Grass and legume silages in the tropics

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Introduction

Livestock is recognized as being an integral component of mixed farming systems which predominate in the tropics, particularly in the developing world. 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 developing world have had a devastating effect on the environment through overgrazing the natural vegetation leading to soil erosion, and ultimate desertification. 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 (Steinfeld, 1998). One such technology is the conservation of forage produced during the wet season which can be fed to livestock kept in at least partially zero-grazed systems during the dry season. This may, in fact, be the only such technology that would ensure satisfying high demand for nutrients for such livestock production operations as small scale dairy farms in the semi-arid regions of the tropics (Dube, 1995).

To put the importance of ensiling tropical grasses and legumes to feed as conserved forages in the dry season in the tropics into perspective, one might ask the question "Why silage?

Why not hay? Surely with all that sun in the tropics, it should be easier and cheaper to make hay than silage?"

The answer to this lies with both season and plant physiology. A comparison can be made with countries where temperate climates allow both ensilage and hay making of rye grasses and legumes, which retain high nutritional quality and, which, with persistent rains and good soils, will provide sufficient regrowth for several cuts (New Zealand, Europe). Then there are those countries where irrigation is plentiful and cheap and legumes such as lucerne (alfalfa) can be grown in abundance for both silage and hay (USA). Other countries again have winter rainfall (Israel, Western Australia and the Cape of South Africa) where lucerne and winter wheat can be produced with relative ease.

In much of the rest 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. Protein and digestibility both decline rapidly in tropical grasses after flowering, as lignification proceeds in most tropical grasses and legumes. In order to harvest grass and legumes of high nutritional quality, cutting has to take place at the early stage of growth, in fact while the rains are still prevalent. Unless a mower-conditioner is used with the harvested crop and it is then taken for treatment with bulk dryers in large hay sheds, it is unlikely a good hay crop can be produced at this time. This requires expensive machinery and buildings and even on the large livestock farms it is questionable as to whether it is economically justifiable.

The rains are hard and driving and will wet the entire crop which then leaches and rots. If harvesting for hay takes place after the rains, not only is the nutritional quality low but in legumes, leaf shattering is likely to occur at cutting, leaving largely poor quality stemmy hay. One could argue that with irrigation, winter (temperate) grasses and legumes could be produced for hay. This is certainly true and indeed is carried out on some of the large commercial dairy farms in the tropics. For smaller dairy farms, however, and certainly for the small-scale farms, irrigation is expensive and likely to provide better returns with horticultural crops than hay crops for livestock feeding. Thus we are left with the other option of conserving grasses and legumes, that of ensilage.

The feasibility of successful ensilage of tropical grasses and legumes

Tropical grasses and legumes are not natural ensilage material, largely because at cutting, they have a low content of water soluble carbohydrates, which are essential to successful ensilage (Table 1). This leads to them having a higher buffering capacity and leaves their proteins susceptible to proteolysis (Woolford, 1984)

However, there are a number of practices which contribute to improving the levels of fermentable carbohydrates, reduce buffering and prevent proteolysis and can succeed in producing good quality silage. These include:

1) Mixing legumes with cereal crops
2) Wilting
3) Silage additives
4) Small scale silos

Table 1. Water soluble carbohydrates WSC (mean values in g/kg DM forage followed by range in brackets) of silage forage crops.

Crop	WSC (g/kg DM)	Reference
Ryegrass	79 (5-220)	Thomas and Thomas (1985)
Maize	350 (280-510)	McDonald, *et al*., 1991
Grain sorghum	75 (56- 132)	Havilah and Kaiser (1992)
Sweet Forage sorghum	220 (180-250)	Mhere *et al*., 1999
Kikuyu	31 (23-41)	de Figueredo and Marais, 1994
Lucerne (alfalfa)	15 (4-20)	Waldo and Jorgensen, 1981

Mixing legumes with cereal crops

The main focus of research in intercropping legumes with cereal crops has been to increase grain yields of crops while improving soil fertility in farming systems in the semi-arid tropics (Willey, 1979) but little attention has, until recently, been paid to the benefits of intercropping cereal and legume for the production of high quality silage for livestock feeding.

Maize silage plays an important role as a winter feed in the livestock industries of many tropical countries. The main reasons for the popularity of maize for silage purposes is the high yield obtained in a single harvest, the ease with which it can be ensiled and its high energy value as a feed. However, its major shortcoming is undoubtedly its low crude protein content, which, on a dry matter basis, is usually of the order of 70 to 80 g/kg DM (Topps and Oliver, 1993). In the high rainfall subtropical areas of Zimbabwe and South Africa maize remains the preferred cereal crop for silage (Titterton, 1997) producing higher yields and higher energy content than grain sorghum, forage sorghum or pennisetums, as shown in Table 2.

Table 2. Yield, dry matter and energy content of maize and forage sorghum silages produced on sand and clay soils [1]

Crop	Yield and energy content of silage		Reference
	Yield (t DM/ha)	MJ/kg DM	
Maize (Var. SC BW93[1])	14.7	10.2	Titterton, 1997
Kikuyu	4.1	7.5	deFigueiredo and Marais, 1994
Grain sorghum (Var. MR Buster)	7.3	10.0	Cole et al., 1996
Forage sorghum (Sugargraze)[1,2]	7.4	9.5	Titterton, 1997

[1] These crops were produced at Henderson Research Station, Mazowe, Zimbabwe, av. yearly rainfall 980 mm.

[2] Sugargraze is a variety of forage sorghum recommended for silage, produced by Pacific Seeds, Australia.

In the semi-arid regions of the tropics, however, maize, being very susceptible to moisture stress, is questionable as the crop of choice for silage. Generally yields are poor and energy values much lower than that found in the higher rainfall areas. Alternative crops such as grain sorghums, forage sorghum and forage pennisetums which are drought tolerant yet high yielding, have been researched as silage crops and found to be suitable (Havilah and Kaiser, 1992; Mhere, *et al.*, 1999) although it has been concluded after an evaluation of grain and forage sorghums in Australia that sweet forage sorghums offered better potential than grain sorghums under dryland conditions (Cole et al., 1996). Sweet forage sorghum yields have been higher under dryland conditions (Mhere, *et al.*, 1999) than in the high rainfall area of Zimbabwe. Again, however, the limitation in terms of nutrient quality is the low protein content, which was, in forage sorghum and pennisetums, approximately 70g/kg DM and 95 g/kg DM respectively (Mhere *et al.*, 1999). One method of improving the protein content of the silage is to add a protein rich crop to the cereal crop. This can be done either by intercropping the cereal crop with a legume or growing them as sole crops and mixing them at ensilage. The feasibility, therefore, of ensiling these crops with legumes has been investigated.

Maasdorp and Titterton (1997) examined the effect of intercropping (in-row) of fifteen tropical legumes with a variety of long-season maize popularly used for silage in Zimbabwe. Of these, forage and grain soybeans, lablab (dolichos bean) velvet bean, sunnhemp and cowpea proved the most promising but in-row intercropping with the maize which was at a density of 65 000 plants/ha did not prove to be viable; with the exception of velvet bean and lablab, the proportion of legume in the biomass was only 15%, not sufficient to make a significant difference to protein yield. Velvet bean and lablab swamped the maize, reducing maize yield. Indeed, it has been shown that proportion of legume and crude protein content of the silage was significantly affected by maize plant density and the time of sowing of each crop. Kaiser and Lesch, (1977) showed dolichos bean proved to be at its maximum proportion of 24% when maize plant density was at 54 000 plants/ha and crude protein content of the silage was 110 g/kg DM. In the same study, however, there was apparently no benefit in intercropping soybean with maize for mixed crop silage, whatever the density of maize. Maasdorp and Titterton (1997) showed that, by planting lablab and velvet bean into a maize crop two weeks after sowing maize, maize yield was not depressed and the legume dry matter yield constituted about 30% of total dry matter yield, bringing silage crude protein content to about 10.5%. Further research is required into the planting pattern and sowing times of maize and legume. While in-row intercropping is apparently the preferred regime for machine harvesting, where single-row cutting is the common practice, between row intercropping may be more beneficial in the case of small-scale farming systems where crops are cut by hand. Here, it is likely there would be less competition between maize and legume and there should be a greater contribution of legume to total yield, with significant improvement in protein content. There are many other benefits of intercropping: reduced soil erosion, incidence of pests and less labour requirements for weeding (Saleem, 1995).

When sole crops of maize and legumes were mixed at harvesting 50:50 by volume for ensilage (Titterton and Maasdorp, 1997) it was found that with all fifteen legumes, fermentation quality was acceptable (pH of the range 3.7-4.5; NH3: N ratio < 12.0) with the exception of velvet bean, sunnhemp and silverleaf desmodium, while crude protein content had increased from 77 g/kg DM in pure maize silage to a range of 93 g/kg DM (yellow lupin) to 153 g/kg DM (forage soyabean). In the case of maize and dolichos bean it was 128 g/kg DM. This trial used recycled plastic garbage bags, in which the maize and legume was layered before compression with a tobacco press and the bags sealed with string. The quality of the silage gave an indication that this might be a suitable method for ensilage of mixed crops for small scale dairying.

When seven legumes (forage soya, grain soya, silverleaf desmodium, lablab, cowpea, lupin and velvet bean) were layered with maize for ensilage in pits, the silage was similar in quality to that of the same legumes proportionately mixed with maize in bags and were found, with the exception of silverleaf desmodium, to be of no significant difference to that of pure maize silage in palatability (dry matter intake) and effect on milk yield in Holstein dairy cows (Taruona and Titterton, 1996).

Agroforestry also offers potential for improving protein content of mixed silages. 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% and reduced the crude fibre content (Bareeba, 1977). Maasdorp and Titterton (1999) successfully ensiled, on a fresh mass ratio of 50:50, the leaf material of four varieties of forage tree legumes with maize with improvement of crude protein content to 14%, 15.5%, 17.2% and 18.7% in maize/Calliandra calothyrsus, maize/Glyricidia sepium, maize/ Leucaena leucocephala and maize/Acacia boliviana silages respectively. Only in the maize/Calliandra silage was organic matter digestibility significantly reduced, while in the other three, it was similar to that of maize silage. A similar trial is planned for forage tree legumes ensiled with forage sorghums and pennisetums.

As with maize, soybean has proved to be of little benefit when intercropped with grain sorghum (Kaiser *et al*., 1993). Sweet forage sorghum on the other hand, when intercropped with lablab in a planting pattern of 1 row sorghum and 1 row lablab, produced silage of good fermentable quality with a crude protein content of 120 g/kg (Mhere, *et al*., 1999). Sorghum and lablab silage has been produced elsewhere with reasonable success (Ojeda and Diaz, 1992; Singh *et al*., 1988).

Forage pennisetums have been successfully intercropped with legumes (Gill and Tripathi, 1991 and Bhagat, Prassad and Singh, 1992, Mhere *et al*., 1997) and ensiled with and without legumes (Mhere, *et al*., 1999; Crowder and Ghheda, 1982 and Bareeba, 1992) Mhere *et al*., 1999 found however, that soil type, planting pattern and weather had significant effects on proportion of legume in both forage sorghum and forage pennisetum crops.

Wilting

Tropical grasses and legumes need to be cut early in the vegetative stage for ensilage while protein and digestibility are high. However, mitigating against this is the relatively high moisture content of the plants at this stage, which can adversely affect fermentation quality of the silage. (McDonald *et al.*, 1991)

Ensiling material with less than 30% dry matter may create an environment which is totally anaerobic (suited to clostridial bacteria) rather than microaerophilic (suited to lactic acid bacteria). In addition, it may result in the loss of valuable nutrients as water and soluble nutrients accumulate at the bottom of the silo as silage effluent. In pit or bunker silos, this effluent can seep away and be lost to the silage. On the other hand, research into time of wilting has produced extremely variable results due, apparently, to weather conditions such as humidity, wind speed and ambient temperature prevailing at the time of the trial (McDonald *et al.*, 1991). Warm humid conditions, such as are found in the high rainfall, tropics, are not conducive to rapid field drying. Biochemical losses from respiration could be higher than losses from unwilted silage and digestibility of the silage is reduced (Thomas and Thomas, 1985). On the other hand, in the semi-arid tropics, it may be possible to achieve rapid wilting in the ideal three to five hours (Michelina and Molina, 1990; Alberto *et al.*, 1993) without resultant decline in digestibility and (Mayne and Gordon, 1986a) and improvement in fermentable quality of silage (Thomas and Thomas, 1985). This may only occur in silages which, without wilting are below 30% dry matter. In studies by Mhere *et al.*, 1999 while increasing wilting time within 12 hours showed no effect on digestibility of mixed forage sorghum/legume and pennisetum/legume silages; pH increased significantly. The dry matter content of these silages was, without wilting, already about 30% and higher, and within 6 hours was up to 40% and higher. This indicates that wilting reasonably dry crops in the field actually results in poorer fermentation probably due to decreasing effective compression in the silo. If the wilting period is extended over several days, soluble carbohydrates will be lost, protein nitrogen contents may be reduced and deamination of amino acids may increase (Henderson, 1993). Another factor which may be of importance is the silo. In pits or bunkers, where the large quantities of effluent produced by very wet material is lost and indeed may be a serious pollutant, wilting under the right conditions may be of benefit. In silos, particularly small ones, where the effluent is sealed in, however, this may not be so critical. In a study of small-scale silos (Ashbell *et al.*, 1999 and Titterton *et al.*, 1999) there are indications that the effluent, being retained in the silage, prevents mould and contributes to good fermentation in forage which has been coarsely chopped and manually compressed in the silo. In other words, the normal criteria for successful ensilage do not apparently apply when the silage is sealed into small portable silos.

In summary, wilting only appears to be necessary if crops in the field are still very wet at harvesting,, conditions are conducive to rapid drying and large silos are used to store the silage.

Additives

Additives are used to improve silage preservation by ensuring that lactic acid bacteria dominate the fermentation phase. Additives can be divided into three general categories: 1) fermentation stimulants, such as bacterial inoculants and enzymes, 2) fermentation inhibitors such as propionic, formic and sulphuric acids and 3) substrate or nutrient sources such as maize grain, molasses, urea and anhydrous ammonia (Woolford, 1984; Henderson, 1993 and Bolsen *et al.*, 1995). A number of trials produced the conclusion that only strong acids, either alone or in combination with formaldehyde have the potential consistently to modify fermentation (Thomas and Thomas, 1985). However, these have largely lost popularity due to both cost and handling difficulties on the farm. Bacterial inoculants have inherent advantages over other additives, including low cost, safety in handling, a low application rate and no residues or environmental problems. However, results of their application are variable probably due to the differing ensilage conditions prevailing at time of application. However, when applied together with enzymes which degrade plant cell walls and starch which could provide additional sugars for fermentation to lactic acid, they appear to have achieved improvement in fermentation and nutritional quality of tropical grasses and legumes (Bolsen, 1999) Studies with kikuyu grass silage, however, suggested that the grass needs to be rapidly wilted before an inoculant is added for an improved fermentation to be achieved (de Figueiredo and Marais, 1994) since there was no improvement when inoculants were added to unwilted grass. In a comparison of maize meal with a commercial silage additive (containing bacterial inoculant and enzymes), Mhere *et al.* (1999) found however that when added to forage sorghum/legume and forage pennisetum/legume mixtures, maize meal (5% of biomass) improved dry matter and both additives improved the nutritional content but had no significant effect on fermentation quality. This may be accounted for by the fact that the silages were stored in small sealed silos where, since the effluent was retained in the silage, there was no benefit to fermentation of the addition of either additive.

On small scale farms, commercial additives, which comprise inoculants and enzymes, may be be too costly or unavailable. It is likely therefore that the third category of additive will be of most benefit to silage made on small holdings. Possibly the most important benefit of additives such as maize or sorghum grain or cassava meal is to improve dry matter in early cut crops when moisture content is high and rapid drying (wilting) is not possible or where effluent is lost to the silage through seepage. Tropical grasses have been successfully ensiled when supplemented with maize meal (Onselen and Lopez, 1988) cassava meal (Panditharane *et al.*, 1986) and sorghum grain (Alberto *et al.*, 1993).

Molasses is the carbohydrate source used most frequently and is of particular benefit when applied to crops low in soluble carbohydrates such as tropical legumes and grasses. Good silages have been reported when molasses was applied at 3-5% (Bareeba, 1977; Sawatt, 1995). However, if the treated silage has a very low dry matter content, most of the carbohydrate source may be lost in the effluent during the first few days of ensilage in pits or bunkers.

Applying urea or anhydrous ammonia to silages has an adverse effect on fermentation and nutrient quality of silages, particularly high moisture forage sorghums (Bolsen, 1999), although Sarwatt (1995) obtained good silage by applying 0.5% urea to maize, sorghum and Rhodes grass in Tanzania. An additive with a urea/molasses blend is possibly the best combination to apply to tropical grasses if they are cut in early vegetative stage (Bolsen, 1999). More research is needed in this field, particularly in the ensilage of natural pasture tropical grasses.

Conclusion

In the tropics, particularly the semi-arid tropical regions, where the major constraint to livestock production is the lack of availability of fodder, conservation through ensilage of forage produced in the rains is likely to be the practice adopted by most small holder livestock owners, particularly those in dairy or beef production. It has been shown that ensilage of forage can be carried out with simple technology and that forages such as tropical grasses, forage legumes, forage tree legumes, forage sorghum and pennisetums can be produced and ensiled successfully this way. However, there is still much to be researched in how the quality of these silages, both in terms of fermentation and nutrition, can be improved through the use of intercropping or mixing at ensilage and with the use of additives. There is also potential for the ensilage of many agro-industrial by-products with forages and legumes and this needs increased attention in the field of research into low cost feeds for livestock.

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