Surviving the dry season. Livestock Talk, a newsletter of the Livestock Production and Animal Health Programmes of DFID. October. P 1.

STEINFELD H. (1998) Livestock and their interaction with the environment: an overview. In (Eds. M. Gill, T. Smith, G.E. Pollott, E. Owen and T.L. J. Lawrence) Food, lands and livelihoods- setting agendas for animal science. British Society of Animal Science. Occ. Publ. No. 21 pp 67-76.

TITTERTON M. and BAREEBA G.B. (1999) Grass and legume silages in the tropics. Paper presented to Electronic conference on Tropical Silage held by Food and Agriculture Organisation. September 15-30.

Web site: Grassland and Pasture Crops. http://www.fao.org./WAICENT/FAOINFO/AGRICULT/AGP/AGPC/doc/pasture/pasture.htm

ZERBINI E. and ALEMU G.W. (1999) Feeding dairy cows for draught. In (Eds.L.Falvey and C. Chantalakhana) Smallholder Dairying in the Tropics. ILRI, Nairobi, Kenya pp 133-153.