
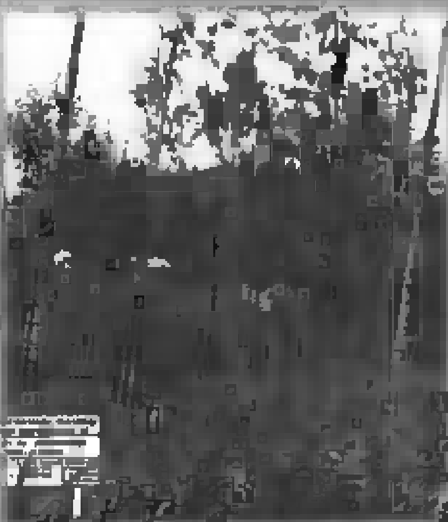

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UTILISATION OF FODDER TREES UNDER SMALL-HOLDER SYSTEMS IN KENYA

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Abstract

Although the technical advantages in terms of animal production and improved soil fertility of the use of herbaceous legumes have been well demonstrated in Kenya and elsewhere, adoption by small-scale farmers has been disappointing. This has led to increased research into the use of both indigenous and exotic fodder trees. In common with conventional pasture legumes, tree fodders contain high levels of crude protein and minerals and many show high levels of digestibility. They are readily accepted by livestock and because of their deep-root systems, they continue to produce well into the dry season. Anti-nutritive factors can be a problem however, and polyphenolics, toxic amino acids, cyanogenic glycosides and alkaloids are found in many tree species. There are abundant niches on small farms where fodder trees can be grown without affecting crop production. In the Embu region, it has been estimated that 3 kg of fresh fodder of *Calliandra calothyrsus* has the same effect on milk production as 1 kg of commercial dairy meal. Up to about 500 trees (250 m of hedgerow) will produce enough fodder to supplement one dairy cow for a complete lactation. The tree fodder can either replace the concentrate without loss of yield, or it can complement it to produce more milk. Calliandra is being enthusiastically adopted by small-scale farmers, many of whom are starting to produce their own seed. Other tree species are now being studied to avoid over-reliance on a single fodder species.

Introduction

The livestock population of Kenya is estimated at 12 million cattle, 19 million sheep and goats, 18 million poultry and 113,000 pigs (KARI, 1991). The distribution of animal species is influenced by both climatic conditions and the prevailing production systems. Cattle are found from semi-arid to humid areas (receiving generally over 500 mm of annual rainfall), while the majority of the small ruminants are found in the semi-arid areas. Poultry are present in all parts of the country, while pigs are commonly kept in the high potential, densely populated regions, especially near urban centres.

Dairy cattle production systems

The national dairy cattle population is estimated at nearly three million (KARI, 1991). About 80% of these animals (Friesians, Ayrshires, Guernseys, Jerseys and their crosses with local zebus) are found on small-scale farms (approximately 1-2 ha) in the high agricultural potential areas of Western and Central Kenya, where

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they produce about 80% of the marketedmilk. Production systems are mainly intensive in nature, largely based on zero- and semi zero-grazing. Most small-scale farmers practise full zero-grazing, while semi zero-grazing systems are often used by larger-scale farmers. Here, cows graze on natural, or improved pastures by day and are confined at night, when they are offered a variety of feeds.

Feed resources

Various types of feeds are carried to livestock, including fodder crops, weeds gathered from cropping areas, crop by-products and residues, agro-industrial by-products and purchased concentrates. The importance and nutritive value of these feed sources vary seasonally. In the wet seasons, the bulk of the feeds consist of fodder crops and weeds, while in the dry seasons, these are supplemented by crop residues (Abate *et al.*, 1992). Napier grass (*Pennisetum purpureum*) or hybrids of this with *P. typhoides*, are the most important fodder crops. Pasture grasses include Kikuyu grass (*Pennisetum clandestinum*), star (*Cynodon* spp.) and Nandi setaria (*Setaria anceps*), while maize stover is the most abundant crop residue. The estimated availability of some common Kenyan feeds is shown in Table 1. In spite of these apparently abundant resources, feed supply is often a major constraint. This is especially so in the dry seasons, which in the high agricultural potential areas are most severe from January to mid-March and from August to mid-October.

In order to improve the nutrition of dairy cattle, mixtures of grasses with herbaceous legumes may be incorporated into the forage system. One commonly recommended association is Napier grass planted with either greenleaf or silverleaf desmodium (*Desmodium intortum* and *D. uncinatum* respectively). The legumes generally have a higher nutritive value than the grasses, being superior in both protein and mineral content (Skerman *et al.*, 1988). Such mixtures promote higher animal intakes of energy and protein, resulting in increased weight gains and milk production.

Legumes have also been shown to improve soil fertility (through their ability to fix atmospheric nitrogen) and organic matter status of the soil (Shelton, 1990) and their use is generally considered to be a more sustainable approach to soil fertility enhancement than the use of inorganic fertilisers.

Despite their clear, demonstrated advantages, the use of herbaceous legumes has not been widely adopted by small-scale farmers. This may be partly due to the present scarcity and associated high cost of legume seed. Farmers have often reported difficulties in establishment and management of mixed stands of grasses and legumes, particularly when the grass is a vigorous species such as Napier grass. Attention is now focusing on the use of multi-purpose fodder trees to provide high quality animal feed, to improve soil fertility and to supply firewood in small-scale farms in the highlands.

This paper examines various aspects of fodder trees, including positive quality factors, anti-nutritive factors and their place within the farming system. It concludes with a case study of the use of *Calliandra calothyrsus* in the Embu region.

Table Annual production of feeds used in zero-grazing systems in Kenya

Feed	Annual Production
Fodder	**DM (t/ha)**
Napier grass	8.5-27.4
Green maize	20.0-26.0
Cassava tops	10.0-30.0
Crop residues	**DM ('000 t)**
Maize stover	7,500
Sorghum/millet stover	676
Wheat straw	187
Rice straw	39
Agro-industrial by-broducts	**DM ('000 t)**
Cotton seed cake	5.4
Sunflower seed cake	8.1
Copra meal	5.1
Coffee pulp	33.0
Sisal pulp	41.0

Source: Adapted from Abate *et al.*, 1992

Quality factors of fodder trees

In comparison with pasture grasses and legumes, the study of fodder trees and shubs is of recent origin, even though pastoral societies have used browse species for feeding their livestock since time immemorial. Woody species have many advantages for animal production, amongst which are high feeding quality in terms of protein and mineral contents (as already mentioned); tolerance to a range of management practices; longevity; and the ability to produce fodder when other species have become dormant due to harsh climatic conditions.

Protein content and digestibility

Some typical figures for feeding quality and digestibility of a range of tree fodders are shown in Table 2, in comparison with a common West African grass (*Oxytenanthera abyssinica*) averaged over a number of sites and sampling dates. In general, the crude protein (CP) contents of the trees are much higher than those of grasses, even at the best times of the year when growth is vigorous. It is generally accepted that a dry, non-pregnant cow requires a diet with a crude protein content of about 7% (DM basis) merely for maintenance. This increases to at least 12% during lactation. While the quality of grasses can fall well below the normal maintenance requirement during a long, dry season, tree fodders will normally provide sufficient CP to justify their use as dietary supplements.

The *in vitro* digestibility of non-leguminous trees (*Morus alba*, *Trema orientalis* and *Manihot glaziovii*) appears to be higher than for the legumes, but care is needed in theinterpreting these data since only the leaf blades (without the stalks which are commonly eaten by livestock) of the non-legumes were analysed and this may have biased the results upwards.

Mineral content

Typical mineral contents of two common tree fodders are compared with the same West African grass in Table 3. Sodium levels of tree fodders are often low, but in many areas of the tropics, animals on grass alone also need a salt supplement to prevent deficiency problems. Tree leaves are commonly richer in calcium and phosphorus than grass pastures at comparable stages of growth and deficiencies of these two minerals are often implicated in reproductive problems of ruminant animals.

The micro-element picture is less clear, as the levels found in herbage are often more closely related to the ability of the soil to supply them than to the species or herbage grown.

Dry season productivity

As with other groups of plants, trees adopt different strategies to cope with adverse conditions. However, they are often more readily manipulated by management practices than grasses. For example, it is well recognised that *Gliricidia sepium*, which will readily shed its leaves in the dry season if left uncut, will retain them and continue to grow long after rain has ceased to fall if it is severely pruned during the normal growing season (Allen and Allen, 1981). It is assumed that since the roots of trees are able to penetrate farther into the soil than those of grasses, they are able to tap a larger volume of soil and can therefore continue to grow under very dry conditions. Whether or not this is true, trees and shrubs are commonly seen with green leaves at times of the year when grasses are dry and have very little nutritive value. They therefore offer great advantages with regard to the feeding of livestock.

Table 2: Nutritive value of selected fodder trees in comparison with typical West African Grass

species	DMD %	OMD % MJ/kg	ME	CP %	DC P%	ADF %	NDF %	Comments	S[c]
Calliandra calothyrsus	41.6 *in vivo*			28.2		22.0	45.5	dried shoot material, cut after 12 weeks	1
				25.8		29.7	49.5	idem, 24 weeks	1
				23.5		30.9	47.5	idem, 48 weeks	1
	44.5-51.5 *in vitro*			14.0-17.7			44.5-52.5	leaves	2
Sesbania grandiflora	66.9 *in vitro*			26.5			45.1-	leaves, Thailand	2
Sesbania seban	69.1-79.0 *in vitro*			24.2-26.4			29.5-38.7	leaves, Australia	2
Leucaena diversifolia				-8.7		28.5-42.4	33.5-46.6	young leaves	3
				25.8-30.3		34.3-47.4	44.7-55.5	mature leaves	3
Morus alba			9.32	15.0				fresh leaves	4
			9.10[a]		10.7				5
				10.7					6
		85.5 *in vitro*		18.9				leaves	7
Trema orientalis		78.8 in vitro		27.1				leaves	7
				25.1				leaves	8
Manihot glaziovii		78.4 *in vitro*		34.6				leaves	7
Oxytenanthera abyssinica (typical West African grass)			7.4[b]	12.8	8.2			means of data from Senegal and Mali	9

[a] ME = %TDN x 0.83 x 18.4 MJ [b] Based on an estimate of Net Energy and assuming that NE = 50% of ME

[c] S=source: 1. Kaitho *et al.*, 1993; 2. Akkasaeng *et al.*, 1989; 3. Toruan-Mathius and Suhendi, 1992; 4. Sen, 1938; 5. Kehar and Goswami; 1956; 6. Joshi and Sing, 1990; 7. Thijssen *et al.*, 1993b; 8. Nag and Matai, 1992; 9. Le Houérou, 1980.

Table 3: Mineral composition of tree leaf meals compared with *Oxytenanthera abyssinica*, a typical West African grass (dry matter basis)

Mineral constituent	*Leucaena leucocephala*[a]	*Gliricidia sepium*[a]	*Oxytenanthera abyssinica* (average)[b]
major elements (g/kg)			
Calcium	18.1	13.0	4.0
Phosphorus	2.5	1.8	1.1
Sodium 0.0	2.5		
Potassium	8.0	33.0	6.6
Magnesium	5.1	3.4	3.2
trace elements (mg/kg)			
Copper	9.9	5.8	
Iron	239.9	207.0	
Zinc	21.2	26.0	
Manganese	42.1	69.7	

Source: [a] D'Mello, 1995
[b] Le Houérou, 1980

It cannot be assumed, however, that because of the obvious advantages outlined above, tree fodders are totally free of problems. Anti-nutritional factors are also present in most trees and some of the most important ones are discussed below.

Anti-nutritive factors

Anti-nutritive factors are physical and chemical features of plants which result in lower levels of animal productivity than would be expected from chemical analyses of the foliage. They protect plants from excessive damage by acting as feeding deterrents. Many appear to be the result of co-evolution of the plants with herbivorous animals (Levin and York, 1978), or insect pests and plant diseases (D'Mello, 1982) They range from the purely physical, to symbiotic relations and chemical reactions

Most trees will rapidly grow out of the reach of livestock unless they are carefully managed. Plants can be rendered unattractive as forage by their effects on any of the senses of the animal. *Acacia lysiphloia* has sticky foliage, and *A. coriacea* gives off an offensive odour, both of which may be repellent to livestock (Fox, 1987). Many genera, for example, *Acacia, Erythrina, Mimosa* and *Prosopis*, are recognised for their dangerous thorns and spines (Allen and Allen, 1981).

Myrmecophily is a symbiotic association of ants with plants, the best known example being the swollen, stipular thorns of some nine neotropical *Acacia* spp. which are inhabited by ants of about five species of the genus *Pseudomyrmex*. The ants feed on the enlarged foliar nectaries and modified leaflet tips of the plant. In return, they protect it from defoliation by insects and herbivorous animals by swarming to attack when the tree is disturbed (Allen and Allen, 1981). The ants present a formidable defensive barrier to the grazing animal.

Chemical constituents

The leaves of woody plants tend to contain more anti-nutritive components (plant secondary compounds) than those of herbaceous plants. Some of the most important ones to be found in fodder trees are discussed below.

Phenolic compounds

Plant materials contain a wide range of phenolics, from low molecular weight, metabolisable phenols to the much larger polyphenols, a group which includes the tannins. These are commonly found in the leaves, bark, fruit and twigs of trees and are thought to confer resistance against both insect and fungal attack (D'Mello, 1982).

Hydrolysable tannins can be degraded either chemically or enzymatically into a sugar residue and a phenol-carboxylic acid. The components may then be absorbed through the gut wall of the animal. They can influence animal performance through their effect on the palatability of the feed, although in some cases they may also be toxic (Mangan, 1988). They are mainly found in fruit pods and plant galls (Liener, 1980).

Condensed tannins (procyanidins or proanthocyanidins) are the principal tannins of forage legumes and are usually derived from condensation of flavonoid precursors. They cannot be degraded by enzymes and are therefore unlikely to pass through the gut wall. The formation of protein-tannin complexes may depress the nutritive value

of fodder by reducing both voluntary feed intake and digestibility. The acceptability of browse appears to be, in part, related to the concentration of condensed tannins, although there may be a threshold (about 5%), below which there is no measurable effect (McNaughton, 1987).

The principal effect of tannins is probably due to their ability to precipitate proteins. They provoke an astringent reaction in the mouth of the animal, probably by reacting with proteins in the saliva and the mucous epithelium, which impairs lubrication. They may inhibit digestibility by the formation of relatively indigestible protein-tannin complexes and by the direct inhibition of digestive enzymes and micro-organisms. Tannins are assumed to reduce voluntary intake, either by their astringent effect, or by reducing protein digestibility and absorption. The exact mechanism is poorly understood and results are conflicting. Tannic acid added directly to the feed does not always produce the results ascribed to natural tannins.

Tolerance of tannins varies between animal species. The saliva of some species such as deer, rodents and goats, appears to contain proline-rich proteins, which may constitute a first line of defence against tannins. Cattle, sheep and chickens appear to have less, or possibly no capacity to secrete these proteins (D'Mello 1992). Poultry and horses show toxicity symptoms when fed tannic acid at levels of about 2% of diet (DM basis) while ruminants are able to handle higher levels without adverse effects. Deaths in sheep and cattle have been attributed to high levels of tannins found in *Quercus* spp. and tannins have been implicated in low milk yields, reduction in available sulphur; toxic, degenerative changes in the intestine, liver, spleen and kidney; the appearance of mucus in urine and fatal constipation (Kumar and Singh, 1984). It is suggested that tannin-rich fodder for ruminants be restricted or fed with caution, but the risk to unconfined animals is generally small, since given a choice, they will seldom consume enough tannin to suffer harm.

Condensed tannins are generally considered to have two beneficial effects in ruminant nutrition. Firstly, they may protect labile plant proteins from microbial degradation in the rumen. This could potentially increase the supply of high quality protein entering the duodenum and becoming available for absorption by the animal. Secondly, tannins appear to be implicated in the prevention of bloat in sheep and cattle by hindering the formation of stable protein foams in the rumen.

Toxic amino acids

Free, non-protein amino acids occur in the leaves and seeds of many plant species, including a number of grain, pasture and browse legumes. They can interfere with the normal metabolic processes of animals as a result of their effects on either amino acid biosynthesis and transport, or on activation and incorporation of amino acids into protein molecules (Hammond, 1987). The best known of these compounds are mimosine and canavanine. Mimosine is found at high concentrations in *Leucaena* and *Mimosa* spp. where it acts as a natural fungicide. Canavanine occurs in some species of *Canavalia* and *Sesbania*, and in some temperate pasture legumes, where it appears to have insecticidal properties.

Mimosine is typically found in foliage of mature leucaena (*Leucaena leucocephala*) at concentrations in the range of 2-5% (Brewbaker and Hylin, 1965), with higher levels of up to 10% in young, expanding leaves. This can result in depilation, growth reduction, general ill health and reproductive disorders when the fodder is fed to non-ruminants at levels of 5-15% of dietary DM (Hutton and Gray, 1957) or to ruminants at levels of over 30% (Jones and Hegarty, 1984).

In areas where leucaena is native or naturalised and animals have eaten it for many years, rumen bacteria have evolved which are capable of degrading mimosine to non-toxic metabolites (Jones and Megarrity, 1983). In such areas, ruminants can be maintained on diets of 100% leucaena for months at a time without showing toxicity symptoms (Quintyne, 1987). The capacity to render mimosine harmless was transferred from goats in Hawaii to goats and subsequently to cattle in Australia by inoculation with imported rumen liquor (Jones, 1985). For a modest cost, ruminant resistance to mimosine toxicity can be introduced into areas where it does not occur naturally.

Canavanine is a water-soluble, heat resistant structural analogue of arginine which is capable of radical interference in the metabolic pathways of livestock. Mammals are considered to be more tolerant of canavanine than are birds (D'Mello, 1992) Cattle consuming in excess of 30% of their diet as seed or meal of *Canavalia ensiformis* are at risk (Skerman *et al.*, 1988). Symptoms of toxicity include low body temperature, a clear nasal discharge, frequent passing of clear urine, lameness, prostration and death.

Cyanogenic glycosides

Hydrogen cyanide (HCN) is potentially one of the most serious anti-nutritional factors in fodder trees, since it can lead to rapid death. Symptoms of poisoning are due to oxygen starvation at the cellular level and include laboured breathing (dyspnoea), intense red conjunctiva, frothing at the mouth, bloat, convulsions and a staggering gait. Post mortem examination often reveals a characteristic almond smell from the stomach contents.

Cyanogenic substrates, usually glycosides, react in the digestive tract of the animal with a hydrolysing enzyme to produce HCN. When HCN production is low, little threat is posed to the animal. Maslin *et al.* (1987) suggested that plants producing HCN at levels above 200 mg/kg (7.5 µmol/g) fresh weight could be dangerous to

livestock. Plants containing both large amounts of cyanogenic glycosides and also an endogenous hydrolytic enzyme have the highest potential for toxicity (Maslin *et al.*, 1987), although broad spectrum enzymes present in other fractions of the diet could react with the cyanogenic compounds to release HCN. In South African *Acacia* spp., leaves and immature pods produced higher levels of HCN than mature pods (Steyn and Rimmington, 1935). *Acacia robusta* contained the glycoside but not the hydrolysing enzyme and so was considered to be less dangerous than other species.

Hydrogen cyanide levels of *Manihot esculenta* can vary from 400 mg/kg of fresh material in mature leaves to 620 mg/kg in young leaves (Gondwe, 1974). Through sun drying, however, these can be reduced to acceptable levels for feeding to ruminants (Devendra, 1977). This simple treatment opens the possibilities of wider utilisation of *Manihot glaziovii*, a naturalised tree in Central Kenya that is sometimes used by farmers as a source of fodder. *Manihot glaziovii* has an exceptionally high crude protein content (Table 2) but is believed to also have high levels of HCN in the fresh fodder.

Alkaloids

The alkaloids are a heterogeneous group, with diverse chemical structures. They are complex compounds containing nitrogen, usually in heterocyclic and/or aromatic ring structures. Often they are poisonous to livestock but there are many examples of alkaloids with medicinal properties. They are almost universally bitter in taste and while their role in plants may be as possible defence mechanisms against plant pests (Levin, 1976), they are commonly thought to represent evolutionary aberrations of nitrogen metabolism (Kingsbury, 1964).

Alkaloids are found in some 5-10% of all plants, being more common in tropical than in temperate species. Plant families such as Leguminosae, Amaryllidaceae and Compositae are noted for high levels of these compounds. The alkaloid content of a plant is usually a feature of the cultivar, varying little with ecological factors such as climate, season and availability ofwater, although there can be wide differences between varieties of the same species. Unlike tannins and toxic amino acids which tend to be concentrated in certain plant parts, alkaloids are often uniformly distributed throughout the plant, all parts being equally dangerous (or beneficial) to livestock. The reaction in a given organism is usually quite specific, although there may be considerable variation between different alkaloids in the same animal species, or with the same alkaloid in different animals (Kingsbury, 1964).

Shrub and tree species containing appreciable quantities of alkaloids should be fed with caution and the fodder should be evaluated with a range of animal species before being recommended for general use. However, species of *Erythrina* for example, a genus noted as a source of alkaloids, is attracting attention in Africa and

South America as multi-purpose trees suitable for use as fodder and for windbreaks, shade, fences and fuel (Brewbaker, 1989). It is not possible to draw general conclusions regarding the effects of these compounds on animal production as information on this subject is insufficient.

Animal production from tree fodders

There are many examples from all parts of the tropical world where a range of tree fodders have been shown to have positive effects on animal production. These are typified by research results obtained in Kenya. Milk production from cows fed on a basal diet of Napier grass increased with increasing levels of daily supplementation with leucaena (Table 4). Similarly, zebu bulls kept on maize stover showed significant liveweight gains only when the basal diet was supplemented by a daily ration of leucaena hay (Table 5). These findings indicate the potential of tree fodders used in relatively small quantities to complement the medium-to-poor quality roughage provided by pastures, fodders or cereal stovers, in order to obtain increased levels of animal production.

Table 4: Effect of leucaena supplementation on milk production of crossbred cattle kept on a basal diet of Napier grass (*Pennisetum purpureum*)

Daily Supplement (kg leucaena DM)	Total DMI (kg/day)	Milk production (kg/day)
nil	7.8	7.2
1.0	9.3	7.6
2.0	10.4	8.3

Source: KARI (1990)

Table 5: Effect of leucaena supplementation on growth rates of Zebu bulls kept on a basal diet of maize stover

Daily supplement (kg leucaena hay)	Total DM intake (kg/day)	Growth rate (g/day)
nil	4.20	8.0
1.0	4.14	236.0

Source: Adapted from Abate *et al.* (1992)

Case study: ***Calliandra calothyrsus*** in the Embu Region

Introduction

In a relatively early, general planning document, Minae and Akyeampong (1988) noted the importance of livestock in all of the six land-use systems (LUS) which they identified in the bimodal highlands of East Africa. Pure or cross-bred dairy cows were commonly zero-grazed in the higher potential areas, while extensive grazing of both zebu cattle and small stock were mostly restricted to the drier areas of lower agricultural potential. Shortage of fodder, coupled with low levels of protein in the feed, was identified as a major constraint to animal production across all LUS, particularly in the dry seasons (Hoekstra, 1988) and research into tree fodder was proposed as a potential solution to this problem (Minae and Nyamai, 1988).

Coordination and collaboration in the approach to this work was established at two levels: Regionally, in September 1986, ICRAF set up an East and Central African Agroforestry Research Network (AFRENA) within the highlands covering Burundi, Kenya, Rwanda and Uganda. It seems likely that both Ethiopia and Madagascar will join this initiative in the future. Within Kenya, the National Agroforestry Research Project (NAFRP) was started in May 1991 as a joint activity between the Kenya Agricultural Research Institute (KARI), the Kenya Forestry Research Institute (KEFRI) and ICRAF. One of the principal sites chosen for NAFRP activities was the KARI Regional Research Centre in Embu and in February 1994, AFRENA decided that this centre should take the lead in regional research into fodder and livestock issues.

Fodder trees in the farming system

The potential of trees to contribute to farming systems in terms of production of fodder, meat and milk has been clearly demonstrated in many countries, although much of the work has been conducted with fodder banks (Paterson *et al.*, 1987; Ruiz and Febles, 1987), a technique that may be of limited acceptability on the very small farms characteristic of the East African highlands. To ensure adoption of fodder trees, specific niches would be required that do not result in competition with, and reduction of yields of crops grown on the farms. Where possible, fodder trees would be more attractive if they also served other purposes such as soil erosion control, or boundary demarkation (Minae and Nyamai, 1988). The Agroforestry Research Network for Africa (AFRENA) activities were initiated within the East African Highlands, concentrating on the following planting niches (Hoekstra and Beniest, 1991), which were thought to best address these conditions:

Tree/grass combinations on field bunds
Fodder hedges on contour lines/boundaries

- Inclusion of tree hedges in fodder blocks (as in the fodder bank technology found in other tropical regions)
- Upper storey trees with a fodder understorey

These activities are currently practised in Kenya (Embu and Maseno) and Uganda, and were also initiated in Burundi and Rwanda before the recent civil problems.

Objectives and hypotheses

The principal broad objective of the research was to increase animal production, primarily in the small-holder, intensive dairy sector, through improved nutrition. This objective was subdivided into a number of components for investigation on both research stations and private farms. These can be detailed as follows:

- Identification of agronomically suitable, adapted tree species for the chosen niches
- Measurement of fodder production potential of the trees in the various niches
- Identification of appropriate, practical management techniques
- Study of the effect of the trees on animal production
- Adoptability by farmers of the recommended practices (socioeconomic aspects)

The work was based on the hypothesis that the deep root systems of trees should enable them to continue to be productive well into the dry season. Many trees, particularly leguminous species, have been shown to contain high levels of protein in their foliage (Ruiz and Febles, 1987; Thijssen *et al.*, 1993a, b). This feature has been used to provide animals with balanced diets by mixing the protein-rich tree fodder with grasses and other forages containing much lower protein levels. In many cases, this has proven to be more economical than the use of concentrate feeds (Paterson *et al.*, 1987). Adaptive research was needed to show that similar effects could be obtained locally.

Methodologies

The methodologies employed varied widely, depending upon the objectives of the particular experiment. They ranged from formal, on-station experiments to on-farm work with varying degrees of farmer control, in combination with surveys to describe current farmer practices. The work was, however, aimed mainly at the areas with higher rainfall and greater agricultural potential, since in these areas, livestock are kept in confinement and fed under a cut-and-carry system. In the semi-arid regions, it is more difficult to see where an agroforestry intervention could have a role, since the presence of uncontrolled animals causes many problems during the establishment phase of the trees.

Results

In the coffee zone of the Embu region, a survey conducted amongst 50 farmers in 1991 showed that while tree fodder was considered to be important for goats, it was not, at that time, routinely used for cattle except during times of extreme feed shortage. Of more than 90 tree and shrub species found on farms in the area, only 10 were being used as fodder (Thijssen *et al.*, 1993b). Of these, *Commiphora zimmermanii* was found on 70% of the farms surveyed, followed by *Croton macrostachyus* (46%), *Ficus* spp. (38%) and *Leucaena leucocephala* (26%).

In a survey conducted in the following year with 29 farmers, it was observed that 41% had no experience with tree fodder, but all showed interest in planting trees or shrubs for this purpose (Thijssen *et al.*, 1993a). The preferred niche planting sites were within crop lands (38%), along boundaries (31%), as fodder banks (14%), around the home compound (10%) and near the zero-grazing unit (10%).

In both on-station and on-farm activities, much of the early work on fodder production was conducted on the tree legumes sebania (*Sesbania sesban*) leucaena (*Leucaena leucocephala*) and calliandra (*Calliandra calothyrsus*) largely because these species were known to be agronomically adapted to the area. Despite good establishment and early growth, sesbania suffered high mortality under frequent defoliation and was therefore of limited use for intensive fodder production. It is capable of producing high yields of biomass when allowed to grow uncut for a year or more. It could therefore be used as a short-term fallow, at the end of which the available foliage may be either fed to livestock or incorporated into the soil as green manure (Heineman *et al.*, 1990; Otieno *et al.*, 1991).

In August 1992, the Leucaena psyllid (*Heteropsylla cubana*) was first seen in Mombasa (Reynolds and Bimbuzi, 1993), and reached Embu by the end of that year. Although a high proportion of leucaena trees survived the attack, it caused severe defoliation, greatly reducing the usefulness of the species as a fodder producer. Alternative species such as *L. diversifolia*, *L. esculenta* and *L. palida* have been tested for fodder production as they show some degree of tolerance to the psyllid but in many instances they are less leafy and therefore less productive from a livestock perspective, than the more common *L. leucocephala*. It is to be hoped that with the passage of time, a biological balance will be reached between the psyllid population and a range of natural predators (ladybirds, lace-wings, etc.), as has occurred in S.E. Asia and Australia. This should result in a drastic reduction in the level of damage caused by the pest. Research continues with leucaena, although most farmers have lost interest in it and some have even uprooted the trees that they had planted in previous years.

The most useful fodder species from the three that were planted out on farm is calliandra. It has shown excellent adaptation to conditions in the highlands, being both productive and persistent. In Rwanda, when planted on bunds, some 95% of trees continued to survive after seven cuttings over a period of 48 months (Niang *et* *al*., 1992). It is occasionally attacked by both large- and small-scale insects which adhere to the trunk and branches to suck the sap from the plant. These pests are easily controlled by spraying or dousing with a water solution of common laundry detergent. Calliandra is susceptible to attack, with fatal results, by Armillaria root rot, a fungal disease that is found in the indigenous forests of Mt. Kenya (Paterson and Mwangi, 1996). This disease spreads from infected to healthy trees mainly by root contact. Although it can live for decades in dead stumps and can infect many tree species and a range of crops such as potatoes, and cassava, there appears to be little danger of it spreading into clean areas, except by the introduction of infected planting material. No other pests and diseases have so far been seen on calliandra in the region.

In view of the small numbers of indigenous fodder trees presently found on farms in the Embu region and the problems encountered with alternative exotic species, calliandra has become the tree of choice for many farmers. It is currently attracting much attention and almost all farmers who have planted it as a source of fodder are actively seeking more seedlings. It isgenerally considered to be of high feeding quality and in view of the rapidly increasing cost of commercial concentrates, there is a general desire to either supplement or replace purchased feed with home-grown calliandra fodder (Franzel *et al*., this conference). The evaluation that follows is based on results obtained to date, in work with calliandra conducted both on farm and on station.

Yield

Although the fodder production by any species will vary widely according to soil type, manure application and cutting management among other factors, experience suggests that when calliandra is maintained on commercial farms in hedgerows in a bimodal rainfall regime, a reasonable estimate of the edible fodder yield (leaves plus green stems to a diameter of about 0.8 cm) obtained from trees planted at spacings of 30-50 cm would be about 2 kg of DM per tree per year. This converts to an annual production of some 5 kg of DM per metre of hedgerow, a figure that agrees well with on station results from Western Kenya (Kaitho *et al*., 1993).

Feeding value

There have been few analyses of local material, but those that are available (eg. Kaitho *et al*., 1993) agree with published data from other countries. While the leaf material may contain higher levels, the DM component of the total edible fraction of the foliage contains about 24% CP. If compared with commercially available concentrates, 1 kg of dry calliandra fodder would contain the same quantity of nitrogen as 1.5 kg of dairy meal with 16% CP. Allowing for digestibilities of 80 and 60% respectively for the concentrate and the fresh tree fodder, 1 kg of calliandra DM should have the same effect when used as a protein supplement as 1.1 kg of dairy meal. In on-farm experiments in 1994 and 1995, together with an on-station observation in 1994, the replacement value was measured as 1 kg of concentrate equivalent to 3 kg of fresh calliandra fodder (Paterson *et al*., in press); thus the theoretical calculation above has been shown to hold true. At current farm levels of production, the effects of calliandra and dairy meal on milk yields were totally additive. Calliandra had a consistent positive effect on butterfat content, increasing it by about 0.5%.

Utilisation

Reports from Australia suggest that while fresh calliandra fodder has a digestibility in ruminants of some 60%, a few hours drying at ambient temperature can reduce this figure to below 40% (Palmer and Schlink, 1992). The results of Kaitho *et al*. (1993) appear to support these findings. The fodder should therefore be fed fresh, as soon as it is cut and while still in optimum condition. In this state, it is readily consumed by all classes of cattle, sheep and goats, after a short period of adaptation. Some farmers in the area have also fed it to rabbits with apparently good results.

Amount required

Most dairy cows in the Embu area are genetically capable of producing at least 15 litres of milk per day (about 4000 litres per lactation), due to their breeding which includes high proportions of exotic dairy Jersey blood. At present, few give more than 10 litres (about 2500litres per lactation), the production levels being limited by poor nutrition (including inadequate provision of digestible energy and protein) and sub-optimal management. In informal interviews in the region, it emerged that despite an awareness of recommendations for higher feeding levels, most farmers fed only 2-4 kg of dairy meal per cow per day. High cost (lack of cash), logistical problems and unreliable quality of commercial dairy meal were reasons commonly cited for the low feeding levels. In a typical lactation of 270-300 days, most cows presently consume about 700 kg (10 bags) of dairy meal. At the fodder yields noted above, an equivalent amount of supplementary digestible protein would be supplied by about 320 calliandra trees. Even allowing for conservative yield estimates, supplementation of one cow for a full lactation would require some 160-250 metres of hedgerow, depending upon the spacing used between trees. Allowing for moderate germination and common rates of seedling mortality, these trees could be produced from 120 grammes of seed (about 19,000 seeds per kg).

Planting niches

On farms where calliandra has been planted, formal surveys have found it around homesteads, along boundary lines, internal divisions, terrace edges, contour lines (bunds) and as hedges in napier grass. At the moment in the Embu area, the typical farm with calliandra has only some 40-100 trees, usually planted in at least two of the niches noted above, although almost all farmers who have used it want more seedlings (Franzel *et al.*, this conference). It is too early to say where additional plantings will be made on the farm, but from informal discussions with farmers, likely sites are under upperstorey trees (usually *Grevillea robusta*) along boundary lines, and as reinforcement along terrace edges and bunds.

Over the past few years, calliandra seedlings have been made available to farmers in small numbers by several bodies, including government ministries, research entities and non-government organizations. The popularity of the tree has led to a growing demand that has rapidly outstripped supply. Several farmers have recently started to leave either complete trees or one-or-two stems on selected trees to flower for seed production. In a recent survey of 45 farmers randomly selected from a list of 95 who had received calliandra from projects between 1989 and 1993, 67% were leaving some trees to flower and 44% had already produced seed which they had shared with an average of 10 of their neighbours (Franzel *et al.*, this conference).

Implications

While the agronomic information on the production of fodder from trees is far from complete, trends as noted above are becoming clearer and further results from experiments already under way will permit more reliable conclusions in the near future.

Predicted effect

There are two possible ways of utilising calliandra. It could either replace the existing use of dairy meal, or it could be offered in addition to the present feeding regime to improve the level of nutrition of the animals in terms of both quantity and quality. The first alternative would have little, or no effect on milk production, although it should lead to reduced feed costs. If fed in addition to the present dietary regime, it would increase production. If this were to be adopted by all dairy farmers in the area, on-farm research suggests an increase in the supply of milk ofsome 10% over present levels (Paterson *et al.*, in press). At present, there appear to be few milk marketing problems and it is unlikely that an increase of this magnitude would cause insurmountable difficulties. A more probable scenario, at least in the medium term, is that those farmers who are further away from the markets or the milk collection plants will replace dairy meal with calliandra to reduce their production costs. Those with more ready access to markets may choose to increase production. This could result in a potential increase of perhaps 5% in total milk production in the area.

Economic evaluation

An *ex-ante* analysis of hedgerow prunings in Kenya (based on 1992 prices for inorganic fertilisers, dairy meal, milk and maize) indicated that even without returning the cow manure to the soil, the substitute fodder value of leucaena leaves was some 6.5 times that of the substitute green manure value. The end-product

fodder value of the leaves was three to four times that of the end-product green manure value (Hoekstra and Darnhofer, 1992). If the value of the brown manure were to be included in the calculations, the ratios would be widened to perhaps 10 and 5 respectively. The estimates have not been repeated with 1996 prices, but there is no reason to expect the ratios to have changed markedly over the past 4 years. Neither is there reason to expect the value of calliandra foliage to be very different from that of leucaena. It therefore appears that it would be much more economic to pass tree fodder through ruminant livestock than to apply it direct to the soil as green manure.

Currently, dairy meal sells in Embu for about KSh 10 per kg, although the cost on the farm will be higher than this. If the feeding value of calliandra is as calculated above, then in replacement terms, the fodder is worth at least KSh 11 per kg of dry matter. This equates to about KSh 55 per metre of hedgerow per year. A full economic analysis of the fodder tree will have to await the generation of more detailed data. It would appear, however, that the cost of establishment of the seedlings should be easily covered by the value of the fodder produced in the second season of growth (within the first year). Annual maintenance costs are low, since pest control is minimal and calliandra requires no more manure than Napier grass. Cutting takes slightly longer than for the grass, but the difference as reported by farmers is not great and in any case, some fodder source has to be cut for feeding to zero-grazed animals. An investment in calliandra should therefore show a profit in the second year. When it is considered that the expected useful life of calliandra is not less than a decade, the planting of fodder hedges with this species should stand up to the most rigorous economic evaluation. The present farmer enthusiasm for this tree as a source of supplementary protein for dairy cows in the Embu region would seem to be fully justified from an economic standpoint.

Future developments

On farm

The majority of the farmers in the region keep a range of livestock, including cattle, goats, sheep, poultry and rabbits, that could potentially benefit from the inclusion of calliandra in their diets. Small ruminants, particularly goats, are often kept under zero-grazing conditions similar to those employed for dairy cattle. They are commonly fed a diet based on Napier grass and supplemented with calliandra and leaves from naturally occurring trees. Poultry forage forthe bulk of their food, receiving small supplements of grain on a regular basis. Fresh, or possibly even dry calliandra leaves could be offered in small quantities to vary the diet and to improve the colour of the egg yolks. Some farmers already give calliandra to rabbits, together with household scraps and weeds. It seems likely that as more calliandra trees are established in the region, they will be increasingly offered to the other animal species on the farm.

From the size of the existing farms (average about 1.5 ha) and herds (average 2.6 cows plus assorted small stock), the potential for calliandra for use in animal production at presently predicted levels might be some 1200 trees per farm, a total of about 600 m of hedgerow. Given the dimensions of the farms, there should be plenty of room for these trees in the planting niches noted above. Indeed, if terrace edges, contour bunds and boundary lines on the typical sloping farms in the area were all planted, there could be in the region of 1000 m of hedgerow with a potential production of some 5 t of DM per year. The excess tree fodder could be used to increase the levels on offer to the animals, but this may not be attractive to farmers by virtue of the labour involved in carrying the fodder from the farthest corners of the land. In this case, despite the lower economic return, some could be applied to the soil as green manure to prevent, or to slow down, the depletion of soil fertility under the present system of continuous cropping with low levels of external inputs. However, the foliage is used, the benefits of the trees could potentially be felt by all of the enterprises on a small, mixed farm.

In conclusion, a cautionary note should be sounded. No matter how attractive calliandra appears to be in the region, danger is always involved in placing total reliance on a single species, whether it be a crop or a fodder. Both farmer interest and the physical niches exist to extend the planting of trees on the farms in the area. In the programme of work on-station in Embu, a range of indigenous, naturalised and exotic trees (such as *Trema orientalis*, *Morus alba*, *Manihot glaziovii*, and *Leucaena* spp.) is under investigation from the point of view of both agronomy and animal production. This work will lead to the identification of suitable alternatives to calliandra, in order to provide much-needed diversity in available species for fodder production.

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