The potential of indigenous and naturalized fodder trees and shrubs for intensive use in central Kenya

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Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
dr. C.M. Karssen,
in het openbaar te verdedigen
op vrijdag 7 januari 2000
des namiddags om half twee in de Aula.

Doctoral thesis 2000
Wageningen University
The Netherlands

ISBN 90-5808-158-3

NN08201, 2738

Stellingen

1. Boeren in centraal Kenia hebben een gedetailleerde kennis van inheemse voederbomen en –struiken, die gebruikt kan worden als basis voor het selecteren van superieure soorten met betrekking tot voederproductie en benutting. *Dit proefschrift*

2. Het proces van het testen van nieuwe voedersoorten is efficiënter als het begint met onderzoek op de boerderij en eindigt met onderzoek op het proefstation, dan omgekeerd zoals traditioneel gebruikelijk is. *Dit proefschrift*

3. Het feit dat veel inheemse voederbomen minder voer produceren dan bekende uitheemse soorten, zorgt ervoor dat zij beter in de landbouwbedrijfsystemen passen in centraal Kenia. *Dit proefschrift*

4. Toenemende bevolkingsdichtheid in centraal Kenia leidt tot grotere productie per eenheid land en per dier. *Dit proefschrift*

5. Boeren hebben duidelijke meningen over welke inheemse voederbomen zij wel en niet moeten planten. *Dit proefschrift*

6. Het begrip giftigheid van boomvoer is relatief, daar het afhangt van de hoeveelheid die geconsumeerd wordt, de fysiologische leeftijd van het geconsumeerde plantendeel, de diersoort, en de aanpassing van het dier.

7. Het probleem van lage smakelijkheid van sommige voedersoorten belemmert de boer meer dan het dier.

8. Boeren schamen zich voor het gebruik van inheemse voederbomen, terwijl dezelfde soorten geëxporteerd naar een naburig land aldaar wel worden gewaardeerd.

9. Omdat kwaliteitscontrole mogelijk wordt als de Keniaanse overheid het privé produceren van gedestilleerde dranken legaliseert, zal het aantal slachtoffers door methanolvergiftiging afnemen.

10. Spreken in het openbaar is gemakkelijk met een mobiele telefoon.

Ralph L. Roothaert

Stellingen bij het proefschrift: *Het potentieel van inheemse en genaturaliseerde voederbomen en -struiken voor intensief gebruik in centraal Kenia.*

Wageningen, 7 januari 2000

Abstract

Roothaert, R.L. 2000. The potential of indigenous and naturalized fodder trees and shrubs for intensive use in central Kenya. There are opportunities for increasing milk production in central Kenya through the use of tree fodder, leading to higher farm income. Most research for intensive use of fodder trees has been carried out on exotic species, neglecting indigenous ones. The objectives of this study were to assess the potential of indigenous and naturalized fodder trees and shrubs (IFTS) in central Kenya, involving farmers in all phases of research in order to increase the adoption of so developed technologies. Formal surveys and feedback meetings were conducted. Farmers chose tree seedlings, planted them on-farm, and the performance was monitored. Farmers' assessments of qualities of IFTS were compared with laboratory nutritive analyses. Two feeding trials with dairy heifers were conducted involving seven fodder tree species. Farmers used a total of 160 different IFTS. Their ratings on palatability for cattle and goats and milk production for goats differed significantly among tree and shrub species. On-farm assessment of planted IFTS provided useful information on preference of species, in addition to the survey results. There were strong relationships between laboratory nutritive analyses and farmers' assessment of quality of IFTS and useful characteristics of individual species were obtained through comparing the two methods. Dry matter intake by heifers was higher for some IFTS than for the popular exotic species *Calliandra calothyrsus*. Selective feeding behaviour of heifers caused an improvement of nutrient concentrations of consumed feed of up to 29 %. It was concluded that there is a large potential for intensive use of IFTS in central Kenya. Promising species for the subhumid zone are: *Ficus thoningii, Lantana camara, Morus alba, Manihot glaziovii, Sapium ellipticum, Tithonia diversifolia, Trema orientalis, Triumfetta tomentosa* and *Vernonia lasiopus*; for the medium and semi-arid zone they are: *Acacia ataxacantha, Aspilia mossambicensis, Crotalaria goodiiformis, Grewia tembensis, Indigofera lupatana, Lantana camara* and *Melia volkensii*. Future research is needed on experiments with lactating cows, agronomic performance, protein quality and current mechanisms preventing toxicity of *L. camara*.

To: The small miracle in Hilda

Preface

The research described in this thesis was planned and carried out between 1994 and 1999, while I was an associate animal scientist in the National Agroforestry Research Project in Kenya. The project was a partnership of the Kenya Agricultural Research Institute (KARI), the Kenya Forestry Research Institute (KEFRI) and the International Centre for Research in Agroforestry (ICRAF). The project was funded by the Swedish International Development Co-operation Agency (Sida), ICRAF, and the Natural Resources Institute (NRI, UK). I was employed by the Ministry of Foreign Affairs of the Netherlands, and seconded to ICRAF.

I had a clear task to fulfill in the project: to carry out research leading to increased income of small scale farmers, through better utilization of fodder trees. Although initially it was not my intention to write a Ph.D. thesis, it soon became clear that the research was suitable for it. If anybody was going to do it, so I reasoned, why not I? I owe thanks to many people and several institutions that have made this thesis possible. First of all my direct colleagues in Embu: Dr. Rob Paterson, Dr. Mick O'Neill, Festus Murithi, George Karanja, Paul Tuwei, Jayne Mugwe, Maushe Kidundo and the late Zacharia Nyaata; thanks for believing in me. Nyaata, your work has made an impact. I thank the Director of the KARI – Regional Research Centre, Embu, Samuel Gachanja, for endorsing and supporting my activities. At the ICRAF headquarters I wish to thank Dr. Pedro Sanchez, Dr. Peter Cooper, Dr. Kwesi Atta-Krah and Bruce Scott for the administrative and logistic support, and for assisting to look for solutions during times of crisis. I have appreciated Dr. Steve Franzel's push and help to publish papers. Professor Leendert 't Mannetje agreed to be my promoter at the Wageningen University. I thank him for his visit to Kenya, his advice and the confidence he has given me during the writing of this thesis.

To my parents I want to say thanks for supporting whatever I have done in my life. It is unfortunate that my ambition and idealism takes me away from home most of the time. Your visits have kept me in touch. A big thank you for Hilda, my wife, for taking good care of me. I thank my friends in Embu for giving me another home. Last but not least, I want to thank all farmers I have worked with in Embu and Mbeere Districts. They have inspired me and I gained a lot from their knowledge. Their hospitality during numerous visits will not be forgotten. I hope that this work

will benefit them; that continued research results will contribute to their welfare; and that this work will increase the status of their natural wealth.

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General introduction

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General introduction

Livestock products are an important source of food and income for people in the tropics. In Africa, 11 % of food production is of animal origin (FAO, 1997). It is expected that through population growth and a dramatic migration from rural to urban areas, patterns of food production, marketing and consumption will change. If livestock production in developing countries does not grow faster than it does now, these countries will face a massive shortage of meat and milk supplies in 25 years time (Winrock International, 1992).

Livestock production in central Kenya

In the subhumid zone of Embu District, central Kenya, agricultural production contributes 73 % of the total value of household output (Murithi, 1998). Livestock contributes half of the total household cash income from agricultural activities, and milk production is the most important livestock activity in this regard. However, there is vast room for improved economic performance through increased milk production.

The farming system in the subhumid zone of Embu District, situated along the slopes of Mount Kenya, probably has the most diverse number of tree species in cropping land. Farms have a relatively small size of 1.5 ha (Minae *et al.*, 1988) and consist of a mosaic of trees in lines along contours, boundaries, paths and scattered within food and cash crops. Food crops are mainly maize, beans, bananas and vegetables; cash crops are mainly coffee, tea or macadamia nuts. Eighty three to ninety eight percent of these farmers keep cattle, ninety percent of which are improved dairy cows. What many farmers see as an advantage of milk production is the daily cash income, as opposed to earnings from coffee, tea or macadamia, which are accumulated and only paid a few times a year. Major constraints in these farming systems are the low quality of feeds and the shortage of feeds during the dry season (Snijders, 1991; Minae *et al.*, 1988).

Further down the slopes of Mt. Kenya, as one moves into Mbeere District, rainfall diminishes, and land use is less intensive. Main food crops grown are maize, beans, cowpeas, greengrams, millet and sorghum; while cotton and the chewing drug miraa (*Catha edulis*) are cash crops. Livestock is economically less important in these farming systems than crops. Cattle are mostly Zebu and they are grazed. However, land use is becoming increasingly intensive (Sutherland *et al.*, 1995), due to an influx of people from the higher zones where land pressure is very high, and from Machakos District across the Tana river. At the same time, communal grazing land is disappearing as the Kenyan government started a process of individual land adjudication and registration in this area in 1971. As a result, more grazing areas are fenced, cattle are tethered, fodder crops are grown and local animals are upgraded for dairying. There are opportunities for increased economic performance of livestock.

Advantages of fodder trees

Tropical grasses are different from grasses in temperate regions, as their growth pattern is influenced by high temperature, high solar radiation and periodical drought stress. A physiological implication is a higher cell wall related fibre content and less plasma related cell content. Furthermore, the C_4 photosynthetic pathway of tropical grasses creates a higher growth potential, but this is accompanied by a higher content of structural elements such as fibre (Humphreys, 1991). As cell contents are more digestible for animals than cell walls, tropical grasses are per definition less digestible than temperate ones. Another physiological difference of tropical and temperate grasses is the lower protein content of tropical grasses, especially after experiencing drought stress.

Cattle and other livestock which are kept by pastoralists, and which depend mainly on grass during part of the year, can switch their eating pattern to leaves and twigs of woody plants when grass has become scarce (Dicko and Sikena, 1992). In fact, cattle, sheep, goats and camels of nomadic tribes in west and east Africa often survive on browse during periodic times of drought. Trees and shrubs stay green longer than grass in times of drought, probably due to their deeper root system which can tap water beyond the reach of grass roots. Although nutritive value of browse drops during the dry season, it still remains much higher than that of grass. Leloup and 't Mannetje (1996) found a sudden increase of N and P concentrations of browse in southern Mali were highest at the end of the dry season, when browse consumption was also at its highest. Crude fibre concentration did not vary much during the year.

In many parts of the tropics, fodder trees and shrubs are actively harvested by farmers and fed to cattle, buffaloes, goats and sheep. When used as supplements to low quality diets, tree fodder increases live weight gain, milk and wool production (Devendra, 1990; Djogo, 1994; Roothaert *et al.*, 1998).

Anti-nutritive factors

Woody plant species have many ways to protect themselves from being eaten by herbivores or insects. The most conspicuous protection in African browse are thorns and spines which can be extremely hard, sharp and as long as 10 cm in *Acacia xanthophloea*. Other defense mechanisms are of a chemical nature involving secondary compounds, such as phenolics, toxic amino acids, saponins, alkaloids and cyanogenic glycosides. They can have negative health effects, fatal effects on the animal, or interfere with absorption of nutrients (Paterson, 1993). There are many types of tannin, varying not only among plant species but also among different parts of the plant, and also in time scale within a plant. It is also known that plants can synthesise tannins within hours after being browsed to protect them against subsequent browsers. Tannins can be divided into two major groups: hydrolysable tannins and condensed tannins (also called proanthocyanidins). Consumption of hydrolysable tannins can cause death in ruminants, whereas condensed tannins are more responsible for reducing digestibility of feed (Reed *et al.*, 1985; Norton, 1994). Once consumed, these tannins can bind dietary protein, preventing it from being degraded by rumen microorganisms, or from being absorbed in the intestinal duct. Tannins can also indirectly affect digestibility of food by inhibiting digestive enzymes of rumen microorganisms or by forming complexes with proteins in their cell wall. Screening tree and shrubs species for minimum levels of harmful tannins would seem an obvious solution. However, many of the active ingredients have not been identified yet and they can change within a species in terms of both chemistry and concentration, triggered by many factors. Tannins prevent the plant from being eaten by chewing insects but not from being sucked by sucking insects.

Indigenous fodder trees

In the realm of offering farmers multiple technologies to choose from, but also to reduce the risk involved in single species dependence, research has been carried out on different fodder tree species. The best known genera are *Leucaena, Sesbania, Gliricidia and Calliandra*. Most species in these genera originate from South or Central America, apart from *Sesbania spp.*, some of which are believed to be native to Asia and Africa. Growing exotic species can create other risks though. For example, *Leucaena leucocephala* has been widely adopted all over the world, providing the bulk of feed in some farming systems. When the leucaena psyllid (*Heteropsylla cubana)* later on found its way to the parts of the world where *L. leucocephala* was introduced, it caused major damage up to the extent that farmers had to give up livestock production (Djogo, 1994). It is in this light that there seem many advantages in selecting indigenous tree species to develop fodder terchnologies. Local species are well adapted to the climate and have evolved surviving strategies during periodic adverse climatic conditions. If they are affected by pests at all, there should be natural predators of these pests as well, as is the case of *L. leucocephala* in Latin America. Natural predators don't control the pest but reduce the damage to insignificant levels.

Farmers' involvement

During surveys carried out in Embu District it was found that farmers use many different tree species to feed their livestock (Thijssen *et al.*, 1993a,b). Samples of several of these species were collected and analysed in a laboratory. Chemical composition showed huge differences in nutritive components among the species. However, conventional indicators of the nutritive value from the proximate analysis can be misleading in the case of woody species because of the presence of anti-nutritive factors. The complexity of factors which influence nutritive value makes screening of new fodder tree species is difficult, and the only reliable information seems to be long term feeding trials with different animal species under a range of conditions. It is therefore logical to try to obtain as much information as possible from farmers and pastoralists who have fed local tree and shrub species to their animals on a routine basis for a long time. It has been demonstrated that farmers in Nepal (Rusten and Gold, 1991) and pastoralists in west Africa (Bayer, 1990) have a consistent knowledge of nutritive value of fodder trees and shrubs.

Agroforestry has been defined as *a dynamic, ecologically based, natural resource management system that, through the integration of trees in farm- and rangeland, diversifies and sustains smallholder production for increased social, economic and environmental benefits* (Leakey, 1996). From this definition it is clear that farmers involvement in the development of new agroforestry technologies is important, right from the beginning. Trees do provide many useful products. However, when grown on-farm, they can have a negative impact on other crops, be it through under or above ground competition, or through allelopathy. The resulting negative effects of trees on crops are relatively easy to observe in the field, even though mechanisms can remain obscure. Farmers decisions to allow trees to grow on the farm are not only influenced by these factors but also by less straight forward factors such as beauty, tradition, believes or personal preferences. Ignoring these farmers' factors would imply an intentional reduction of chances of farmers adoption of the agroforestry technology.

When farmers seem to have a clear idea of the feeding value of fodder trees, and know which trees they want to grow on-farm, the relevance of scientists' involvement in developing new technologies can be questioned. However, farming systems are changing and becoming more intensive. Using the correct mixture of different types of fodder in the diet of a stall fed cow can cause a considerable improvement of milk production. Although farmers can differentiate bad fodder trees from good ones, their knowledge does not reach as far as determining which amounts of feed have to be mixed for the appropriate animal ration. Optimising milk production still requires accurate information about the quality of energy and protein in the consumed feed. Farmers' and scientists' knowledge are of complementary rather than exclusive nature.

Source of dietary minerals

Tree fodder can provide important amounts of dietary minerals to livestock. The mineral requirements for cows of 350 kg body weight producing 20 kg of milk per day would be 6.7, 4.7, 1.9 and 1.8 g kg^{-1} dry matter for calcium, phosphorus, magnesium and sodium, respectively (McDonald *et al.*, 1981). Mineral and other nutrient contents have been compiled for 105 browse species in west Africa, 150 in east Africa and 325 in northern Africa (Le Houerou, 1980a,b,c). As the compilation was derived from many different sources, the data on of mineral contents of all species were not complete. Nevertheless, a fair overview can be obtained. The average values of calcium and posphorus in the regions of west and east Africa combined are 17.5 and 1.75 g kg^{-1} dry matter, respectively. Magnesium content was only complied for west African species and averaged 6.0 g kg^{-1} dry matter. Sodium content has been determined in northern African browse, and has an average of 2.8 g kg^{-1}, excluding *Atriplex spp.*, which have on average of 51 g Na kg^{-1}. Minerals needed in small amount such as potassium, iron, cobalt, manganese are generally covered in browse (Le Houerou, 1980a). From these figures it appears that, except for phosphorus, browse is a generous supplier of dietary minerals. For growing cattle, phosphorous content of browse is also adequate.

Economics

The degree of intensity of utilisation of fodder trees ranges from nomadic grazing of livestock on unimproved communal or government range land to cut and carry system of planted trees on private farm land. The economical value of fodder trees at farm level can be assessed when land, labour and capital are considered. In the most extensive form, there are few inputs and therefore on farmers' level the use of browse can be called economical. Growing fodder trees on large scale in Africa can be economical if cost of enclosure is kept to the minimum (Le Houerou, 1989). Economic viability of these systems increases when other benefits such as energy supply and environmental protection are also taken into account. In the smallholder cut and carry dairy system in Kenya, feeding calliandra to dairy cattle increases farmers' income with US $ 93 per cow per year if calliandra is added to the normal diet. If concentrates are replaced by calliandra, farmers' yearly income increases by US $ 104 per cow (Franzel *et al.*, 1996). Very little economic information is available about fodder trees in tropical regions of other continents.

Objectives and outline of the thesis

This study attempts to identify indigenous and naturalized fodder trees and shrubs (IFTS) which show potential in terms of intensive use, involving farmers right from the start. More specifically the objectives were:

1. To identify local tree or shrub species which can contribute to solving the problem of fodder shortage and poor quality diets, for cattle, under a range of climatic and cultural conditions in central Kenya.
2. To compare farmers' practices and knowledge about indigenous fodder trees and shrubs (IFTS) in different agroecological zones.
3. To assess the potential of intensive use of IFTS on-farm in terms of planting, management and animal response.
4. To assess animal feed intake and selection of selected local IFTS.
5. To compare social and laboratory tools for assessing nutritive value, and to examine their relationship.

In Chapter 2, the role of fodder trees in East Africa is reviewed through recent publications on this topic, and a framework of activities is developed for the screening of IFTS. In Chapter 3, farmers' knowledge and preferences are assessed about IFTS in different farming systems along the altitudinal gradient of Mt. Kenya. In Chapter 4, the cultivation of most preferred IFTS is evaluated on-farm. In Chapter 5, nutritive value of IFTS is assessed through laboratory methods and compared with farmers assessments. In Chapter 6 and 7, fodder intake and selectivity are assessed when dairy heifers are fed on different IFTS supplements. In Chapter 8, findings of previous chapters are synthesised, the potential of intensive use of IFTS in this region is discussed, and recommendations are made for future research.

Chapter 2

Recent work on the production and utilization of tree fodder in East Africa

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Animal Feed Science and Technology (1997) 69:39-51

Chapter 2

Recent work on the production and utilization of tree fodder in East Africa

Abstract

Most of the work discussed in the paper is part of the Agroforestry Research Network for Africa (AFRENA). In the sub-humid highlands the most common form of livestock management is a mixture of grazing, tethering and stall feeding. In the arid and semi-arid lowlands of Kenya the normal livestock management practice is grazing. *Leucaena leucocephala* was a popular fodder species until it was attacked by the leucaena psyllid *(Heteropsylla cubana)* to which other species like *L. diversifolia, L. esculenta* and *L. pallida* have shown some degree of tolerance. *Sesbania spp.* showed early promise but did not withstand intensive cutting management. In Kenya, when *Calliandra calothyrsus* is grown in 4:1 and 1:1 grass:legume combinations the fodder yields are higher than for pure hedgerows. Cutting *C. calothyrsus* six months before the height of the dry season gives maximum yield during that season. For dairy cows 1 kg of concentrates can be successfully replaced by 3 kg of fresh *C. calothyrsus*. At altitudes above 2300 m supplementation with *Mimosa scabrella* enabled local goats to gain 50 g/day compared with 31 g/day for grass alone. In Kenya a survey was conducted on farmers' practices and knowledge of indigenous fodder trees. Some identified popular species were *Commiphora zimmermanii, Triumfetta spp., Tithonia diversifolia, Melia volkensii* and *Crotalaria goodiiformis.* Both indigenous and exotic tree species are being fed to cattle to determine the exact parts that are consumed and to assess their nutritive value. Further research is needed on inclusion levels of tree fodder in diets, optimal management of fodder trees in the dry land farming systems and anti-nutritive factors in some tree species.

Key words: fodder trees, fodder utilization, ruminant production

Introduction

This paper gives an overview of some recent achievements of research in the area of production and utilization of fodder trees in East Africa. Most of the research that is reviewed is part of the Agroforestry Research Network for Africa (AFRENA).

Firstly the role of fodder trees in a few farming systems are described. After that some results of research are given on positive and negative aspects of tree fodder and management practices of some of the trees. The paper continues with the current research programme of AFRENA and recommendations for research.

The role of fodder trees in the farming system in East Africa

Within the Eastern and Central Africa AFRENA highland zone, which comprises the areas in Kenya, Uganda, Rwanda and Burundi that are higher than 1000 m above sea level with an average rainfall of 1000 mm or more, 21 major land-use systems were identified (Hoekstra, 1988). Most of the land-use systems are characterized by an agricultural orientation, practised on a relatively small scale. In principle, each system has a unique configuration in terms of its agroforestry potential.

Livestock management varies considerably within this area. In the less densely populated areas, herding on grazing land is common. Paddocking of privately owned land has also been introduced in some of these areas with commercial potential. In the more densely populated areas, very little grazing land is left and usually fewer animals are found. The most common form of management in these areas is a mixture of grazing (public lands, bottom land, cropland), tethering and stall feeding. In the coffee-based system in Central Kenya however, zero grazing systems with improved dairy cattle and cultivated fodder crops are most common (Minae *et al.*, 1988).

An important problem diagnosed in the zone is lack of fodder during the dry season (Hoekstra, 1988; Minae *et al.*, 1988). In Central Kenya where the main diet of the dairy cattle is napier grass a major constraint to milk production is lack of protein (Snyders, 1991). This problem becomes worse during the dry season when the quality of the grass is reduced. In view of the potentially high nutritive value of tree foliage, it was reasoned that deep rooted, woody plants could help to overcome these problems if fed as a supplement to the basal diet.

A different situation occurs in the semi-arid lands of Central Kenya where rainfall averages between 600 to 900 mm per year. Most farmers keep goats, either of local breeds or crosses, and Zebu cattle. The normal management practice is grazing on private or communal land. In the more densely populated parts of the region, there is a trend towards greater intensification of livestock management. This appears to be associated with a shift away from emphasis on goats, Zebu cattle and bee-keeping, in favour of poultry and cross-bred cattle (DAREP, 1994). During recent workshops of the Dryland Applied Research and Extension Project (DAREP) some recommendations were made for areas of research related to fodder trees:

1. Current management, nutritive value and farmer preferences for both indigenous and exotic fodder trees.
2. Production of multipurpose trees in farm compounds and linear niches.
3. Optimal management of existing vegetation.
4. Range rehabilitation.
5. Fodder banks.

There is a potential for the integration of fodder trees in the farming systems. In the Central Kenyan highlands farmers like to plant these trees mixed with crops, along the farm boundaries, as a fodder bank, around the compound or near the zero grazing unit (Thijssen *et al.*, 1993b). Trees along the farm boundaries and around the compound are often managed as hedges which are frequently pruned and lopped. These niches provide a great fodder production potential if good fodder tree species are used.

In Tanzania the research agenda of AFRENA restricts itself to the unimodal upland plateau, which covers 40 % of the country. The altitude in this zone ranges from 600 m to 1500 m and the upper and lower limits of the crop growing period are 270 and 90 days respectively (Kamau and Odra, 1988). The land use systems that showed potential for the growing of tree fodder were the 'Sukuma agropastoral system' and the 'cotton-cereal system'. The recommended areas of research were:

1. Fodder banks.
2. Enriched fallows with fodder trees and permanent hedges.
3. Shrub legume and grass leys.

Research findings on positive and negative effects of tree fodder for ruminant nutrition

Because of the diversity of climatic and edaphic conditions and farming systems in East Africa, many different species of fodder trees have been screened to suit the particular situation. The most important woody genera assessed include: *Cajanus, Calliandra, Crotalaria, Gliricidia, Leucaena, Manihot, Margaritaria, Mimosa, Morus, Sesbania, Tithonia, Trema* and *Triumfetta.*

In many parts of the region with relatively neutral soils, *Leucaena leucocephala* was a most productive fodder species and was becoming popular with farmers before the arrival of the leucaena psyllid (*Heteropsylla cubana*) into the region. The pest first appeared on the African mainland just north of Mombassa (Kenya), in August 1992 (Reynolds and Bimbuzi, 1993). The psyllid is now endemic in the whole region and it remains to be seen if natural, or possibly introduced predators will be able to control it in the long run. Other species such as *L. diversifolia*, *L. esculenta* and *L. pallida*, together with a number of inter-specific hybrids, have shown some degree of tolerance to the psyllid (Dzowela *et al*, 1994; Otsyina *et al.*, 1994, 1995), but work with them is of recent inception and more local experience will have to be gained before these species and lines can be recommended to farmers.

Work has recently been initiated in Shinyanga in Tanzania, to study the effect of tree fodder as a supplement for oxen in the latter part of the dry season. Early indications are that 2 kg/day of fresh *L. leucocephala* can result in a notable improvement in the body condition of the animals. It is expected that better physical condition should result in improved ability to perform heavy work during the critical period of land preparation (R. Otsyina, personal communication).

Another species to show early promise was *Sesbania sesban* because of its high nutritive value (see Table 1.). However, most accessions died out after a few

Table 1. Chemical composition (g kg^{-1} DM) and *in vitro* dry matter digestibility (g/kg) of foliage from fodder trees.

Species	CP	DCP	ADF	NDF	DMD	Comments	S
Calliandra calothyrsus	282		220	455		Dried shoot material, 12 weeks regrowth, Kenya	1
	258		297	495	416[a]	idem, 24 weeks	1
	235		309	475		idem, 48 weeks	1
Calliandra calothyrsus	219	122	175	393		Dried leaves, 8 weeks regrowth, Rwanda	2
Sesbania sesban	267	218	95	216		idem	2
Leucaena	261	138	169	371		idem	2
Calliandra calothyrsus	140-177			445-525	445-515	Leaves, Thailand	3
Sesbania grandiflora	265			451	669	idem	3
Sesbania sesban	242-264			295-387	691-790	idem	3
Sesbania sesban	212		204		620	Dried leaves and twigs, 4 months regrowth, Tanzania	4
Leucaena	200		383		472	idem	4
Leucaena diversifolia	297-384		285-424	335-466		Young leaves	5
	258-303		343-474	447-555		Mature leaves	5
Morus alba	150					Fresh leaves	6
Morus alba		107					7
Morus alba	189				855[b]	Leaves	8
Trema orientalis	271				788[b]	Leaves	8
Manihot glaziovii	346				784[b]	Leaves	8

[a] Measured *in vivo*

[b] Organic matter digestibility

S source: 1 Kaitho *et al.* (1993); 2 Kamatali *et al.* (1992); 3 Akkasaeng *et al.* (1989); 4 Karachi and Zengo (1997); 5 Toruan-Mathius *et al.* (1992); 6 Sen (1938); 7 Kehar and Goswami (1956); 8 Thijssen (1993a).

Table 2. Dry matter yields of fodder trees.

Species	Fodder yield (block) t ha^{-1} yr^{-1}	Fodder yield (hedge) kg 10 m^{-1} yr^{-1}	Cutting frequency	Comments	S
L. leucocephala[a]	15.9	14.8[b]	3 months	1500 m above sealevel, Kenya	1
C. calothyrsus	15.1	20.2[b]	3 months		
C. calothyrsus	13.9[c]		5-6 weeks	rows 2m apart and 0.5m within row, intercropped with Taro, W. Samoa	2
S. sesban	6.8[c]		8 weeks		
C. calothyrsus		100	4 months	1m cutting height, rows 5m apart, 1700 m above sealevel, Rwanda	3
		45	4 months	idem, 40 cm cutting height	3
C. calothyrsus	6.0		3 months	1250 mm rainfall, infertile soil	4
C. calothyrsus		58	12 weeks	1600 m above sealevel, Kenya	5
		74	24 weeks		
		85	48 weeks		
C. calothyrsus	9.9		3-4 months	2400 mm rainfall, 1 m cutting height, leaves only	6
L. diversifolia	2.2		3-4 months		
S. grandiflora	7.8			25 cm cutting height, first year	7
	6.4			idem, 50 cm	7

S source (1 O'Neill *et al.*, 1995; 2 Kidd and Taogaga, 1984; 3 A. Gahamanyi, unpublished data; 4 Gichuru and Kang, 1989; 5 Kaitho *et al.*, 1993; 6 Blair *et al.*, 1988; 7 Sampet and Pattaro, 1987)

a Sprayed with insecticide every fortnight

b Intercropped 1 row of trees with 4 rows of napier grass

c The original value of fresh weight has been converted into dry weight through multiplying by 0.3 .

cuts, seldom lasting for much more than two years when managed as a hedgerow under frequent cutting (e.g. ICRAF, 1992; Niang *et al.*, 1998; Gahamanyi, unpublished). *Sesbania grandiflora* has similar nutritive characteristics and a higher biomass production (Table 2) but is subject to the same cutting management problems. Because both species are prolific seed producers and are easily established by direct seeding of untreated seeds, resowing the trees after harvesting might be more appropriate than allowing it to regrow. In this regard *Sesbania spp.* are showing much promise as improved, short-term fallows (ICRAF, 1993).

In western highlands of Kenya leafy biomass yields of hedges maintained at a height of 0.5 m were compared for *L. leucocephala, C. calothyrsus* and *S. sesban.* In the establishment year the fresh yields were 11.2, 17.2 and 20.3 tonnes/ha respectively. However, in the next 8 months calliandra had the highest yield (36.7 t/ha), followed by leucaena (24.3 t/ha) and sesbania had the lowest (10.8 t/ha). The low yields of sesbania were caused by death of the trees as a result of pruning stress (Heineman *et al.*, 1990).

In the areas where rainfall exceeds about 1100 mm *Calliandra calothyrsus* appears to have the widest general potential. At Embu in Kenya with a bimodal rainfall pattern, an experiment was established in 1992 to study fodder yields in block plantings. Treatments were arranged as a substitution series with a total of 20,000 plants per ha, these being either pure grass (*Pennisetum purpureum* cv. Bana), pure tree hedgerow (either *C. calothyrsus* or *L. leucocephala*), or combinations of 1:1 and 4:1 grass to legume. On average, after the initial establishment period, the grass was cut at intervals of two months and the trees at three months. The work is designed as a five year study and results so far available are very preliminary. They show that the cumulative fodder yields over the first ten cuts for the 4:1 and 1:1 grass:legume combinations are higher than for the pure hedgerows (O'Neill *et al.*, 1995). The cumulative yield of crude protein (CP) is much greater from all of the combinations than from any of the species grown alone (O.Z. Nyaata, unpublished data). Similar results were obtained in Maseno (Kenya) where a 3:1 ratio of Napier to *L. leucocephala* produced the highest yields (H.J.O. Otieno, unpublished data). On-farm work in Embu has shown that these tree species can be successfully introduced into existing stands of Napier or Bana grass (O'Neill *et al.*, 1993). There would appear to be the potential to increase fodder production through the introduction of trees into existing grass plots.

In areas with a unimodal rainfall and a long dry season, moisture stress and leaf senescence can lead to the loss of fodder material unless cutting times are chosen judiciously. If the aim is to maximise the yield of fodder at the height of the dry season in August, research has shown that the final wet season cut should be made six months earlier, in February (Akyeampong and Muzinga, 1994).

Work at Maseno in Kenya has shown that *C. calothyrsus* can be successfully used as a concentrate for milking animals (van der Veen, 1993). In Embu, the replacement value of the fodder within the normal range of feeding of commercial concentrates (2-4 kg/d), is in the region of 3 kg of fresh material (0.8-1.0 kg DM) equivalent to 1 kg of dairy meal with 16 % CP. Normal milk yields are about 10 kg/day from upgraded dairy cattle, fed on a ration based on Napier grass, maize stover and banana stems.

A constraint to the feeding of calliandra is the low digestibility in the rumen when the material is dried or wilted (Palmer and Schlink, 1992). Until recently nutritive analysis has always been carried out on dried samples. This explains the low values for dry matter (DM) digestibility found in most literature (Table 2). It is not clear what causes the drop of digestibility during the drying (Kaitho *et al.*, 1993). Kaitho *et al.* (1993) found that unlike fodder trees such as *Gliricidia sepium, Tithonia diversifolia, Erythrina sp.* and *L. leucocephala,* the proportion of by-pass protein is higher than the rumen degradable protein. It is likely that the high content of polyphenolic compounds in *C. Calothyrsus* are responsible for the protection of the protein against degradation in the rumen by the micro flora. For highly productive dairy cows, which need some amount of by-pass protein, calliandra can make a good dietary ingredient.

Gliricidia sepium has performed well down to 700 mm rainfall (e.g. ICRAF, 1993; 1994). Farmers in Kenya complain that the fodder is not palatable to their animals (M. Kidundo, personal communication). This problem was also reported by Nochebuena and O'Donovan (1986) who attributed it to the strong odour which occurs when the leaves are crushed. While differences between provenances may explain some of the variability in reported animal acceptance, wilting for 24 hours between cutting and feeding appears to improve the intake by reducing the odour of the foliage (Bennison and Paterson, 1993). It has been reported that animals which initially refused gliricidia became accustomed to it in a few days, after which it was readily consumed. The presence of animals used to eating the foliage accelerated acceptance by others which were being introduced to it (Atta-Krah and Sumberg, 1987).

Mimosa scabrella has been shown to out-perform most other species at altitudes above 2300 m, on extremely acidic soils (pH below 4) in Rwanda (ICRAF, 1994; Niang, 1994). The tree foliage has consistently shown CP contents of about 25%. Young, local goats (about 6 months old with a mean liveweight of 10.4 kg at the start of the trial) fed on a basal diet of *Setaria splendida* (7-10% CP) consumed over 400 g/day DM of the fresh tree fodder, resulting in an increase in the total DM intake, with little substitution of the additive for the grass. In a separate experiment where similar animals were fed mixtures of the grass and the tree fodder, they gained weight at some 50 g/day compared with 31 g/day on the grass alone (ICRAF, 1994; Niang *et al.*, 1994; Niang *et al.*, 1996).

In Central Tanzania, separate groups of local goats with an average initial age and liveweight of 8 months and 8.4 kg were allowed to graze daily on natural range for two wet and two dry seasons. They were supplemented at night *ad libitum* with sun dried leaves and small twigs of either *Cajanus cajan, L. leucocephala* or *S. sesban*, the mean intakes of which were 82, 81 and 76 g/day and the mean daily liveweight gains of which were 34, 30 and 24 g/head, respectively. The animals in the unsupplemented control group only gained 5.6 g/head on average which suggests that at least in the miombo woodlands of Tanzania, the natural range is incapable of producing optimum growth rates in local goats (Karachi and Zengo, 1997). In a similar experiment *Margaritaria discoides*, a non-leguminous shrub, native to the Miombo woodlands of Western Tanzania, showed comparable results to *C. cajan, L. leucocephala* and *S. sesban* as a supplement to grazing natural range (Otsyina *et al.*, 1994).

On-going research

One of the research activities of the National Agroforestry Research Project in Embu in Kenya is the screening of indigenous trees that farmers use for their animals as browse or cut and carry. The exercise has inputs from five major fields: farmer's preferences and knowledge, nutritive analysis, animals' selection, agronomic information and propagation methods (see Fig. 1). The first step is a survey that explores farmers' current practices and knowledge on the use of indigenous fodder trees. Three different agro-ecological zones are covered, varying from semi-arid land 900 m a.s.l. to sub-humid highland 1800 m a.s.l. The popularity of the trees is ranked and the quality of the fodder is assessed through farmer's own criteria. The fodder tree species that farmers are interested in planting on their farms are identified and so are the plant niches and arrangements.

Preliminary results show that *Commiphora zimmermanii, Triumfetta spp.* and *Tithonia diversifolia* are the most popular indigenous fodder tree species in the sub-humid highland. In the dry lowland the most popular ones are *Melia volkensii* and *Crotalaria goodiiformis*. There seem to be two types of fodder trees and shrubs with regard to their management. Trees and shrubs of the first type are frequently coppiced or even uprooted. They offer scope for intense cutting management. Trees of the second type are only pruned or pollarded and their main stem remains intact as source of timber, poles or support for climbing plants. *Triumfetta spp., T. diversifolia* and *C. goodiiformis* belong to the first type, *C. zimmermanii* and *M. volkensii* to the second.

The survey will be followed up by an on-farm trial in which seedlings of preferred indigenous fodder species will be distributed to farmers. This trial aims to verify the information in the survey on planting niche, planting arrangement and pruning regime and will measure survival rate, initial growth rate and acceptability by livestock.

The organic matter digestibility and crude protein content of the leaves of some indigenous trees which are traditionally used as fodder in Central Kenya are very high (Thijssen *et al*, 1993a). On-farm however, not only the leaves are fed to the cattle but also petioles and the branches. The part that is eaten by the cattle varies with tree species. No research has been carried out yet on the nutritive value of the part of the

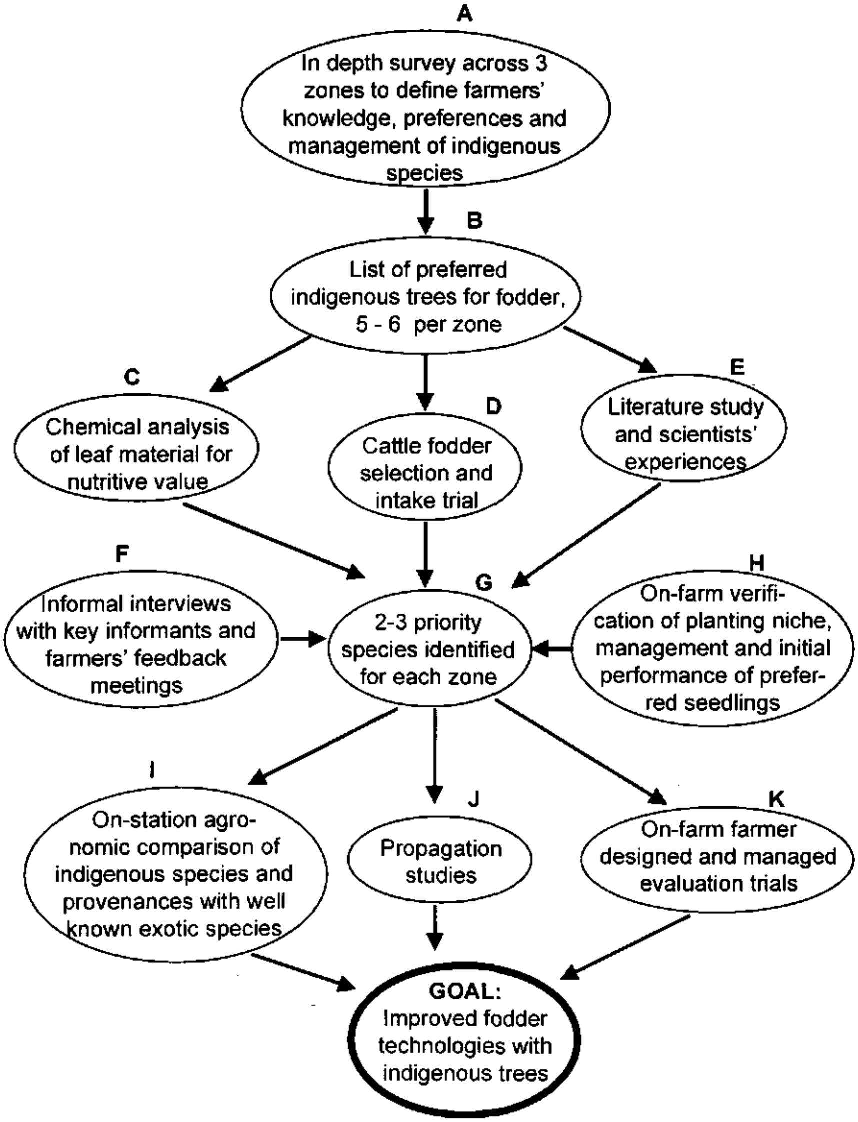

Figure 1. Framework of activities in the evaluation of indigenous trees for fodder production.

tree fodder that is actually eaten by the animals. An experiment is being carried out in Embu to identify which parts of the trees are consumed by cattle, to determine the nutritive value of the ingested tree fodder and to compare the dry matter intake for each tree when it is supplemented to a basal diet of napier grass (Fig. 1D). Some popular exotic trees in the area are also included in the experiment. The species examined at the moment are *Calliandra calothyrsus, Morus alba, Manihot glaziovii, Trema orientalis* and *Leucaena diversifolia,* all of which have promising feeding values (Table 1).

The examined trees were planted in blocks for fodder bulking and coppiced at a height of 50 cm every three months. *M. glaziovii* and *M. alba* showed the fastest regrowth followed by *C. calothyrsus* and *T. orientalis*. *L. diversifolia* was heavily infested by psyllids and showed a poor regrowth. Although the origin of the particular strain used was not known its poor performance in terms of psyllid resistance showed similarities with *L. diversifolia* No.8 of the multi-purpose tree evaluation trial of Otsyina *et al.* (1994). Preliminary results from a cattle feeding trial show that *T. orientalis* and *M. alba* are consumed most readily by the animals and big parts of the twigs and bark are eaten in addition to the leaves.

A drawback for the utilization of *Manihot spp.* as a fodder is the HCN content. Although the HCN content in *M. glaziovii* has not been determined, in *M. esculenta* HCN levels (mg/kg fresh material) range from 568 to 620 in young leaves and 400 to 530 in mature leaves (Gondwe, 1974). Nevertheless, white clover containing cyanogenic glycosides equivalent to 1290 mg of cyanide per kg dry matter produced no deleterious effects in dairy cows, but plasma thiocyanate increased, producing evidence for a metabolic effect (Buttler *et al.*, 1957). On the other hand, high levels of cyanogens (180 ppm HCN in *Cynodon plectostachyus*) and low levels of iodine (±0.05 ppm) have been reported to cause thyroid dysfunction in sheep (Herrington *et al.*, 1971). In the feeding experiment in Embu the leaves and petioles are sundried. This practice is believed to reduce the level of HCN in the leaves of a species of the same genus, *M. esculenta* (Devendra, 1977).

Research recommendations

Future work for fodder production should concentrate on intensive management systems (Otsyina *et al.*, 1995). Even where animals are kept under extensive, communal grazing, the opportunity exists for intensive fodder production in specific niches of the land under control of the farm family. Research is needed to arrive at recommended inclusion levels of tree fodder in the diets of dairy animals using tree species that have proved compatible in the farming system. For the extensive cattle, goat and sheep husbandry system optimal management practices and impact of fodder trees within the farming system have to be assessed first, followed by studies on the impact of these practices.

Anti-nutritive factors are common in many fodder tree species. There is a need to study the relationship between polyphenolics and the drop of digestibility during drying of calliandra. Levels of cyanogenic glycosides need to be assessed for *M. glaziovii* both in fresh and sundried leaves and petioles to determine maximum inclusion levels in ruminant diets.

Acknowledgements

The authors which to thank Peter Cooper, Kwesi Atta-Krah and Mick O'Neill for their contributions to the 'sunshine meeting' during which the basis of the framework of activities was developed.

Chapter 3

Farmers' preferences and use of indigenous fodder trees and shrubs in Kenya

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Chapter 3

Farmers' preferences and use of indigenous fodder trees and shrubs in Kenya

Abstract

Fodder researchers are increasingly showing interest in indigenous fodder trees and shrubs but have gathered little systematic information from farmers about the ones they use. This study's objective was to find out farmers' ranking of indigenous fodder tree species of their choice, their criteria for assessing fodder trees, how the most preferred species rated on each criterion, and species' uses, management, niches and ways of establishment. The study consisted of informal and formal surveys in three agroecological zones with mean annual rainfall of 775, 950 and 1300 mm, respectively. Farmers used an indigenous board game, *bao*, to rank species. Improved, stall-fed dairy animals were the dominant livestock type in the subhumid zone whereas communally-grazed, local-breed cattle and goats were common in the dry zone. A total of 160 different IFTS were used by farmers in the three zones. The three most preferred species in the subhumid zone were *Triumfetta tomentosa, Commiphora zimmermanii,* and *Bridelia micrantha;* in the medium zone, *Aspilia mossambicensis, Lantana camara, and Grewia tembensis,* and in the low zone, *Melia volkensii, Crotalaria goodiiformis, and A. mossambicensis.* In the subhumid zone, the most frequently mentioned criteria were the ability of the fodder to satisfy hunger and contributions to animal health. Palatability and drought resistance of the tree were the most important criteria in the medium zone and, effect on the condition of the animal and palatability were most important in the dry zone. Farmers' ratings on palatability for cattle and goats and milk production for goats differed significantly among tree and shrub species ($p<0.05$). The study has helped identify species for further research and development activities, with the aim of improving their productivity and disseminating them among farmers.

Key words: browse, farmers' preferences, indigenous fodder trees and shrubs, indigenous knowledge, participatory research

Introduction

The conventional way of screening fodder tree species in the tropics involves on-station agronomic trials comparing biomass production of selected species under different management regimes. These trials usually emphasise exotic species, such as *Leucaena leucocephala* and *Gliricidia sepium*, because planting material and information are readily available from international sources. In recent years, some researchers have examined indigenous tree species and involved farmers in their search for promising fodder trees (Bayer, 1990; Rusten and Gold, 1991; Antilla *et al.*, 1993; Kanzilla, 1994; Morrison *et al.*, 1996). Indigenous fodder trees and shrubs[a] (IFTS) have the advantage over exotic ones in that they are well adapted to the local environment, farmers know them, and locally available planting material is abundant. Involving farmers in the process is important because as potential users of new technologies, their knowledge and preferences are critical (Haugerud and Collinson, 1990). Whereas quantitative data is used to assess the biophysical performance of fodder species, data on farmers' assessments are generally qualitative and anecdotal. Among the research involving farmers mentioned above, only Bayer (1990) sought to assess farmers' preferences among species but the species were ones he selected, not ones chosen by farmers. No studies were found that assessed the criteria that farmers used in their preferences, or how farmers rated different species on the criteria important to them.

In central Kenya fodder availability and quality are important constraints to cattle and goat production and increasing smallholder income (Minae *et al.*, 1988; Snijders, 1991; Sutherland *et al.*, 1995). The overall objective of this study was to quantitatively assess indigenous fodder trees and shrubs in central Kenya, through studying farmers' knowledge, practices and preferences. Specific objectives were to

- get farmers' ranking of tree species of their choice in order of importance for feeding their livestock,
- identify the criteria that farmers used for assessing fodder trees and how the most

[a] Indigenous species in this paper include naturalized exotic species, that is, species introduced one hundred years or more ago, such as *Latana camara* and *Tithonia diversifolia*.

preferred species rated on each criterion, and

- describe farmers' preferred species uses, management, niches, and establishment.

It was hypothesised that knowledge of individual farmers would be consistent enough to form a basis for selecting the most useful fodder species. The study is part of a holistic approach to screen IFTS in central Kenya with inputs from farmers, animals, on-farm and on-station trials, propagation studies and literature (Roothaert and Paterson, 1997).

Research on fodder trees in central Kenya

Many tropical trees and shrubs provide high nutritive value with crude protein content ranging from 10 to 30% of dry matter. The advantage of a tree crop over a herbaceous one is that it is deep rooted and can therefore produce green fodder during the dry season. Suitable trees or shrubs for fodder production have several characteristics: high nutritive value, palatability, and biomass production, persistence after frequent pruning, resistance to drought, pests and diseases, and compatibility with other crops (Ivory, 1990). In addition, farmers' preferences and cultural practices also need to be considered when species are screened for their appropriateness.

Exotic fodder trees have been introduced in central Kenya but most have not been adopted by farmers. *Leucaena leucocephala* has become unproductive because of the infestation with the psyllid *Heteropsylla cubana*, which first appeared in East Africa in 1992 (Reynolds and Bimbuzi, 1993). *Sesbania sesban* cannot withstand frequent pruning (ICRAF, 1992) and *Gliricidia sepium* has a low acceptability for livestock (Nochebuena and Donovan, 1986). Only *Calliandra calothyrsus* appears to be spreading, but its use is restricted to farmers in the subhumid zone (Franzel *et al.*, 1996a).

Surveys conducted in the central Kenyan highlands (Thijssen *et al.*, 1993a; Murithi *et al.*, 1993) and lower areas (Shepherd, 1989; T. Blomley and N. Mbogo, 1992, pers. comm.) showed that farmers feed many different indigenous trees to their animals. But there is no detailed information available on the species farmers use and prefer and the reasons underlying their preferences. Such information is especially important concerning cattle as they are much more selective in feeding on browse than are goats.

Methods

The three agroecological zones considered in this study, subhumid, medium, and dry, are located along a transect extending from about 1600 m down to 750 m along the slopes of Mount Kenya, in central Kenya (Table 1). As the altitude decreases, rainfall and population density decline and soils become less fertile.

Table 1. Characteristics of the agroecological zones of the study area, central Kenya.

Zone	Subhumid	Medium	Dry
District	Embu	Mbeere	Mbeere
Locations	Gaturi South	Mbeti North Mbeti South	Kianjiru
Land classification[a]	Upper Midlands 2	Lower Midlands 3	Lower Midlands 5
Mean annual rainfall (mm)	1200 – 1400	900 – 1000	750 - 800
Altitude (masl)	1400 - 1600	1070 - 1280	830 - 1130
Geographical co-ordinates	37 30'E 0 27'S	37 30'E 0 35'S	37 35'E 0 41'S
Population density (people per km^2)	450	170 - 220	70 – 200
Soils	Humic Nitisols derived from basic vulcanic rocks with deep, well weathered parent material of moderate to high fertility.	Nito-rhodic Ferralsols, low fertility, well-drained, very deep, dark red, very friable clay.	Rhodic and orthic Ferralsols, low fertility, well drained, moderately deep to deep, dark red to yellowish red, friable, sandy clay loam to clay.

[a]Classifications according to the Ministry of Agriculture, Livestock Development, and Marketing, Kenya.

Locations were purposively selected from the centre of each zone. Sample frames of 250-300 households were compiled, either by an assistant chief (subhumid zone) or by assembling lists of primary school pupils (middle and lower zones). Thirty households were randomly selected in each zone and the owner of the farm, his wife, other relatives and employees were interviewed together. Farmers without cows (less than 20 % of farmers in each of the three zones) were excluded from the survey.

Interviews were conducted by a team using a pre-tested and pre-coded questionnaire. Interviews began with a tour of the farm to view the principal fodder trees that the farmer grew and used. Farmers were asked to rank their six most important fodder tree species in order of importance. Each species was then scored on selected criteria, which were determined by a group of seven farmers in each zone. In addition, two criteria, growth after establishment and regrowth after cutting, were determined by the researchers in order to obtain information about biomass production potential. Farmers rated the species using the *bao* game, a traditional African board game involving the moving of seeds among pockets on a board (Franzel et al., 1995; 1996b). Farmers were asked to put one to three seeds in the pocket next to a branch of each species; three for 'good', two for 'medium' and one for 'poor'. The analysis of the medium and dry zones was combined, as most of the preferred species in the two zones were the same.

Livestock density was determined by dividing the number of livestock units (LU) by the number of hectares available for fodder production and grazing including fallow land. A head of cattle was valued as 1.0 LU (200 kg liveweight) and a head of small ruminants as 0.1 LU (20 kg liveweight).

Results and discussion

Farm and household characteristics

There are important changes in the farming systems as the altitude decreases from the subhumid zone to the dry zone (Table 2). Average cultivated area declines,

Table 2. Selected land use practices in the study area, central Kenya.

Zone	Subhumid	Medium	Dry
Average farm size (ha)	2.0 (1.3)	4.8 (5.0)	2.8 (2.0)
	2.4[a] (1.1)		
Average cultivated area (ha)	1.9 (1.1)	1.5 (0.9)	1.2 (0.7)
Average fallow area (ha)	0.04 (0.16)	0.35 (0.9)	0.68 (0.9)
	0.33[a] (0.9)		
Average pasture area (ha)	0.10 (0.2)	2.8 (4.4)	0.85 (1.2)
% using communal grazing land	0	53	83
% using government land	0	0	30
% using other land (rented, relatives', other AEZ)	23	0	3

Note: Figures in parentheses are standard deviations
[a]including owned land in medium and dry zones

from 1.9 ha to 1.2 ha, and average fallowed area and communal grazing land increases. The cropping system changes from predominantly cash crops, such as tea, coffee, and macadamia to primarily food crops, including maize, beans, cowpeas, millet, and sorghum. Privately-owned farms predominate in all three zones; farm size is greatest in the medium zone because this area was settled more recently than the other two. The medium zone also has the greatest number of cattle per farm. About equal numbers of males and females were interviewed in the subhumid and medium zone; males, females and both sexes together were 40, 35 and 25 % of the interviews, respectively. This reflects the involvement of both genders in farming activities. In the dry zone, however, males accounted for only 10 % of the interviews, females for 67 %, and both sexes 23%, reflecting the fact that many males work away from the farm.

Improved, zero-grazed dairy animals are the dominant livestock type in the subhumid zone whereas communally-grazed, local-breed cattle and goats are common in the dry zone (Table 3). Napier grass plots are the main feed source for

Table 3. Livestock ownership in the study area, central Kenya.

Zone	Subhumid		Medium		Dry	
Type	% owning	Mean number per household	% owning	Mean number per household	% owning	Mean number per household
Exotic cattle	60	2.8 (1.9)	13	1.5 (1.0)	0	0
Cross bred cattle	50	2.5 (1.1)	13	2.5 (1.0)	0	0
Local cattle	0	0	87	5.5 (3.4)	100	3.9 (2.9)
Total cattle		2.9		5.3		3.9
Exotic goats	7	3 (1.4)	0	0	0	0
Local goats	50	2.5 (1.8)	47	3.2 (1.9)	67	4.3 (3.3)
Sheep	7	1 (0)	13	3.3 (1.5)	23	3.0 (1.0)
Total small ruminants		1.5		1.9		3.6

Note: Figures in parentheses are standard deviations

livestock in the subhumid zone whereas farmers in the medium and dry zone rely on pasture within their farm or communal grazing land. Livestock densities for the subhumid, medium, and dry zones are 38.1, 1.7 and 2.7 LU/ha respectively. The low density in the medium zone is mainly caused by the larger sizes of the farms in this zone.

In the subhumid zone, feeding of IFTS is done by the farmer and his wife and frequently by hired labourers; in the other zones it is done by children, mostly male. Fodder shortages are most evident in the subhumid zone; however, the problem is increasing in the medium and dry areas as the population increases, farm size decreases, and communal grazing land is adjudicated (Sutherland *et al.*, 1995).

Farmers' most preferred IFTS

A total of 160 different IFTS are used by farmers in the three zones to provide tree fodder. Over 90% of the farmers in each of the three zones use IFTS for feeding their livestock. The percentage using exotics ranges from 37% in the medium zone to 68% in the high zone Farmers stated that IFTS accounted for less than 50% of the total feed consumed by cattle in all three zones. For goats, IFTS accounted for more than 50% of the total quantity of feed consumed in the medium and dry zone but less than 50% in the subhumid zone.

The three most preferred species in the subhumid zone were *Triumfetta tomentosa, Commiphora zimmermanii,* and *Bridelia micrantha;* in the medium zone: *Aspilia mossambicensis, Lantana camara, and Grewia tembensis,* and in the low zone, *Melia volkensii, Crotalaria goodiiformis, and A. mossambicensis* (Table 4). Only *A. mossambicensis* appears in the top three of more than one zone. *L. camara* appears in the top 10 of all three zones, and *Ficus spp.* (including *F. glumosa, F. natalensis* and *F. thoningii), G. Tembensis, Indigofera lupatana,* and *C. goodiiformis* appear in the top 10 of two zones.

The sample size was too small to precisely determine the association between species preferences and farm and household characteristics; nevertheless, the analysis suggested some associations. For example, *L. camara* appeared to be more preferred by women than men in the subhumid and medium areas; the percentages of the male, female and both-sexes respondents, who mentioned *L. camara* in the top 3, were 8%, 45% and 29% respectively. *A. mossambicensis* was also more preferred by women than by men in these zones; numbers of male, female and both sexes respondents, who mentioned the species in the top 3, were 13%, 30% and 36% respectively. *C. africana* was only mentioned by male respondents in the top 3 in these zones. In the dry zone, *C. goodiiformis* was more preferred by men than by women; the numbers of male, female and both-sexes respondents, who mentioned the species in the top 3, were 100%, 37%, and 23% respectively. *M. volkensii* was more preferred by women; the numbers of male, female and both-sexes respondents, who mentioned the species in the top 3, were 0, 68 and 29 % respectively. Gender

Table 4. Farmers' most preferred indigenous fodder tree and shrub species

Species in humid zone	No. of respondents[a]	Score[b]	Species in medium zone	No. of respondents	Score	Species in dry zone	No. of respondents	Score
Masiso, Mugiso (*Triumfetta tomentosa*)	18	79	Muuti (*Aspilia mossambicensis*)	20	80	Mukao (*Melia volkensii*)	20	96
Mururi (*Commiphora zimmermanii*)	17	69	Mucimoro, Mucirigu (*Lantana camara*)	19	74	Mucugucugu (*Crotalaria goodiiformis*)	24	77
Mukwego (*Bridelia micrantha*)	12	47	Mutuva, Muruva (*Grewia tembensis*)	12	48	Muuti (*Aspilia mossambicensis*)	18	67
Mucatha (*Vernonia lasiopus*)	12	46	Muthunthi (*Maytenus putterlickioides*)	15	47	Mutuva, Muruva (*Grewia tembensis*)	11	49
Kirurite (*Tithonia diversifolia*)	9	43	Mugiti (*Indigofera lupatana*)	9	36	Mukuru (*Acalypha fruticosa*)	12	40
Mucimoro, Mucirigu (*Lantana camara*)	11	37	Mucugucugu (*Crotalaria goodiiformis*)	6	30	Murangare (*Acacia ataxacantha*)	12	38
Murinda ngurue (*Triumfetta rhomboidea*)	7	27	Kingoyo/ Rungoyo (*Indigofera sp.*)	7	24	Mugiti (*Indigofera lupatana*)	7	36
Moringa (*Cordia africana*)	5	21	Mugumo (*Ficus spp.*[c])	7	20	Muvugua (*Balanites pedicellaris*)	6	22
Mugumo (*Ficus spp.*[c])	5	19	Mugaa (*Acacia tortilis*)	5	19	Muthigira (*Acacia mellifera*)	8	22
Muvangua (*Milletia dura*)	3	15	Mutheru (*Rhus natalensis*)	6	18	Mucimoro, Mucirigu (*Lantana camara*)	9	22

Note: The local name of a species is followed by the latin name
[a]Number of respondents who included the species in the top 6. Sample size was 30 households in each zone.
[b]If a farmer ranked the species first, it received a score of 6, if second, a value of 5, if third, a value of 4 etc. Scores shown are sums of individual farmers' scores
[c]Includes *F. glumosa*, *F. natalensis* and *F. thoningii*

preferences for particular species might be related to other uses rather than animal fodder. For instance, *L. camara* is used for perfume and its fruits are eaten; *A. mossambicensis* is also used for medicine and for cleaning pots and gourds; *C. africana* is used for poles, timber and making beehives (Riley and Brokensha, 1988; Table 5). In the case of *C. goodiiformis,* tradition dictates that the shrub is only collected by malesThese traditional restrictions might fade with time; some females have already planted the shrub on their farms and were feeding it to their livestock. The reasons why females prefer *M. volkensii* is unclear.

Table 5. Feeding management and other uses of main indigenous fodder trees and shrubs

Zone	Subhumid					Medium					Dry				
	Tri.t..	Com.z..	Bri.m.	Ver.l.	Tit..d.	Asp.m.	Lan.c.	Gre.t.	May.p.	Ind.l.	Mel.v.	Cro.g.	Asp.m.	Gre.t.	Aca.f.
Animals fed	(percentage of respondents)														
Improved cattle	96	80	100	85	100	0	0	0	0	0	0	0	0	0	0
Local cattle	0	0	0	0	0	61	52	50	25	33	73	25	50	69	27
Goats	55	60	65	69	54	100	100	100	95	100	100	100	100	100	100
Season of feeding															
Dry seasons	18	25	24	21	23	9	32	6	0	0	50	0	8	6	9
Throughout the year	77	70	77	71	62	74	68	88	95	85	50	88	88	94	91
Parts fed															
Leaves only	0	11	6	0	0	35	43	50	91	0	42	35	12	31	18
Twigs and leaves	100	90	94	100	100	65	61	50	5	92	62	65	88	69	73
Fruits or pods	0	0	6	0	0	9	50	6	10	8	74	47	24	6	9
Other uses															
Timber, poles, construction	0	5	77	11	0	23	46	63	0	38	100	30	8	47	78
Fuel wood	61	32	77	78	50	31	58	19	50	25	54	70	54	67	67
Live fence	0	26	24	11	83	8	50	6	6	0	4	0	0	0	0
Live stake for yams	0	95	6	0	0	0	0	0	0	0	0	0	0	0	0
Medicine (human, vet., antidote)	0	0	0	33	33	69	4	6	67	63	8	20	39	0	11
Fruits	0	0	6	0	0	0	15	31	0	0	0	0	0	60	0
Fibres, ropes	72	0	0	0	0	0	0	0	0	0	0	0	8	0	0

In the subhumid zone, farm size did not appear to be associated with species preference In the drier zones, *M. volkensii, A. ataxacantha A. fruticosa* and *A. mossambicensis* seemed to be preferred by farmers with small farms (less than 2 ha) and *G. tembensis* by farmers with larger farms (bigger than 2 ha). *T. diversifolia* seemed to be preferred in this zone, however, by farmers without any fallow or grazing land (55 % of the farmers in the subhumid zone had no fallow or grazing land). *A. mossambicensis* was also more preferred by farmers with small areas of fallow and grazing land (less than 0.8 ha in the dry zone and less than 1.6 ha in the medium zone), whereas *G. tembensis* in the dry zone was more preferred by farmers with large areas of fallow and grazing land.

The percentages of farmers that would plant IFTS if they were given seedlings were 63%, 76%, and 90%, for the subhumid, medium, and dry zones, respectively. The lower interest in planting in the subhumid zone is probably related to the smaller farm size and lack of land available for planting trees. The list of species for planting is similar to the list of preferred species, with a few exceptions. For example, *Trema orientalis* is the fourth most desired species for planting but was not a preferred tree; probably because it is difficult to propagate and is thus scarce.

Farmers' evaluations of IFTS

Farmers' criteria for evaluating IFTS were either animal-related (for example, palatability or effects on animal nutrition), or tree-related (such as drought resistance or effect on soil fertility) (Table 6). In the subhumid zone, the most frequently mentioned criterion was the ability of the fodder to satisfy the hunger of the animal, which includes both the quantity available and the satisfaction of the animal after eating it. Contributions to animal health and palatability were also important. Palatability, drought resistance of the tree, and effect on the condition of the animal were the most important criteria in the medium zone. In the dry zone, the most important criteria were effect on the condition of the animal, palatability, and effect on goats' milk production.

Farmers' assessments of highest ranking IFTS by farmers' and researchers' criteria are shown in Table 7 and 8. In the subhumid zone, the most preferred species,

Table 6. Criteria that farmers use to evaluate indigenous fodder trees and shrubs and percentages of respondents in each zone who mentioned them

Criteria/ Zone	Subumid	Medium	Dry
	(percentage of respondents)		
Animal-related criteria			
satisfies hunger of animals	48	14	13
improves health of animals	38	21	17
palatability	31	55	37
improves milk production: cows	21	3	7
improves condition of animal; fattens	7	35	50
improves growth of animals and meat production	7	0	3
improves milk production: goats	3	7	37
Tree-related criteria			
drought resistance	21	38	13
compatibility with other crops	21	0	3
improves soil fertility	17	0	7
no dropping of leaves	0	3	20

T. tomentosa, did not rank first or second on any of the six criteria. But the species was considered important in satisfying the hunger of the animal, a criterion omitted from the survey because it was considered to be too vague and ambiguous to score. *C. zimmermanii*, the second most preferred species, rated highest on growth after establishment, compatibility with crops, and drought resistance. *T. diversifolia* rated highest on regrowth and *L. camara*, on palatability for cattle and for improving health.

In the medium and dry zones (Table 8), *L. camara*, the highest rated species, and *A. ataxacantha* rated highest on growth after establishment and regrowth after pruning. *C. goodiiformis* rated highest on palatability for goats and cattle, improving the condition of the animal, milk production for goats, and drought resistance. *A. mossambicensis* did not score highest on any single criterion but had high ratings on growth and was preferred because of its medicinal properties.

One would expect that the ratings for criteria defined by the farmers would have high variation among species. Differences among species were significant for

Table 7. Farmers' scoring of improved fodder tree species on selected criteria using the *bao* game, subhumid zone.

	Growth after establish-ment	Regrowth	Palatability for cattle	Compatibility with crops	Health	Drought resistance
	(mean scores[a] and standard deviations in parentheses)					
Triumfetta tomentosa	2.2 (0.93)	2.3 (0.86)	2.1 (0.90)	1.9 (1.07)	2.4 (0.81)	2.3 (0.75)
Commiphora zimmmerm.	2.9 (0.34)	2.9 (0.33)	2.6 (0.53)	3.0 (0.00)	2.7 (0.65)	2.8 (0.45)
Bridelia micrantha	1.6 (0.73)	2.1 (0.90)	2.1 (0.69)	1.8 (0.98)	2.4 (0.73)	2.1 (0.99)
Vernonia lasiopus	2.4 (0.79)	2.5 (0.69)	2.1 (0.90)	2.2 (1.10)	2.5 (0.76)	2.3 (0.76)
Tithonia diversifolia	2.9 (0.33)	3.0 (0.00)	1.6 (0.98)	2.2 (1.00)	2.8 (0.50)	2.5 (0.93)
Lantana camara	2.7 (0.47)	2.8 (0.40)	2.7 (0.50)	1.6 (1.00)	3.0 (0.00)	2.1 (0.93)
Significance level	0.004	0.038	0.051	0.11	0.67	0.33

Notes: The number of farmers scoring each species on each criteria varied from 4 to 17. 1 = poor, (s.d.).
[a]A rating of 3 indicates good, 2 indicates medium, and 1 indicates poor.

palatability for cattle and goats and milk production for goats. Differences among species were not significant for drought resistance, compatibility with crops, health and fattening of animals. Ratings on these criteria may not have differed significantly because they might be more difficult to assess than palatability and milk production. For example, good health and fattening of animals are a result of many factors and cannot be attributed to only one ingredient of a diet. Variation in assessments of growth after establishment and regrowth were significant. Even though these criteria were not defined by farmers, they found them relatively easy to assess and were consistent in their assessments.

Feeding, nutritive quality and other uses

In the subhumid zone, over 80% of the farmers using the top three IFTS feed them to their improved cattle; over half also feed them to goats (Table 5). In the other two

Table 8. Farmers' scoring of improved fodder tree species on selected criteria using the *bao* game, medium and dry zone

	Growth after establishment	Regrowth	Palatability for goats	Palatability for cattle	Fattening of animal	Milk prod. of goats[a]	Drought resistance
	(mean scores[b] and standard deviations in parentheses)						
Lantana camara	2.8 (0.46)	2.8 (0.48)	2.4 (0.82)	2.1 (0.97)	2.5 (0.78)	-	1.7 (0.83)
Aspilia mossamb.	2.6 (0.69)	2.6 (0.70)	2.6 (0.70)	2.3 (0.95)	2.5 (0.71)	2.5 (0.52)	1.6 (0.75)
Crotelaria goodiiformis	2.4 (0.78)	2.3 (0.75)	2.9 (0.45)	2.4 (0.84)	2.9 (0.25)	3.0 (0.00)	2.2 (0.76)
Indigofera lupatana	2.4 (0.82)	2.0 (0.76)	2.7 (0.59)	2.3 (0.70)	2.8 (0.40)	2.4 (0.55)	2.1 (0.94)
Melia volkensii	2.1 (0.91)	2.6 (0.76)	2.7 (0.57)	2.3 (0.85)	2.4 (0.72)	2.1 (0.88)	2.1 (0.95)
Acalypha frutocosa	2.4 (0.67)	2.0 (0.89)	2.1 (0.60)	1.5 (0.85)	2.1 (0.83)	2.0 (1.00)	2.1 (0.99)
Acacia ataxacantha	2.8 (0.69)	2.8 (0.44)	2.3 (0.82)	1.6 (0.70)	1.8 (0.83)	2.4 (0.55)	1.8 (0.97)
Grewia tembensis	2.1 (0.85)	2.3 (0.73)	2.7 (0.46)	2.1 (0.97)	2.6 (0.76)	2.9 (0.38)	2.1 (0.92)
Maytenus putterlick.	2.0 (0.84)	2.5 (0.70)	2.2 (0.81)	1.4 (0.81)	2.2 (0.79)	-	1.9 (0.88)
Significance level	0.003	0.031	0.009	<0.001	0.075	0.002	0.48

Notes: The number of farmers scoring each species on each criteria varied from 5 to 36.
[a]For the dry zone only.
[b]A rating of 3 = good, 2 = medium, and 1 = poor
- indicates that there were fewer than three cases

zones, the top three species are fed to goats by all farmers using them; 52% to 61% also feed them to their local cattle. In all zones most of the farmers use the selected species throughout the year. In the subhumid zone, some reserve the IFTS for dry season use. The most common parts of the selected species that are eaten are the twigs plus leaves; for some species some farmers prefer to feed only the leaves.

Little information is available on the nutritive quality of farmers' preferred IFTS. Leaves of *L. camara, C. zimmermanii, T. orientalis, B. micrantha* and *T. tomentosa,* in the subhumid zone were analysed by Thijssen *et al.* (1993a). Protein contents (percentage of dry matter basis) were 21.4, 14.1, 27.1, 17.3 and 17.7 respectively and the *in vitro* organic matter digestibility was 71.8, 37.6, 78.8, 28.1 and 52.4%

respectively. These few data suggest high nutritive value for fodder of *L. camara* and *T. orientalis,* even though soft edible twig material was excluded from the samples. Of all species mentioned in Table 4, only *G. tembensis* and *M. volkensii* appeared in a list of chemical analyses of more than a hundred species that are browsed by wildlife in East Africa, compiled by Lamprey *et al.* (1980). *G. tembensis* had a CP content of 8.7 % in a sample of young branches and leaves; *M. volkensii* had 19.4 % CP in a sample of leaves.

Farmers' preference for *L. camara* is controversial because it is claimed to be toxic to livestock in many parts of the world (Alfonso *et al.*, 1982; Fourie *et al.*, 1987; McLennan and Amos, 1989). Farmers in our study area sometimes associated digestive problems with the feeding of this fodder but more often appreciated it for its high palatability to both cattle and goats. There might be several reasons why toxicity seems less of a problem in central Kenya than in other parts of the world. Micro-organisms present in the rumen of the animals may be able to degrade the toxic triterpene acids lantadene A and lantadene B, a similar process that was observed with mimosine in *L. leucocephala* and a yet unidentified toxin in *Acacia angustissima* (Jones and Lowry, 1994, Odenyo *et al.*, 1997). Another theory is that the livestock are able to acquire a physical immunity to the toxin, as Steward *et al.* (1988) demonstrated using a vaccine containing the toxic triterpene acids lantadene A and B in sheep and cattle. Zebu cattle might be more resistant to the toxin than exotic cattle. The fourth possibility is that the naturalised variety of lantana has a lower concentration of the toxin in its foliage, evidence of which was shown by Munyua *et al.* (1990). It could also be that livestock in Mbeere never eat enough of the shrub to reach the toxic threshold.

Nearly all species were reported to have other uses (Table 5). Among the three most preferred species in each zone, all are used for fuelwood, 89% for timber or poles and 66% for medicine. Other uses of IFTS include fruit, fencing, stakes, and ropes.

Table 9. Niches, establishment, propagation methods, and management of indigenous fodder trees and shrubs.

Zone	Subhumid					Medium					Dry				
	Tri.t.	Com.z.	Bri.m.	Ver.l.	Tit.d.	Asp.m.	Lan.c.	Gre.t.	May.p.	Ind.l.	Mel.v.	Cro.g.	Asp.m.	Gre.t.	Aca.f.
Niche	(percentage of respondents)														
External farm boundary	9	50	41	21	85	26	68	13	10	23	0	12	40	31	55
Within the home compound	0	5	12	7	0	0	0	0	0	0	0	0	0	0	0
Scattered within the food crops	14	85	59	7	0	0	11	13	5	8	92	35	12	31	18
Scattered within grazing land	9	0	6	7	0	91	89	94	100	100	19	59	88	69	100
Off farm	32	0	6	14	0	0	4	6	0	0	0	29	4	13	0
Establishment															
Natural	94	0	88	100	8	100	93	100	100	100	69	100	100	100	100
Cuttings	0	100	0	0	93	0	4	0	0	0	0	0	0	0	0
Other known propagation methods															
Seeds	40	75	46	20	50	46	48	80	56	88	79	94	95	100	78
Cuttings	40	0	8	60	25	23	93	0	11	0	4	6	5	0	22
Roots	0	0	8	0	0	0	0	10	44	0	8	0	0	0	0
Cutting management															
Coppice at knee height	46	0	0	36	23	4	0	0	0	0	0	6	8	0	0
Coppice above 1 m	14	45	18	21	54	0	0	0	0	0	50	12	0	13	9
Pollard branches and leave stem	0	65	82	0	0	0	0	6	0	8	31	0	0	13	0
Cut soft twigs only	0	10	0	7	0	22	32	19	5	15	15	6	24	32	18
Browsing	0	0	0	0	0	91	100	88	100	100	8	100	80	75	91

Niches, establishment, and management

Niches varied considerably among zones and among species (Table 9). In the medium and dry zones, IFTS tended to be found scattered in grazing land or crop land; in the subhumid and dry zones, IFTS were mainly grown in crop land. External boundaries were important for IFTS in all three zones, especially for *L. camara, T. diversifolia, C. zimmermanii.* and *A. fruticosa.* All but the latter are grown in hedges and serve as live fences. A few species were found in home compounds (*Ficus spp)* or off the farm (*T. tomentosa* (UM2) and *C. goodiiformis).* None were found in fodder banks. For future plantings, the external boundary was the most popular niche in all three zones (64% of respondents who were interested in planting). Twenty-three percent of farmers in the medium and dry zones proposed planting IFTS in fodder banks.

Most IFTS are established naturally, once found by farmers they are protected and allowed to grow to maturity (Table 9). In the subhumid zone, *C. zimmermanii, T. diversifolia* and *Ficus spp.* are established primarily through the planting of cuttings. Farmers are also aware of other propagation methods. For most species farmers are aware that they can be planted using seeds and for about half of them, by cuttings.

Pruning is common only in the subhumid zones, where farmers coppice and pollard for the purpose of harvesting animal feed (Table 9). Coppicing height seems to be related to the potential height of the tree. In the medium and dry zone browsing is much more common. Some farmers also cut soft twigs and leaves for feeding their livestock. Treatment of fodder is rare. In the subhumid zone there were a few cases in which the material was wilted, and in the dry zone salt was sometimes sprinkled on it. None of the farmers made hay or silage.

Pests, diseases and other problems

Out of the total of 160 trees and shrubs, 24 species were reported more than once to be affected by pests or diseases. The species that were mentioned five times or more are: *L. camara, B. micrantha, Acacia tortilis, Balanites pedicellaris,* *C. zimmermanii, Lonchocarpus eriocalyx* and *T. tomentosa*. Caterpillars are the most important pest on these trees; they were reported by 56% of all farmers.

Problems of IFTS that were mentioned by more than 10% of the farmers in a zone were toxicity, thorniness and incompatibility with crops. The most common toxic species are *Acacia nilotica, A. tortilis* and *L. camara*; their toxic effects are abortion (the two acacias) and digestive problems (*L. camara*). Incompatibility with crops was reported by about 16% of the farmers in all zones. Thorniness is only a problem in the medium and dry areas where it was mentioned by 15% of the farmers.

Conclusions

This study has provided important information from farmers for setting priorities among IFTS for research and development. Surprisingly little is known about the chemical composition of farmers' preferred species; thus nutritive and antinutritive qualities are being assessed. On-farm agronomic and feeding trials have also begun on the most promising species. More research is also needed on the alleged toxicity of *L. camara,* on the propagation of the much-desired *M. volkensii,* and as to whether a change in cutting regime can reduce the incidence of pests on *T. orientalis and C. zimmermanii.*

Acknowledgement

The authors wish to thank the Cente Director of KARI Regional Research Centre, Embu, their colleagues in the 'KARI-KEFRI-ICRAF National Agroforestry Research Project' in Embu, H.K. Arimi, E.N. Kamau, A. Kithinji, K.J. Muriuki and the farmers of Nemburi Sub-location, Mbeti North, Mbeti South and Kianjiru Locations for their valuable co-operation. Funds for the project were provided by Natural Resources Institute, UK, Swedish International Co-operation Agency and Netherlands Development Assistance.

Chapter 4

On-farm evaluation of farmer preferred indigenous fodder trees and shrubs

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Agricultural Systems (Submitted)

Chapter 4

On-farm evaluation of farmer preferred indigenous fodder trees and shrubs

Abstract

The little research that has been carried out with fodder trees on-farm has mainly involved exotic species, selected by researchers rather than farmers. In this study, farmers who had participated in an earlier survey chose seedlings of indigenous, naturalised and some exotic fodder trees and shrubs, from a nursery during feedback meetings. They planted them on-farm, where the planting niches, management, biomass production, and animal response were evaluated, and compared with the results of an earlier survey. Farmers came from three agroecological zones with mean annual rainfall of 775, 950 and 1300 mm. Data were collected two months, one year and 16 months after planting. The percentage of female farmers during the feedback meeting, when species were chosen, were 41, 65 and 41 %, for the subhumid, medium and semi-arid zones, respectively. The choice of species and planting niches generally reflected the information from the survey but the feedback meetings proved important to understand discrepancies between the survey results and farmers' practices. Survival of seedlings was affected by an extremely dry spell, but some species in the semi-arid zone still showed remarkable growth. Manure was only applied to *S. ellipticum* in the subhumid zone and to *Crotalaria goodiiformis* in the semi-arid zone, stressing farmers' appreciation for these species. In the subhumid zone there were significant differences ($P < 0.001$) of the percentage of trees which had been pruned to feed cattle and goats. Farmers showed a strong interest to intensify the use of indigenous fodder trees and shrubs. The study method was useful to test the willingness of farmers to plant trees.

Key words: on-farm research, indigenous fodder trees, survivability, intensive use, participatory evaluation

Introduction

Small scale dairy production in the tropics is often constrained by animal nutrition. Basal diets consist of tropical grasses which are inferior in nutritive value compared to temperate grasses. During dry seasons, not only does the productivity drop and therefore the availability of grasses, their quality also drops. Due to drought and high temperature stress, grass senesces quickly, which results in lignification and drop of crude protein. Basal diets of grass for dairy cattle need to be supplemented with protein rich and low lignin, highly digestible supplements. Fodder trees could provide such high quality feed. Most research on fodder trees so far has been carried out with exotic species such as *Leucaena leucocephala* and *Gliricidia sepium*, and much of this research has been carried out on-station (Shelton *et al.*, 1998; Steward *et al.*, 1996). Sporadically on-farm research on the performance of these species is reported (e.g. Francis and Atta-Krah, 1989; Jabar *et al.*, 1992; O'Neill *et al.*, 1995). On-farm testing of indigenous species has been carried out in Nepal (Karki and Gold, 1994) and in Costa Rica (*Gliricidia sepium*, Borel and Romero, 1991). No research has been conducted on-farm where farmers selected the indigenous species which they wanted to test.

Traditional on-station research does not take into account important farmers' selection criteria and farmers' methods of evaluation. This process reduces the chance of adoption of the technologies so developed. Indigenous species are hardly considered for on-station experiments since they are thought to have low fodder biomass production potential, one of the most important scientists' criteria, and little is known about them in the first place. Exotic species do have some disadvantages, ranging from pest attacks, lack of palatability or digestibility (Roothaert and Paterson, 1997).

Roothaert and Franzel (in press) described the high potential of indigenous fodder trees and shrubs (IFTS) in central Kenya because of the intensification of land-use and the ideal characteristics of many IFTS in the area to be able to provide high quality feed supplements during the dry season. They conducted surveys in which farmers identified their most important IFTS in the region, and how they rated each species according to their own criteria. The study was part of a holistic approach to assess the potential of IFTS for intensive use in central Kenya. The objectives of this paper were to test the willingness of farmers to plant and manage preferred indigenous species on their farms, to compare their preference with the results of the survey and to monitor the initial performance of the seedlings on farm. Additional objectives were, after one to two years of experience of growing the trees, to solicit farmers' views on the growing of these trees on-farm and to assess animal response after feeding the tree fodder.

On-farm experiments with fodder trees in Kenya.

Agroforestry practices are in many ways more encompassing than other agricultural practices. Time wise, trees grow for many seasons, whereas most other crops only occupy land for one season. Trees can affect other crops underground by water and nutrient competition through their extensive root systems, and above ground by shading. Trees also have a much bigger impact on the landscape than annual and small crops (Rocheleau *et al.,* 1989). Trees on-farm can have a main product such as fruit, but are often multipurpose, providing also fuel wood, timber, medicinal products, vegetables or soil improvement. On-farm research is much more likely to obtain a complete picture of these aspects and their relative importance than well defined on-station experiments. Atta-Krah (1996) distinguished two broad groups in on-farm research: experimental and developmental research. Experiments in the first group are aimed to compare technologies under farmers' conditions, whereas experiments in the second group aim to assess the adoptability and dissemination potential of a particular technology. However, there are often unforeseen benefits of on-farm experimentation, outside the immediate experimental objectives. For example, Borel and Romero (1991) described how a farmer allowed an experimental plot for species evaluation to be grazed by cattle, without the knowledge of the planning scientists, which resulted in accurate information about which species were resistant to browsing and which were not. In an on-farm calliandra biomass productivity experiment in central Kenya (O'Neill *et al.*, 1995), 47 % of the farmers in the coffee zones had harvested the trees before technicians could collect any data, which stressed the importance of the problem of fodder shortage. In an other on-farm experiment with calliandra in Kenya, farmers reported that when they fed calliandra to cows it made the milk fatter and tastier (Paterson *et al.*, 1999).

Table 1. Characteristics of the agro-ecological zones of the study area, central Kenya.

Zone	Subhumid	Medium	Semi-arid
District	Embu	Mbeere	Mbeere
Locations	Gaturi South	Mbeti North Mbeti South	Kianjiru
Land classification*	Upper Midlands 2	Lower Midlands 3	Lower Midlands 5
Mean annual rainfall (mm)	1200 – 1400	900 – 1000	750 - 800
Altitude (masl)	1400 – 1600	1070 - 1280	830 - 1130
Geographical co-ordinates	37 30'E 0 27'S	37 30'E 0 35'S	37 35'E 0 41'S
Population density (people per km^2)	450	170 - 220	70 – 200
Soils	Humic Nitisols derived from basic vulcanic rocks with deep, well weathered parent material of moderate to high fertility.	Nito-rhodic Ferralsols, low fertility, well-drained, very deep, dark red, very friable clay.	Rhodic and orthic Ferralsols, low fertility, well drained, moderately deep to deep, dark red to yellowish red, friable, sandy clay loam to clay.

*Classifications according to the Ministry of Agriculture, Livestock Development, and Marketing, Kenya.

Materials and methods

Survey

The three agroecological zones considered in the survey, subhumid, medium, and semi-arid, were located along a transect extending from about 1600 m asl down to 750 m along the slopes of Mount Kenya, in central Kenya (Table 1). As the altitude decreases, rainfall and population density decline and soils become less fertile. The rainfall follows a bimodal pattern with the long rainy season usually from March to June and the short rainy season from October to November.

There are important changes in the farming systems as the altitude decreases from the subhumid zone to the dry zone. Average cultivated area declines, from 1.9 ha to 1.2 ha, and average fallowed area and communal grazing land increases. The cropping system changes from predominantly cash crops, such as tea, coffee, and macadamia to primarily food crops, including maize, beans, cowpeas, millet, and sorghum. Privately-owned farms predominate in all three zones; farm size is greatest in the medium zone because this area was settled more recently than the other two. The medium zone also has the greatest number of cattle per farm. About equal numbers of males and females were interviewed in the subhumid and medium zone; males, females and both sexes simultaneously were 40, 35 and 25 % of the interviews, respectively. This reflects the involvement of both genders in farming activities. In the dry zone, however, males accounted for only 10 % of the interviews, females for 67 %, and both sexes simultaneously 23%, reflecting the fact that many males work away from the farm.

Improved, zero-grazed dairy animals are the dominant livestock types in the subhumid zone whereas communally grazed, local-breed cattle and goats are common in the dry zone . Napier grass plots are the main feed source for livestock in the subhumid zone whereas farmers in the medium and dry zone rely on pasture within their farm or communal grazing land. Livestock densities for the subhumid, medium, and dry zones are 38.1, 1.7 and 2.7 LU/ha, respectively. The low density in the medium zone is mainly caused by the larger sizes of the farms in this zone. In the subhumid zone, feeding of IFTS is done by the farmer and his wife and

Table 2. Indigenous fodder trees and shrubs that farmers want to plant on their farms and percentage of those who want to plant in each AEZ, according to survey results.

Species in subhumid zone	% of respondents (n=18)	Species in medium zone	% of respondents (n=22)	Species in semi-arid zone	% of respondents (n=27)
Masiso, Mugiso (*Triumfetta tomentosa*)	28	Mucimoro, Mucirigu (*Lantana camara*)	46	Mukao (*Melia volkensii*)	67
Mururi (*Commiphora zimmermanii*)	28	Muuti (*Aspilia mossambicensis*)	23	Mucimoro, Mucirigu (*L. camara*)	41
Mugumo (*Ficus spp.*)	22	Mucugucugu (*Crotalaria goodiiformis*)	18	Mutuva, Muruva (*Grewia tembensis*)	33
Muvevu (*Trema orientalis*)	22	Kirurite (*T. diversifolia*)	14	Muuti (*A. mossambicensis*)	26
Kirurite (*Tithonia diversifolia*)	17	Mugiti (*Indigofera spp.*)	14	Mucugucugu (*Crotalaria goodiiformis*)	22
Mucimoro, Mucirigu (*L. camara*)	11	Muthunthi (*Maytenus putterlickioides*)	14	Muvuru (*Vitex doniana*)	22
Mukeo (*Dombeya burgessiae*)	11	Mucatha (*Vernonia lasiopus*)	9	Mugaa (*Acacia tortilis*)	15
Muvangua (*Milletia dura*)	11	Mugumo (*Ficus spp.*)	9	Mugiti (*Indigofera spp.*)	11
Mucatha (*Vernonia lasiopus*)	11	Mukanda (*Ocimum suave*)	9	Mukarakara (*Premna sp.*)	11
		Mukao (*Melia volkensii*)	9	Muthigira (*Acacia mellifera*)	11
		Mutheru (*Rhus natalensis*)	9		
		Mukururu (*Securinega virosa*)	9		

frequently by hired labourers; in the other zones it is done by children, mostly male. Fodder shortages are most evident in the subhumid zone; however, the problem is increasing in the medium and dry areas as the population increases, farm size decreases, and communal grazing land is adjudicated to individual ownership (Sutherland *et al.* 1995).

Table 3. Species which were planted on-farm per agroecological zone, number of participating farms, and proposed planting niche.

AEZ	Species	Local name	No. of Farms	Niche
Subhumid	*Commiphora zimmermanii*	Mururi	10	boundary
	Ficus thoningii	Mugumo	12	homestead
	Tithonia diversifolia	Kirurite	11	boundary
	Sapium ellipticum	Muthatha	15	homestead
	Morus alba	Mutare	18	boundary
	Calliandra calothyrsus	Calliandra	19	boundary
Medium	*Crotalaria goodiiformis*	Mucugucugu	13	fodder bank
	Aspilia mossambicensis	Muuti	7	fodder bank
	Indigofera lupatana	Mugiti	8	boundary
	Tithonia diversifolia	Kirurite	17	boundary
	Morus alba	Mutare	19	boundary
Semi-arid	*Crotalaria goodiiformis*	Mucugucugu	17	boundary
	Aspilia mossambicensis	Muuti	11	boundary
	Indigofera lupatana	Mugiti	13	boundary
	Acacia ataxacantha	Murangare	12	boundary
	Lantana camara	Mucimoro	12	boundary

Seedlings

Species which the farmers had mentioned in the survey as the ones they would like to plant on their farms were raised in nurseries (Table 2). Seeds of trees which are normally propagated by seeds were collected in the study area. However, some species from Table 2 could not be raised in the nurseries due to germination problems or lack of seeds. These were: *Trema orientalis, Melia volkensii, Securinega virosa* and *Grewia tembensis.* No saplings were raised in nurseries of the species that are normally propagated by cuttings such as *Commiphora zimmermanii, Ficus sp.*[1], *Tithonia diversifolia* and *Lantana camara. Sapium ellipticum* wildings were collected from the forest margin. *T. orientalis* seedlings were raised later from seeds after a delay of one year.

[1] *Ficus sp.* mentioned in this study includes *F. thoningii, F. natalensis* and *F. glumosa.*

Feedback meeting

All farmers who had participated in the survey were invited to three feedback meetings, one for each zone. The feedback meetings took place in October 1996 either at the research station in Embu for the subhumid zone, or at the research station in Machanga for the medium and semi-arid zone. The results of the survey were presented to the farmers and discussed with them. Afterwards they had an opportunity to see the seedlings which were raised in the nursery. Together with the researchers, farmers decided which five species (referred to as 'research species') out of the list of most popular species (Table 2), would be tested on farm. Researchers and farmers agreed to conduct two types of trials to test the research species: researcher-designed and farmer-designed. Both trials were managed by the farmers themselves. For the researcher-designed trials, it was agreed that the species had to be planted and harvested in a uniform way across farms to enable comparison of performance (Table 3). It was also agreed that each farmer would plant a minimum of ten seedlings per species to enable assessment of performance and animal response. The maximum number of seedlings per species a farmer could receive was one hundred. Farmers were free to decide whether they wanted to receive all five research species or fewer. For the farmer-designed trials, farmers planted where and how they wished. The two types of trials are highly complementary; in the researcher-designed trials quantitative data on performance can be collected whereas in the farmer-designed trials, farmers' own preferences and innovations can be monitored (Franzel *et al.* 1999).

On-farm experiment

The study was carried out in the same agroecological zones as the survey. Rainfall data were collected throughout the experiment in the three agroecological zones. For the subhumid zone the rainfall was measured at the Kenya Agricultural Research Institute (KARI) in Embu, 1480 m above sea level, latitude 00°30'S, longitude 37°27'E; for the medium zone at the Divisional Office of the Ministry of Agriculture, Livestock Development and Marketing in Gachoka, 1180 m above sea

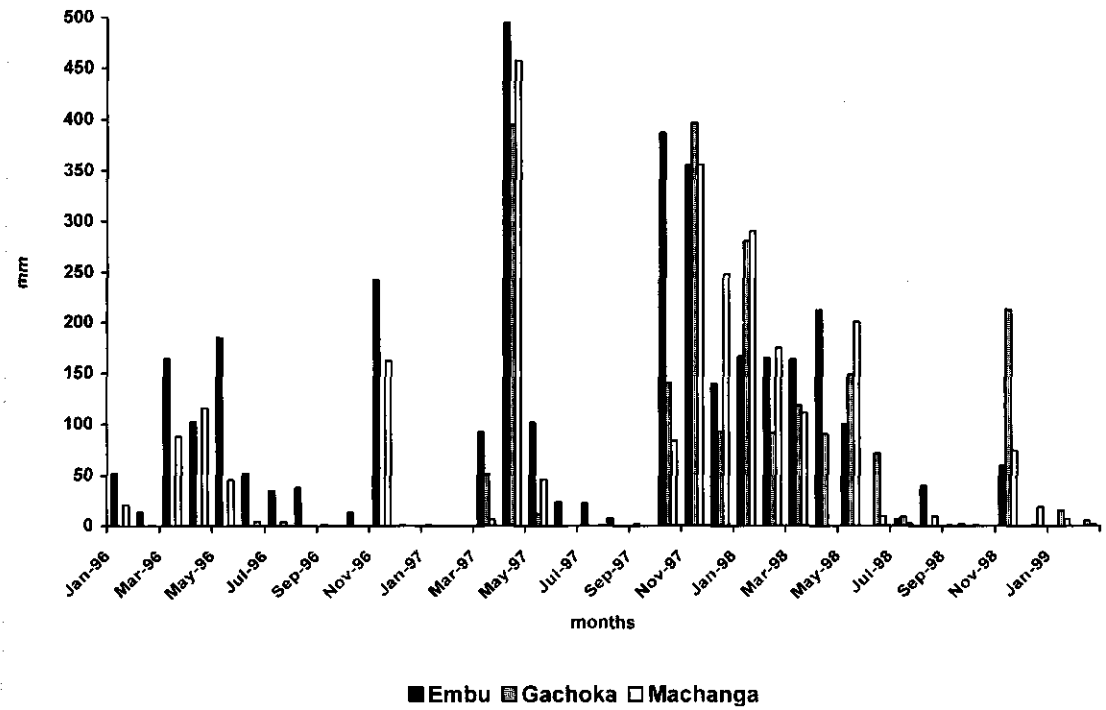


Figure 1. Monthly rainfall in the subhumid (Embu), medium (Gachoka, data starting in Jan. 1999) and semi-arid (Machanga) zones.

level, latitude 00°37'S , longitude 37°31'E ; and for the semi-arid zone at the KARI field station at Machanga, 1095 m above sea level, latitude 00°47'S, longitude 37°39'E. The total rainfall for the two year period from January 1997 to December 1998 was over two years 2608, 2111 and 2178 mm for the subhumid, medium and semi-arid zones, respectively (Fig. 1). This was above the annual average of 1250 mm for Embu and 830 mm for Machanga. The distribution, however, was far from ideal. Just after planting, from December 1996 till March 1997 there was a severe drought, with rainfall in Embu, Gachoka and Machanga totalling 93, 52 and 6 mm, respectively. The rain for the 1997 long rainy season fell mostly during one month, April. From the 1997 short rainy season to the 1998 long rainy season there was excessive rainfall without the usual dry spell in between. This wet condition, which occurred in the whole East African region, and which caused much havoc in low altitude areas, was caused by *el Niño*. It was followed by an extreme dry spell from July 1998 till March 1999 (*la Niña).*

All farmers who had participated in the survey and feedback meetings were given an opportunity to participate in the experiment. Additional farmers had to be selected in order to obtain a minimum target of ten replicates per species. The additional farmers were selected with the help of extension workers in the area. The number of farmers which had to be added in the subhumid, medium and semi-arid zones were sixteen, nine and eight, respectively. The number of farmers who subsequently participated and were monitored in the subhumid, medium and semi-arid zones were 20, 27 and 21, respectively. Only in the medium zone there were less than ten replicates for *Aspilia mossambicensis* and *Indigofera lupatana* (Table 3). The species *C. zimmermanii, Ficus sp., T. diversifolia* and *L. camara* were provided through cuttings. Seedlings and cuttings were distributed to farmers at the start of the short rains (November 1996). Due to severe drought (Fig. 1) and subsequent death of seedlings and cuttings just after first distribution, some species were distributed again at the start of the long rains (April 1997). The farms were monitored twice with the help of a semi-structured questionnaire; the first time two months and again one year after planting. Data which were collected after the first planting were quantitative, such as survival, growth of seedlings, planting niche and spacing; and qualitative, such as reasons why farmers planted a certain way, the way they took care of the seedlings, reasons why seedlings died and famers' other assessments and innovations. A final evaluation was carried out 16 months after the second planting, in February 1999, in the sub-humid and the semi-arid zone. At this stage, some quantitative data were collected for species which had not been included before, such as *S. ellipticum, C. calothyrsus* and *T. orientalis*, about survival, growth and planting niche. For the other species at this time, quantitative data on pruning height were collected. Qualitative data collected included palatability for animals, farmers' expansion of plantings , animal response, and ranking of species by biomass produced. Biomass ranking in the subhumid zone involved seven species: *C. calothyrsus, C. zimmermanii, Ficus sp., M. alba, S. ellipticum, T. diversifolia* and *T. orientalis*. The species with the highest biomass production received value one, the second highest producing value two etc. In the semi-arid zone there were four species which were ranked on biomass production: *A. ataxacantha, A. mossambicensis, C. goodiiformis* and *I. lupatana*. In a similar way they received values ranging from one to four. Because most species were distributed several times, survival and growth could only accurately be recorded up to 1 year after planting, except for *S. ellipticum* and *C. calothyrsus* which could be assessed up to 16 months after planting.

Tree growth was not measured; rather, we calculated the percentage of planted seedlings or cuttings that reached a height of 30 cm or more. Results were analysed by statistical package SPSS for Windows, Release 6.0. Percentages of survival and growth were transformed to arcsine (sqrt (x/100)) before they were tested with ANOVA. Ranks of biomass productivity were analysed by ANOVA.

Results and discussion

Survey and feedback meetings

Seventeen farmers, of whom 41 % female, attended the feedback meeting in the subhumid zone. Between 24 and 47 % of them wanted to try the first five species listed in Table 2. Seventy six percent of them wanted to try *C. calothyrsus, M. alba* and *S. ellipticum*. It was decided to take three species from the top five of Table 2 and include *C. calothyrsus, M. alba* and *S. ellipticum* to form the six research species (Table 3). *T. orientalis* and *T. tomentosa* became non-research species due to lack of seedlings of the first and not enough interested farmers in the second. Farmers agreed with the cutting management which was a result of what farmers had proposed in the survey: *C. zimmermanii, Ficus sp., S. ellipticum* and *T. orientalis* would be pollarded; *Triumfetta tomentosa* and *Vernonia lasiopus* would be cut at 1 m height; *T. diversifolia* would be cut above 1 m. Proposed niches were diverse for most species in the subhumid zone, and reflected the survey results. During the meeting, the farmers with bigger farms proposed to plant IFTS in fodder banks, whereas farmers with little land preferred planting on boundaries. It was decided that all farmers would plant in lines along boundaries but farmers could plant additional seedlings in fodder banks if they wanted to. Potentially upper-storeytrees such as *Ficus sp., T. orientalis* and *S. ellipticum* would be planted around homesteads, according to what farmers had proposed in the survey. During the feedback meeting a consensus was reached that these trees should be planted at least 3 m away from the farm boundary. People preferred planting species separately rather than planting them mixed together. Farmers expressed their concern for pests on *T. orientalis, C. zimmermanii* and *Bridelia micrantha*, especially during the dry seasons.

In the medium zone 23 farmers, of whom 65 % female, came to the feedback meeting. It was decided to make the research species the ones that most people wanted, which resulted in four species from the top five of Table 2 plus *M. alba*. Numbers of farmers who wanted to test *Morus alba, T. diversifolia, Crotalaria goodiiformis, A. mossambicensis and I. lupatana* were 78, 74, 52, 22 and 22 %, respectively. Farmers' proposed cutting management and planting niches, according to the results of the survey, were accepted. The shrubs *A. mossambicensis* and *C. goodiiformis* would be planted in fodder banks and browsed; *I. lupatana, T. diversifolia* and *M. alba* would be planted on external boundaries and used by the cut and carry system. Although farmers agreed that browsing in fodder banks would retard growth of the plants, it was found to be a good system for soil fertility improvement.

In the semi-arid zone, 17 farmers came to the feedback meeting, of whom 41 % women. The species farmers wanted as research species were four from the top eight of Table 2 plus *Acacia ataxacantha* (Table 3). The percentage of farmers who wanted *C. goodiiformis, L. camara, I. lupatana, A. ataxacantha* and *A. mossambicensis* was 88, 71, 47, 41 and 35, respectively. From the survey results it was clear that in this zone all species would be planted on external boundaries. Cutting management would vary from cutting at 1 m for *I. lupatana* and *Balanites pedicellaris*, cutting above 1 m for *C. goodiiformis* and *A. ataxacantha*, or harvesting soft twigs only for *L. camara* and *A. mossambicensis*.

While in the study of Roothaert and Franzel (in press) a list was published about the most popular species which farmers used, Table 2 shows popular species in terms of farmers wanting to plant them. When these two lists are compared, there are some striking differences. *Bridelia micrantha* was the third most popular species in the subhumid zone, whereas only 6 % of farmers were interested in planting it. *Acalypha fruticosa* was the fifth most popular species in the semi-arid zone but only 7 % of the farmers wanted to plant it. *T. orientalis* and *V. doniana* are relatively popular for planting (Table 2) but don't appear in the list of preferred species for utilisation. There are also species which appear in both lists but were not wanted during the feedback meeting, such as *Lantana camara* and *Maytenus putterlickioides*. From these findings one can conclude that *B. micrantha, A. fruticosa, L. camara* and *M. putterlickioides* are trees which are appreciated but hardly ever planted. The findings also demonstrate the shortcoming of a survey as an instrument; the survey showed that in theory *L. camara* and *M. putterlickioides* would be planted by farmers. However, planting these species which are weedy, and thorny in case of *M. putterlickioides*, is socially not acceptable. The findings also show the added value of feedback meetings, where these social motives become clear.

Planting niche

The choice of planting niche reflected the information from the survey in the subhumid zone. Forty three percent of the farmers who received the second lot of cuttings of *Ficus sp.*, however, planted them on internal or external boundaries, in stead of the proposed niche in the compound. The reason for this could be that on the boundaries more space was available. Although Roothaert and Franzel (in press) reported that 85 % of *C. zimmermanii* was found scattered within food crops, this is likely to be a niche where wildings are tolerated rather than a planting niche, as nobody in the experiment planted there. For *S. ellipticum* and *C. calothyrsus* no information was available from the survey about planting niche. The proportion of farmers who planted them on internal boundaries were 33 and 63 %, respectively, on external boundaries 33 and 16 %, respectively, and in the homestead 33 and 16 %, respectively.

In the medium zone, farmers planted on niches that they had proposed during the survey. Seventy two percent of the farmers planted *C. goodiiformis, A. mossambicensis* and *I. lupatana* in fodder banks and 89 % planted *T. diversifolia* and *M. alba* on internal or external boundaries. In the semi-arid zone, 80 % of the farmers planted the research species on external boundaries and 14 % on internal boundaries, according to the predictions of the survey. The shift from external to internal boundary would only be beneficial because internal boundaries are easier to protect from stray browsers during the critical time of establishment. None of the farmers in the subhumid zone planted species together in one spot. In the medium and semi-arid zones the ones who planted species mixed were 17 and 23 %, respectively, in either fodder banks or on boundaries.

Spacing

Eighty percent of the *T. diversifolia* and *M. alba* seedlings were planted in lines with spacings between 15 and 45 cm in the row. This was near the recommended spacing of 30 cm. *C. zimmermanii* had a wider range; 80 % of the seedlings were planted between 45 and 180 cm apart. Although the recommended spacing, according to the survey results, was also 30 cm, farmers gave as reason for wider spacing that it was better for growing passion fruits, which use the tree as a live stake. Eighty percent of *Ficus sp.* and *S. ellipticum* were spaced between 1.5 and 7.5 m. The recommended spacing for these trees was 1.5 m. Farmers explained that if they had enough space, these species would benefit from wider spacing. In the medium zone, 80 % of the seedlings of *C. goodiiformis, A. mossambicensis* and *I. lupatana* were spaced between 45 and 90 cm. *T. diversifolia* and *M. alba* were spaced wider; 80 % of the spacings were between 30 and 180 cm. Farmers explained they planted these species wider because they expected these trees to grow big or they had a big area available. The fact is that *T. diversifolia* and *M. alba* were less well known in this area (Roothaert and Franzel, in press). Forty one percent of the farmers who planted *T. diversifolia* or *M. alba* did not plant any of the well known other research species, such as *C. goodiiformis, A. mossambicensis* or *I. lupatana*. Farmers who planted the well known research species always planted *T. diversifolia* or *M. alba* as well. The farmers who only wanted the unknown species spaced these trees 10 to 40 % wider, most likely a reflection of the high appreciation of those species. These findings show that many farmers appreciate unknown species more than local ones, probably a result of the traditional approach where new technologies are supposed to be superior than traditional practices. In the semi-arid zone, 77 % of the farmers planted the research species between 45 and 60 cm apart, according to recommendations. Most planted one seedling per hole but nine percent planted two seedlings per hole.

Survival, growth and biomass productivity

There was a clear difference of survival among species ($p<0.001$, Fig. 2). *L. camara, Ficus spp., C. zimmermanii* and *S. ellipticum* failed; *C. goodiiformis, A. mossambicensis, I. lupatana* and *A. ataxacantha* did better. The failing species were all planted with fresh cuttings, except *S. ellipticum*, which was planted bare rooted. The ones that did better had been raised in polythene bags. Ninety-eight percent of the farmers stated that the general poor performance was due to the extremely poor rainy season. Planting in a shady place increased the survivability ($p<0.05$), most likely through reduced evapotranspiration. *I. lupatana* had the fastest initial growth (Fig. 3), but *C. goodiiformis* caught up after one year (Fig. 4 and 5).

C. goodiiformis also had the best survival rate after 2 and 6 and 12 months, followed by *A. mossambicensis* (Fig. 6,7 and 8). In the medium zone, more than 20 % of *M. alba* and *T. diversifolia* died because of termite damage. Termites are more common in the semi-arid zone than in the subhumid zone (Kidundo *et al.*, 1997). One can conclude that the in this zone these lesser known species, which do well in the subhumid zone, are outside their climatic range, where termite resistance is an essential asset.

Two months after the second planting, in the subhumid zone, survival of *T. diversifolia* and *M. alba* was better than that of *C. zimmermanii*, whereas *Ficus sp.* had died (Fig. 9). *C. zimmermanii* did not sprout after planting though and died later (Fig. 10). In the medium zone, both survival and growth was better for *M. alba* than for *T. diversifolia* after the second planting (Fig. 11 and 12).

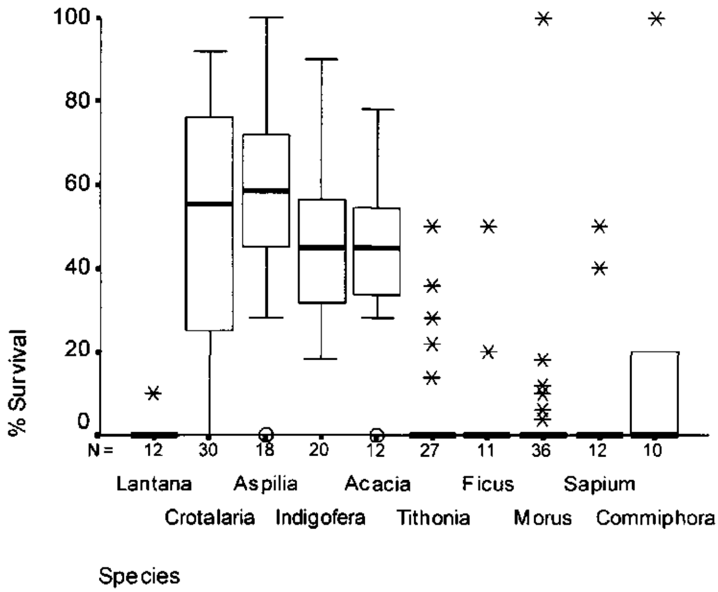


Figure 2. Survival of indigenous fodder trees and shrubs two months after first planting.

Key for Fig. 2 - 12:

N:	Number of farms
Box:	Contains 50 % of observed farms
Thick line in box:	Median
O:	Outlier
*:	Extreme value

In the sub-humid zone, 60 % of the farmers applied manure on *S. ellipticum*, whereas hardly any other seedling received manure. Although under these circumstances this practice did not show improved performance of the species, it clearly demonstrates farmers' appreciation for this tree species. The species that received most manure in the medium zone was *C. goodiiformis* (39 % of farmers). The manure could have contributed to the better performance of this species. Hardly any manure was applied in the dry zone.

Figure 3. Percentage of surviving trees and shrubs that reached a height of 30 cm or more, two months after first planting, semi-arid zone.

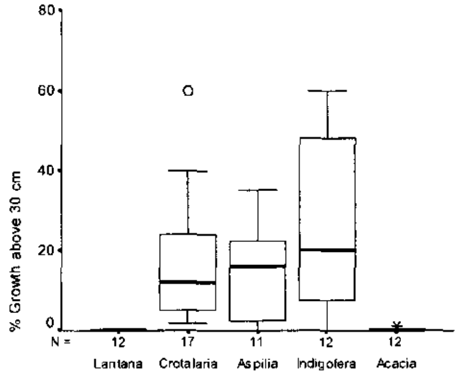


Figure 4. Percentage of surviving trees and shrubs that reached a height of 30 cm or more, six months after first planting, semi-arid zone.

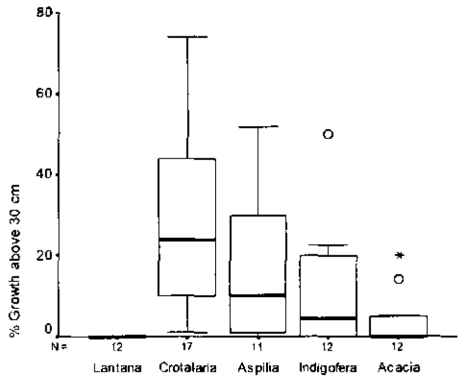


Figure 5. Percentage of surviving trees and shrubs that reached a height of 30 cm or more, one year after first planting, semi-arid zone.

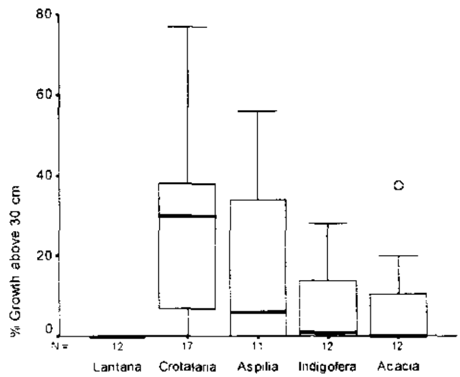


Figure 6. Survival of indigenous fodder trees and shrubs two months after first planting, semi-arid zone.

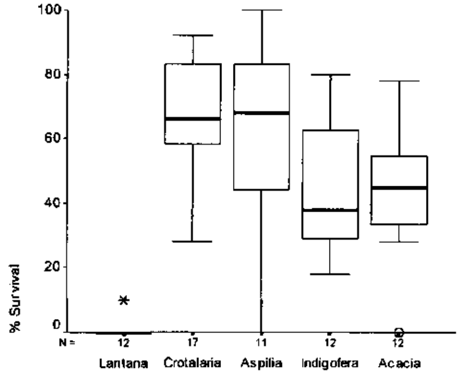


Figure 7. Survival of indigenous fodder trees and shrubs six months after first planting, semi-arid zone.

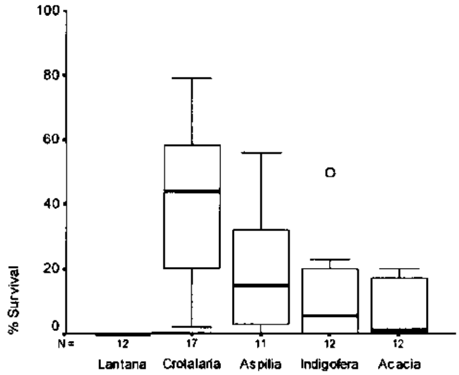


Figure 8. Survival of indigenous fodder trees and shrubs one year after first planting, semi-arid zone.

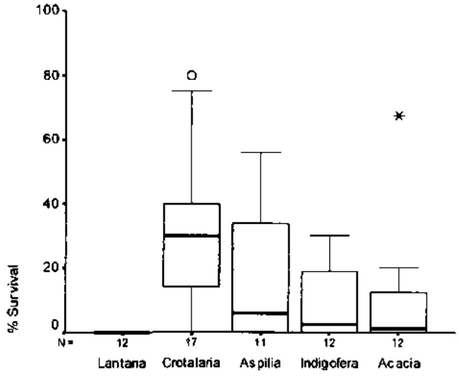


Figure 9. Survival of indigenous fodder trees and shrubs two months after second planting, subhumid zone.

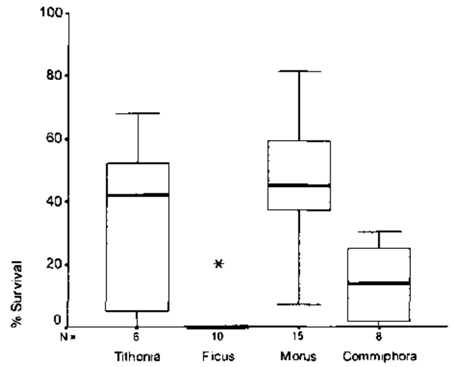


Figure 10. Percentage of surviving trees and shrubs that reached a height of 30 cm or more, two months after second planting, subhumid zone.

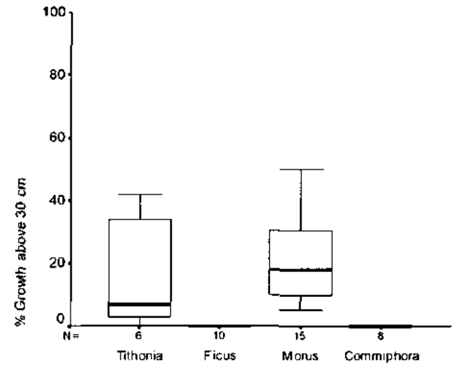


Figure 11. Survival of indigenous fodder trees and shrubs two months after second planting, medium zone.

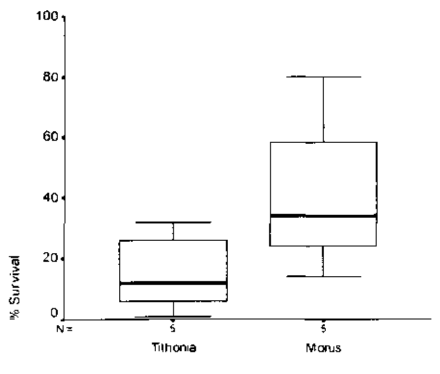
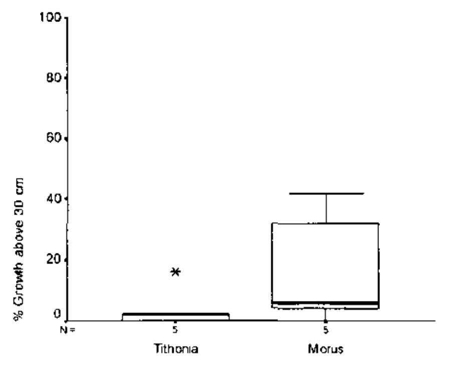


Figure 12. Percentage of surviving trees and shrubs that reached a height of 30 cm or more, two months after second planting, *medium zone.*



It was hypothesized that delay of planting after reception of seedlings would negatively affect performance and would be an indication of less appreciation of the trees. It did not, however, negatively affect survival or growth in any zone. On the contrary, a delay of planting of two days in the subhumid zone gave the best survival rate (76 %, $p = 0.21$). This delay should be seen as an essential period to prepare a proper planting area. In the drier zones the positive effect of delay could have been compensated by drying out of seedlings in excessively delayed cases.

The mean survival rate 16 months after planting of *S. ellipticum* and *C. calothyrsus* were 58 and 89 % respectively and was significantly different ($p = 0.003$) for the two species. All survived seedlings had reached a height above 30 cm. The mean survival rate the *T. orientalis* seedlings was only 27 % after 12 months, and they had all grown above 30 cm height. All *Ficus sp.* saplings had dried up. The mean rank of biomass productivity for *C. calothyrsus, M. alba* and *T. diversifolia* is presented in Table 4. *C. calothyrsus* seems the fastest grower. There is not much difference between *T. diversifolia* and *M. alba*, although growth results as in Fig. 10 and Fig. 12 suggest a slightly faster growth of the latter.

About the non-research species several farmers reported that *Vitex doniana* grew very slowly. Hardly any seedling had reached a height of 30 cm two years after planting.

Feeding

The proportion of farmers in the subhumid zone who had pruned the IFTS during the past two years was significantly different among species ($p < 0.001$); 95 % for *C. calothyrsus*, 89 % for *M. alba*, 64 % for *T. diversifolia*, 30 % for *C. zimmermanii* and 7 % for *S. ellipticum*. Two out of the three farmers who tested *T. orientalis* had pruned the seedlings. The mean pruning heights for *T. diversifolia, M. alba* and *C. calothyrsus* were 113, 105 and 100 cm but these differences were not significant ($P > 0.80$). *T. diversifolia* was less palatable for improved cattle than *C. calothyrsus* and *M. alba*; for goats these species were equally palatable (Table 4). Milk production for cattle was the most common type of animal response which farmers commented on.

Twenty farmers were monitored in February 1999 in the semi-arid zone, that is 22 – 27 months after planting. Browsing was more common in this zone than pruning (Table 5). All species were fed to goats, and were palatable to these animals. Only *C. goodiiformis, A. mossambicensis* and *I. lupatana* were fed to

Table 4. Subhumid zone. Percentage of farms where IFTS were pruned, type of animals which prunings were fed to, palatability, animal response (percentage of farmers who had pruned); and mean rank of biomass productivity.

		Species		
		C. calothyrsus	*M. alba*	*T. diversifolia*
Number of farmers who had pruned (percentage of original farmers)		18 (95)	16 (89)	7 (30)
Pruned		95	89	64
Average pruning height (cm)		100	105	113
Fed to improved cattle[1]		94	88	100
Palatable for improved cattle	Yes	89	88	29
	No	6	0	71
Fed to local goats		44	56	43
Palatable for local goats	Yes	44	56	43
	No	0	0	0
Cattle response				
Good milk production		56	50	29
Good health		6	6	0
Good growth		6	0	0
Can't tell		33	31	71
Goat response				
Good milk production		6	6	0
Good health		6	6	0
Can't tell		22	31	43
Mean rank[2] of biomass productivity ($p = 0.124$)		1.4	1.9	2.1

[1] Friesian, Ayrshire, Guernsey or crosses of these with local zebu cattle.
[2] Ranking among seven species, 1 = highest, 7 = lowest

cattle; the first two were found palatable but for the latter there was no information about palatability. More than 50 % of the farmers who browsed or pruned reported good animal responses in terms of goat milk production and good growth of goats. The results about the use of this tree fodder reflected the information of the previous

Table 5. Semi-arid zone: Percentage of farms where IFTS were browsed or pruned; type of animals which prunings were fed to, palatability, animal response (percentage of farmers who had pruned or browsed); and mean rank of biomass productivity.

			Species				
			L. camara	*C. goodii-formis*	*A. mossambicensis*	*I. lupatana*	*A. ataxacantha*
No. of farmers who had pruned or browsed (percentage of original farmers)			6 (50)	16 (94)	8 (73)	11 (85)	6 (50)
Browsed			67%	63%	67%	60%	57%
Pruned			33%	50%	22%	30%	43%
Pruning height	60 cm or less		0	19	13	9	17
	75 – 120 cm		17	25	13	18	33
Fed to	Local goats		100	100	100	100	100
	Local cattle		0	25	25	18	0
	Sheep		0	6	0	9	0
Palatable	Local goats	Yes	100	94	88	82	100
		No/ Not known	NA[2]	6	12	18	NA
	Local cattle	Yes	NA	19	13	NA	NA
		No/ Not known	NA	6	13	18	NA
Goat response	Good milk production		50	63	50	64	84
	Good growth		50	69	75	64	67
	Good health		0	13	13	9	33
	Goat got twins		0	6	13	9	17
	Fat kids		0	6	0	0	17
	Satisfaction		0	6	0	0	17
	Can't tell		0	6	0	9	0
Mean rank[1] biomass productivity ($p = 0.445$)			1.50	1.64	2.00	2.30	2.33

[1] Ranking among four species, 1 =highest, 4 = lowest.

[2] Not applicable

survey. However, the relatively low use of tree fodder for cattle compared to goats in this zone was more apparent in this study than in the survey.

Expansion

Only 17 % of the times that farmers in the subhumid zone received a species to plant, they expanded on it with their own means. *S. ellipticum* is excluded from this percentage, as it is forbidden to collect wildings from the forest without a permit. Many farmers mentioned though that they were not aware that the experiment would allow them to expand by themselves. Forty two percent of the times a species was expanded, farmers got the planting material from their own farm. Seventeen percent of the times they got seedlings from nurseries. In the semi-arid zone the proportion of farmers who increased *L. camara, A. mossambicensis, C. goodiiformis, A. ataxacantha* and *I. lupatana* with their own means were 71, 43, 25, 17 and 11 %, respectively. All of the seedlings were wildings; 46 % were from within the farms, either from the planted hedge or from elsewhere within the farm. Nobody obtained seedlings from nurseries. Apart from the 25 % of farmers who had increased seedlings of *C. goodiiformis*, another 25 % were intending to increase this species, whereas the number of farmers intending to expand other species was negligible.

Gender

The percentage of female contact farmers in the sub-humid, medium and semi-arid zones was 21, 48 and 38, respectively. The percentage of female respondents, however, increased during monitoring and was 32, 52 and 57 % respectively. This indicates that women became more involved as time went on, an observation which was confirmed by the fact that male respondents frequently mentioned that certain activities concerning the management of the seedlings were carried out by their wives. *Ficus* was only chosen by male contact farmers, probably because the harvesting of its leaves involves climbing. More than 75 % of *I. lupatana* and *A. mossambicensis* seedlings were chosen by male contact farmers Of all the species, only *M. alba* was slightly more often chosen by females than males in the medium zone, i.e. 52 % by females versus 48 % by males.

Conclusion

The study demonstrated its use as a method to test the willingness of farmers to plant certain IFTS on their farm. Especially the farmers feedback meetings provided good information about why farmers wouldn't plant certain species, which they had indicated in the survey they would. On-farm planting provided additional information on preference of species through selective allocation of manure. The experiment also demonstrated the difference of opportunistic niches of species in farms and actual planting niches. Clearest differences among species in terms of performance were obtained by their ability to survive. Among the surviving species, small growth differences could be measured. In the sub-humid zone, both the exotic species *C. calothyrsus* and the naturalized species *M. alba* were preferred by farmers and showed the best agronomic performance and animal responses. Among the species in the semi-arid zone, *C. goodiiformis* was most popular with farmers and had the best agronomic performance. The study shows a strong interest of farmers in intensifying the use of indgenous fodder trees. The use of IFTS for cattle only in the semi-arid zone was less practiced than in the sub-humid zone, but this could increase in future as land use intensifies. All species that established well during the experiment deserve further attention for on-farm research, in order to obtain additional information about animal responses and long term effects within the farming system. These species should also be tested on-station to determine the full agronomic potential.

Acknowledgement

The authors wish to acknowledge the indispensable participation of all farmers during the whole research process, and thank them for welcoming many visitors. We also thank the Director of the KARI - Regional Research Centre, Embu; our colleagues in the National Agroforestry Research Project; and the extension staff of the Ministry of Agriculture, Livestock and Development in the study area for facilitating the study and helping to carry out the work. Funds were made available through the Swedish International Development Agency (Sida), the International Centre for Research in Agroforestry (ICRAF) and the Netherlands Development Assistance (Neda).

Chapter 5

Nutritive value of indigenous fodder trees and shrubs – comparing laboratory and farmers' assessments.

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Animal Science (Submitted)

Chapter 5

Nutritive value of indigenous fodder trees and shrubs – comparing laboratory and farmers' assessments.

Abstract

Trees and shrubs are very suitable as supplements to low quality diets, but anti-nutritive factors can be a disadvantage. In this study, indigenous fodder trees and shrubs were screened for nutritive value through laboratory analysis and this was compared with farmers' assessment. Fodder samples were collected from 29 woody species, in two seasons, in three different agroecological zones along the eastern altitudinal gradient of Mount Kenya. There was a large variability in chemical composition and nutritive value parameters among species and between seasons. Except in the case of soluble tannins, season had either a significant positive or negative effect on nutritive parameters. The species that ranked consistently highest for seasons and indices were *Achyranthes aspera, Lantana camara, Morus alba, Manihot glaziovii, Tithonia diversifolia, Trema orientalis and Sapium ellipticum* in the subhumid zone; and *Crotalaria goodiiformis, Indigofera lupatana, L. camara* and *Melia volkensii* in the medium and dry zones. Regrowth after cutting had more significant regression coefficients ($p < 0.05$) in the subhumid zone than in the drier ones, which reflects the more active harvesting in this zone as opposed to browsing in the other zones. Palatability for cattle had no significant regression coefficients in the subhumid zone, but it did in the other zones. It was concluded that there are strong relationships between farmers' assessments and laboratory nutritive analyses. It is important to identify the properties of individual species which cause a large deviation from the regression.

Key words: Nutritive value, indigenous fodder trees and shrubs, farmers' assessment, relationship.

Introduction

The feeding of cattle, goats and sheep on browse has been investigated for at least fifty years (e.g. Staples *et al.*, 1942; Whyte, 1947). It is not surprising that much of the research on fodder trees has been carried out in tropical regions. Pastures in the tropics are often a reflection of natural vegetation such as savannah or woodland, where woody species occupy a significant proportion of the land. Improved pastures consisting of exclusively grass either with or without herbaceous legumes are relatively uncommon (Webster and Wilson, 1968). Although the bulk of the diets of cattle consists of grass, during the dry season grass stops growing and the old grass loses its nutritive value. Trees and shrubs on the other hand can continue to grow to some extend because of their extensive root system which can tap water deep in the ground. Trees and shrubs are very suitable as supplements to low quality diets as their concentration of protein and minerals are normally high (Le Houerou, 1980; Leloup and 't Mannetje, 1996). Used as such, tree fodder can reduce the cost of feeding dairy cows and even increase milk production (Paterson *et al.*, 1999).

Factors limiting the quality of conventional fodder are cell wall content, lignification and lack of protein. In tree fodder it has been demonstrated that secondary compounds, such as tannins, can suppress protein and dry matter digestibility (Baggio and Heuveldop, 1884; Woodward and Reed, 1989) However, most current methods of determining tannins are unsatisfactory to demonstrate clear links between tannin concentrations in fodder and animal performance such as feed intake, palatability and growth (Woodward and Reed, 1989; Kaitho *et al.*, 1997a). In an other study of Kaitho *et al.* (1997b), with different accessions of *Sesbania sesban*, a clear positive correlation was observed between tannin concentration on the one hand and growth and feed intake on the other. Animal performance increased with increasing levels of tannins up to a threshold, after which animal performance dropped with increasing levels of tannins.

In order to estimate nutritive value of fodder trees a combination of chemical and tannin analysis; digestibility, degradability, and gas production tests, seems to be more reliable than any individual method. Farmers in some parts of the world have practical knowledge about the quality of fodder trees (e.g. Bayer, 1990; Thapa *et al.*, 1997). Tapping this knowledge would be much faster and cheaper than carrying out elaborate analyses in laboratories, for the purpose of screening the nutritive values of trees. However, previous studies in this field have shown variable correlations between farmers' knowledge and laboratory assessments (Thapa *et al.*, 1997).

Type and level of anti-nutritive factors not only depend on the plant species but also on growing stage and morphological part of the tree (Salawu *et al.*, 1999; Milimo, 1994). The objectives of his study were to screen indigenous and naturalised fodder trees in central Kenya for their nutritive value using chemical analysis, digestibility and degradability tests, in different seasons; and to compare these analyses with farmers assessments of a previous study (Roothaert and Franzel, in press). It was hypothesised that there is a strong relation between farmers assessment and the combination of laboratory analyses, and that farmers assessment could be used more often in future to save time and costs.

Materials and methods

Sample collection

Fodder samples were collected from 29 woody species, in two seasons, in three different agro-ecological zones (AEZ) along the eastern altitudinal gradient of Mount Kenya. The first collection was during the rainy season in April 1997 and the second during the dry season in August 1997. The three collection sites were Embu (1480 m asl, latitude 00°30'S, longitude 37°27'E), Gachoka (1180 m above sealevel asl, lattitude 00°37'S, longitude 37°31'E) and Machanga (1095 m above sea level asl, latitude 00°47'S, longitude 37°39'E) with average annual rainfall of 1250, 950 and 830 mm, respectively. All sites have bimodal rainfall patterns. The soils are as in the subhumid, medium and dry zones described in Roothaert and Franzel (in press), for Embu, Gachoka and Machanga, respectively. At the first collection, only the new growth of that season was harvested, consisting of both leaves and succulent twigs. At the second collection, leaves and succulent twigs that were formed during the previous rainy season and during the current dry season were harvested.

Species to be sampled were selected on the basis of most popular indigenous fodder trees and shrubs (IFTS) with farmers (Roothaert and Franzel, in press; Thijssen *et al.*, 1993a). *Calliandra calothyrsus* was added as a control, because it is one of the most popular exotic fodder trees in Embu. *Grevillea robusta* was added as an example of one of the worst fodder trees in terms of nutritive value (Thijssen *et al.*, 1993a).

Chemical analysis

Fodder samples were collected in sealable polythene bags to retain moisture. They were oven dried at 60°C, ground and passed through a 2 mm sieve. Concentrations of DM, ash and crude protein (CP) were analysed for all samples following the procedures of the Association of Official Analytical Chemists (AOAC, 1990). Neutral detergent fibre (NDF) was determined according to Van Soest and Robertson (1985). Soluble tannins and insoluble condensed tannins (ICT) were analysed according to the methods of Reed *et al.* (1985) and Reed *et al.* (1982), respectively. The method of Tilley and Terry (1963), modified by Van Soest and Robertson (1985), was used for in vitro digestibility of both DM and CP. CP digestibility was calculated with the formula:

$$D = 1 - ((N\ \%\ \text{residue} \times g\ \text{residue}) / (N\ \%\ \text{sample} \times g\ \text{sample}))$$

In sacco rumen degradability of DM was determined by the method of Ørskov *et al.* (1980), with 48 hours incubation in the rumen of cross bred cattle fed on Rhodes grass hay ad libitum and 2 kg cotton seed cake supplement per head. The analyses were carried out at the International Livestock Research Institute in Debre Zeit, Ethiopia.

Gas production analysis was carried out at the KARI National Agricultural Research Centre, Muguga, using a pressure transducer, according to Theodorou *et al.* (1994) and modified by Sileshi *et al.* (1996). The duration of time in which half of the assymptotic gas production was formed (half time) was determined by the maximum likelihood programme (Ross, 1987). To distinguish secondary compounds in the fodder samples, a high performance liquid chromatography (HPLC) method was used, according to Heering *et al.* (1996), using a Spectro Monitor Absorption Detector at 280 nm, with a retention time of 40 minutes.

Ranking according to energy and protein indices

The value of IFTS for the supply of energy and protein was expressed in indices. For this purpose the data were split into rainy and dry season values. Relative indices for in vitro dry matter digestibility (IVDMD), in sacco dry matter degradability (ISDMD), total gas production, half time of assymptotic gas production, in vitro digestible CP (DCP), in sacco degradable CP (DegCP), were calculated by expressing the value as a percentage of the maximum value of the season, e.g.:

$IVDMD_{rel}$ = 100 * IVDMD/ highest value of IVDMD of the season

The energy index was the mean value $IVDMD_{rel}$ and $ISDMD_{rel}$. The protein index was the mean value of DCP_{rel} and $DegCP_{rel}$. Indices were grouped into two seasons for each of two zones (the subhumid zone alone and a combination of the medium and dry zone). Species were ranked for indices of energy, protein, and in case of rainy season also for total gas production. Species listed in the top half for the two or three indices, in every subgroup, were considered to have superior nutritive value.

Statistical analysis

The statistical computer package Genstat 53 (Genstat Five Committee, 1993) was used for all statistical analyses. Differences between seasons of chemical composition and nutritive value of species were determined through paired *t* tests. Linear regression was determined between quality parameters of fodder trees according to farmers (Roothaert and Franzel, in press) and nutritive value parameters derived from laboratory analyses. The percentage of variance accounted for, also called the adjusted R^2, is presented in the results as R^2 together with the probability values of the regression coefficients.

Results and discussion

Chemical analysis, in vitro digestibility and in sacco degradability

There was a large variability in chemical composition and nutritive value parameters among species and between seasons (Table 1 and 2). Except in the case of soluble tannins, season had either a significant positive or negative effect on nutritive parameters (Table 3). In 54 % of the cases soluble tannins were higher during the rainy season than during the dry season, in the other cases it was vice versa. Extreme values of soluble tannins were observed during the rainy season, with concentrations ranging from 28 in *Tithonia diversifolia* to 260 g kg^{-1} DM in *C. calothyrsus* (Table 2). Big relative decreasing effects of dry season on soluble tannins (decrease of 70 % or more) were found in *Maytenus putterlickioides, Morus alba, Triumfetta rhomboidea, Ficus thonigii* and *C. calothyrsus*. Similarly increasing effects were found in *T. diversifolia, Aspilia mossambicensis* and *Lantana camara* (medium zone).

The mean ICT value was lower during the dry season than during the rainy season (Table 3). There was a large variability during the rainy season, but slightly less so during the dry season. Of the trees with condensed tannin values listed in the top half (> 15 absorbancy units in the dry season), 73 % showed higher values in the rainy season than in the dry season. Species in this category that showed increases of ICT of more than 100 % were *Triumfetta tometosa, Ficus thoningii* (both locations), *Commiphora zimmermanii* and *Bridelia micrantha*. During the HPLC analysis for secondary compounds, all species exhibited peaks ranging from 2.2 to 3.0 absorption units between one and two minutes from the start. Later peaks were much lower and generally did not exceed 0.5 absorption units.

Ash concentration increased during the dry season in almost all the species. Exceptions were *C. africana, Ocimum suave, T. diversifolia* and *T. tomentosa*. IVDMD generally decreased during the dry season. The biggest exception was

F. thoningii, IVDMD of which increased by 44 g kg^{-1} DM. ISDMD decreased during the dry season, although this change was less significant than for IVDMD (Table 3). The maximum absolute decrease of ISDMD was in *B. micrantha* (256 g kg^{-1} DM), whereas the maximum absolute increase was in *C. zimmermanii* (109 g kg^{-1} DM).

In most cases both CP and IVCPD decreased during the dry season. The maximum absolute decrease of CP was in *L. camara* in the medium zone (235 g kg^{-1} DM). All species except *G. robusta* had IVCPD values above 540 g kg^{-1}, during both seasons. It is not clear whether extreme high values of CP, such as in *A. ataxacantha*, represent amino acids or other nitrogenous compounds. However, CP values higher than 310 g kg^{-1} DM had CP digestibilities of at least 800 g kg^{-1} (Table 2), indicating a high potential utilisation of available nitrogen.

Ranking of species, according to energy, protein and gas production indices

The species that ranked consistently highest for seasons and indices were *Achyranthes aspera, L. camara, M. alba, M. glaziovii, T. diversifolia, T. orientalis* and *S. ellipticum* in the subhumid zone; and *C. goodiiformis, I. lupatana, L. camara* and *M. volkensii* in the medium and dry zones (Table 4 and 5). *A. mossambicensis* ranked among the highest in the rainy season but not in the dry season. *G. tembensis* scored high for energy and gas indices but only average for protein index, which was mainly caused by the average CP concentration. *A. ataxacantha* ranked high for protein index only during the rainy season, and not for any other indices. *G. tembensis* and *A. ataxacantha* could therefore well complement each other in a diet in the rainy season. *T. tomentosa* was close to ranking consistently among the highest in the rainy season. *C. calothyrsus* ranked consistently in the lower half, apart from protein index, for which it ranked number seven. *G. robusta* ranked almost consistently lowest in the subhumid zone.

Table 1 Dry season values of in vitro dry matter digestibility (IVDMD, g kg^{-1}), in sacco rumen dry matter degradability (ISDMD, g kg^{-1}), in vitro crude protein digestibility (IVCPD, g kg^{-1}), in vitro digestible crude protein (DCP, g kg^{-1} DM), in sacco rumen degradable crude protein (DegCP, g kg^{-1} DM), chemical composition (CP, NDF, Ash, g kg^{-1} DM), soluble tannins (g kg^{-1} DM), insoluble condensed tannins (ICT, absorbancy units per gram fibre), for fodder trees and shrubs in central Kenya.

Botanical name	Zone	IVDMD	ISDMD	CP	IVCPD	DCP	DegCP[a]	NDF	Ash	Soluble tannins	ICT
Achyranthes aspera	Subhumid	743	902	259	957	248	233	414	182.6	38	12.3
Bridelia micrantha	Subhumid	385	538	134	611	82	72	551	71.1	226	133.7
Calliandra calothyrsus	Subhumid	551	608	239	703	168	146	439	82.9	153	46.5
Commiphora zimmermanii	Subhumid	512	701	144	587	85	101	428	85.7	217	112.6
Cordia africana	Subhumid	441	534	192	523	100	103	549	106.0	73	11.7
Croton megalocarpus	Subhumid	596	756	153	789	120	115	431	116.9	129	45.6
Ficus thoningii	Subhumid	577	777	152	758	115	118	546	105.8	116	170.2
Grevillea robusta	Subhumid	323	460	83	135	11	38	550	69.0	115	106.4
Lantana camara	Subhumid	616	886	235	632	149	208	420	129.0	98	14.0
Manihot glaziovii	Subhumid	715	904	266	921	245	240	328	93.4	84	34.2
Morus alba	Subhumid	778	940	144	945	136	136	354	103.2	49	5.9
Ocimum suave	Subhumid	699	859	129	821	106	111	394	115.1	69	17.0
Sapium ellipticum	Subhumid	696	891	175	808	141	156	307	95.3	137	8.0
Tithonia diversifolia	Subhumid	717	934	264	884	233	246	345	147.0	77	14.8
Trema orientalis	Subhumid	745	920	294	939	277	271	299	126.1	50	10.5
Triumfetta rhomboidea	Subhumid	647	841	179	871	156	151	461	89.5	84	57.6
Triumfetta tomentosa	Subhumid	593	799	152	815	124	121	476	93.3	78	19.1
Vernonia lasiopus	Subhumid	713	914	241	831	200	220	416	129.2	78	13.3
Acacia ataxacantha	Medium	557	588	178	700	124	104	417	79.3	210	51.2
Aspilia mossambicensis	Medium	701	841	127	886	112	107	342	197.2	131	8.3
Indigofera lupatana	Medium	748	917	160	931	149	147		174.9	100	10.3
Lantana camara	Medium	673	904	152	733	111	137	335	128.0	137	8.6
Rhus natalensis	Medium	433	585	87	559	49	51	508	103.3	222	139.5
Crotalaria goodiiformis	Dry	736	904	192	934	179	173	302	93.3	95	5.0
Ficus thoningii	Dry	635	813	118	779	92	96	265	137.4	115	65.7
Grewia tembensis	Dry	633	794	156	907	141	123	311	141.4	74	15.4
Maytenus putterlickioides	Dry	626	841	97	787	76	82	417	113.6	31	40.0
Melia volkensii	Dry	718	846	138	910	125	116	405	176.5	89	8.8

[a] DegCP = CP * ISDMD/1000

Table 2 Rainy season values of in vitro dry matter digestibility (IVDMD, g kg^{-1}), in sacco rumen dry matter degradability (ISDMD, g kg^{-1}), cumulative gas production (Gas, ml), half time of gas production (Half, hrs), in vitro crude protein digestibility (IVCPD, g kg^{-1}), in vitro digestible crude protein (DCP, g kg^{-1} DM), in sacco rumen degradable crude protein (DegCP, g kg^{-1} DM), chemical composition (CP, NDF, Ash, g kg^{-1} DM), soluble tannins (g kg^{-1} DM), insoluble condensed tannins (ICT, absorbancy units per gram fibre), for fodder trees and shrubs in central Kenya.

Botanical name	Zone	IVDMD	ISDMD	Gas	Half	CP	IVCPD	DCP	DegCP [a]	NDF	Ash	Soluble tannins	ICT
Achyranthes aspera	Subhumid	777	897	266	15.3	296	930	275	266	388	176.1	60	11.3
Bridelia micrantha	Subhumid	516	794	206	32.0	273	805	220	217	444	63.5	157	315.7
Calliandra calothyrsus	Subhumid	639	715	219	23.0	294	823	242	211	337	55.7	260	30.7
Commiphora zimmermanii	Subhumid	542	592	171	18.1	231	709	164	136	409	71.0	214	245.4
Cordia africana	Subhumid	588	711	167	24.8	290	717	208	206	382	127.2	90	7.2
Croton megalocarpus	Subhumid	574	745	202	16.5	215	870	187	160	412	56.7	123	83.0
Ficus thoningii	Subhumid	533	717	216	27.9	122	541	66	87	478	89.2	215	354.4
Grevillea robusta	Subhumid	358	477	179	18.7	103	484	50	49	544	31.3	88	104.5
Lantana camara	Subhumid	758	932	261	13.7	289	950	275	270	279	126.3	116	7.6
Manihot glaziovii	Subhumid	687	855	281	10.6	271	931	252	231	353	75.5	93	38.1
Morus alba	Subhumid	803	949	300	12.1	281	977	275	267	269	100.6	105	3.9
Ocimum suave	Subhumid	759	889	237	15.7	307	964	296	273	403	124.7	46	16.7
Sapium ellipticum	Subhumid	774	950	278	15.0	272	951	259	258	263	57.9	180	5.1
Tithonia diversifolia	Subhumid	691	957	117	10.8	379	899	341	363	381	181.4	28	18.7
Trema orientalis	Subhumid	754	915	284	12.8	298	946	282	272	264	107.7	33	10.9
Triumfetta rhomboidea	Subhumid	663	838	196	21.5	178	867	154	149	361	75.5	198	96.0
Triumfetta tomentosa	Subhumid	695	862	242	17.0	263	933	246	227	359	110.2	82	101.1
Vernonia lasiopus	Subhumid	702	836	234	14.8	190	839	159	159	356	114.8	80	10.9
Acacia ataxacantha	Medium	640	797	200	22.5	396	797	316	316	350	58.4	205	31.1
Aspilia mossambicensis	Medium	712	891	269	16.2	306	945	289	272	319	158.4	76	10.6
Indigofera lupatana	Medium	757	912	277	15.0	277	952	264	253	349	118.3	113	6.9
Lantana camara	Medium	743	949	253	16.0	387	940	364	367	284	116.8	69	9.6
Rhus natalensis	Medium	491	605	203	21.1	193	637	123	117	529	77.5	180	259.5
Acalypha fruticosa	Dry	749	896	244	18.2	223	943	210	200	348	120.3	175	6.1
Aspilia mossambicensis	Dry	756	907	254	17.7	302	956	288	274	310	173.9	61	9.0
Crotalaria goodiiformis	Dry	762	925	293	16.3	349	961	335	323	244	73.1	73	11.7
Ficus thoningii	Dry	609	840	252	17.8	144	765	110	121	432	101.3	137	195.9
Grewia tembensis	Dry	694	897	298	17.8	249	931	232	223	385	102.8	65	25.8
Maytenus putterlickioides	Dry	623	734	232	17.7	206	787	162	151	385	76.7	102	72.0
Melia volkensii	Dry	708	881	277	8.9	277	930	258	244	226	102.4	126	5.7

[a] DegCP = CP * ISDMD/1000

Table 3 Effect of season on in vitro dry matter digestibility (IVDMD, g kg^{-1}), in sacco rumen dry matter degradability (ISDMD, g kg^{-1}), in vitro crude protein digestibility (IVCPD, g kg^{-1}), in vitro digestible crude protein (DCP, g kg^{-1} DM), in sacco rumen degradable crude protein (DegCP, g kg^{-1} DM), chemical composition (CP, NDF, Ash, g kg^{-1} DM), soluble tannins (g kg^{-1} DM) and insoluble condensed tannins (ICT, absorbancy units per gram fibre) (n = 28).

	IVDMD	ISDMD	CP	IVCPD	DCP	DegCP	NDF	Ash	Sol. tan.	ICT
Mean dry season	625	793	173	773	138	140	414	117	110	42
Mean rainy season	669	829	262	849	230	222	361	101	118	70
Mean difference	37	31	89	76	91	81	-50	-20	9	32
S.d. of difference	53	84	72	112	72	72	80	24	49	60
p	< 0.001	0.062	< 0.001	0.001	< 0.001	< 0.001	0.003	< 0.001	0.363	0.009

Table 4 Relative indices during the dry season for energy related (IVDMD, ISDMD, energy index) and protein related (DCP, DegCP, protein index) parameters of fodder.Bold values indicate ranking in the top half of the subhumid zone, or of the medium and dry zone together.

Botanical name	Zone	$IVDMD_{rel}$	$ISDMD_{rel}$	DCP_{rel}	$DegCP_{rel}$	Energy $index_{rel}$	Protein $index_{rel}$
Morus alba	Subhumid	100.0	100.0	49.3	50.1	**100.0**	49.7
Trema orientalis	Subhumid	95.7	97.9	100.0	100.0	**96.8**	**100.0**
Tithonia diversifolia	Subhumid	92.1	99.3	84.3	90.9	**95.7**	**87.6**
Achyranthes aspera	Subhumid	95.5	95.9	89.5	86.1	**95.7**	**87.8**
Vernonia lasiopus	Subhumid	91.6	97.2	72.3	81.1	**94.4**	**76.7**
Manihot glaziovii	Subhumid	92.0	96.1	88.4	88.6	**94.0**	**88.5**
Sapium ellipticum	Subhumid	89.4	94.7	51.1	57.5	**92.1**	**54.3**
Ocimum suave	Subhumid	89.8	91.3	38.2	40.8	**90.6**	39.5
Lantana camara	Subhumid	79.2	94.3	53.7	76.9	86.7	**65.3**
Triumfetta rhomboidea	Subhumid	83.2	89.4	56.5	55.7	86.3	**56.1**
Triumfetta tomentosa	Subhumid	76.2	85.0	44.7	44.8	80.6	44.8
Croton megalocarpus	Subhumid	76.6	80.4	43.5	42.6	78.5	43.0
Ficus thoningii	Subhumid	74.2	82.6	41.6	43.5	78.4	42.6
Commiphora zimmermanii	Subhumid	65.8	74.5	30.6	37.3	70.2	34.0
Calliandra calothyrsus	Subhumid	70.8	64.7	60.9	53.7	67.7	**57.3**
Cordia africana	Subhumid	56.7	56.8	36.3	37.8	56.8	37.1
Bridelia micrantha	Subhumid	49.5	57.2	29.7	26.7	53.3	28.2
Grevillea robusta	Subhumid	41.6	48.9	4.1	14.1	45.3	9.1
Indigofera lupatana	Medium	96.1	97.6	53.9	54.2	**96.8**	**54.0**
Crotalaria goodiiformis	Dry	94.6	96.1	64.8	64.0	**95.4**	**64.4**
Lantana camara	Medium	86.5	96.2	40.3	50.7	**91.4**	**45.5**
Melia volkensii	Dry	92.3	90.0	45.2	42.9	**91.1**	**44.1**
Aspilia mossambicensis	Medium	90.2	89.5	40.7	39.4	**89.8**	40.0
Maytenus putterlickioides	Dry	80.5	89.5	27.6	30.1	85.0	28.8
Ficus thoningii	Dry	81.7	86.4	33.3	35.4	84.0	34.3
Grewia tembensis	Dry	81.4	84.4	51.0	45.6	82.9	**48.3**
Acacia ataxacantha	Medium	71.6	62.5	44.9	38.5	67.1	41.7
Rhus natalensis	Medium	55.6	62.2	17.6	18.7	58.9	18.1

Table 5 Relative indices during the rainy season for energy related (IVDMD, ISDMD, Gas, Half time, energy index) and protein related (DCP, DegCP, protein index) parameters of fodder. Bold values indicate ranking in the top half of the subhumid zone, or of the medium and dry zone together.

Botanical name	Zone	IVDMD	ISDMD	Gas	Half time	DCP	DegCP	Energy index	Protein index
Morus alba	Subhumid	100.0	99.2	**100.0**	73.7	75.6	72.7	**99.6**	**74.1**
Tithonia diversifolia	Subhumid	86.1	100.0	**94.2**	82.8	93.8	98.9	**93.1**	**96.3**
Trema orientalis	Subhumid	93.9	95.6	**94.5**	69.4	77.4	74.2	**94.8**	**75.8**
Manihot glaziovii	Subhumid	85.6	89.4	**93.7**	83.8	69.3	63.0	87.5	**66.1**
Sapium ellipticum	Subhumid	96.4	99.3	**92.5**	59.4	71.1	70.3	**97.8**	**70.7**
Lantana camara	Subhumid	94.4	97.4	**86.9**	65.2	75.6	73.5	**95.9**	**74.5**
Achyranthes aspera	Subhumid	96.7	93.7	**88.5**	58.1	75.7	72.4	**95.2**	**74.1**
Ocimum suave	Subhumid	94.5	92.9	79.1	56.8	81.4	74.3	**93.7**	**77.8**
Vernonia lasiopus	Subhumid	87.4	87.3	77.8	60.2	43.8	43.2	87.4	43.5
Triumfetta tomentosa	Subhumid	86.6	90.1	**80.5**	52.3	67.5	61.8	**88.3**	64.6
Triumfetta rhomboidea	Subhumid	82.5	87.6	65.2	41.5	42.3	40.5	85.1	41.4
Croton megalocarpus	Subhumid	71.4	77.9	67.4	54.0	51.4	43.6	74.6	47.5
Calliandra calothyrsus	Subhumid	79.6	74.8	72.8	38.8	66.6	57.4	77.2	62.0
Ficus thoningii	Subhumid	66.4	74.9	71.8	32.0	18.1	23.8	70.7	21.0
Bridelia micrantha	Subhumid	64.2	83.0	68.6	27.8	60.4	59.0	73.6	59.7
Cordia africana	Subhumid	73.2	74.3	55.5	35.9	57.2	56.2	73.8	56.7
Commiphora zimmermanii	Subhumid	67.5	61.8	57.1	49.3	45.0	37.1	64.6	41.1
Grevillea robusta	Subhumid	44.6	49.9	59.6	47.7	13.7	13.4	47.2	13.6
Melia volkensii	Dry	88.1	92.0	**92.2**	100.0	70.8	66.4	**90.1**	**68.6**
Crotalaria goodiiformis	Dry	94.9	96.7	**97.5**	54.8	92.2	87.9	**95.8**	**90.0**
Indigofera lupatana	Medium	94.3	95.3	**92.3**	59.6	72.5	68.8	**94.8**	**70.6**
Lantana camara	Medium	92.6	99.2	**84.4**	55.8	100.0	100.0	**95.9**	**100.0**
Grewia tembensis	Dry	86.4	93.8	**99.1**	50.1	63.7	60.8	**90.1**	62.2
Aspilia mossambicensis	Medium	88.7	93.1	**89.7**	54.9	79.4	74.1	**90.9**	**76.8**
Aspilia mossambicensis	Dry	94.2	94.7	**84.7**	50.4	79.3	74.5	**94.5**	**76.9**
Acalypha fruticosa	Dry	93.3	93.6	81.1	48.9	57.9	54.4	**93.4**	56.1
Ficus thoningii	Dry	75.8	87.8	84.0	50.0	30.4	33.0	81.8	31.7
Maytenus putterlickioides	Dry	77.6	76.7	77.2	50.4	44.5	41.1	77.1	42.8
Acacia ataxacantha	Medium	79.7	83.3	66.5	39.6	86.8	86.0	81.5	**86.4**
Rhus natalensis	Medium	61.2	63.3	67.7	42.2	33.8	31.8	62.2	32.8

Effect of anti-nutritive factors on energy index and half time

All anti-nutritive factors such as NDF, soluble or ICT had a significant negative relationship with energy index ($p < 0.001$), with adjusted R^2 of 0.59, 0.23 and 0.32, respectively. Season seemed to have an effect on the relationship between energy index and ICT, but not on the relationship between energy index with NDF or soluble tannins (Fig. 1). Season did not have any effect on the relationship between protein index with any of the anti-nutritive factors. Species can be grouped into two categories: the first one where ICT are higher in the dry season than in the rainy season; and the second one, where ICT are higher in the rainy season than in the

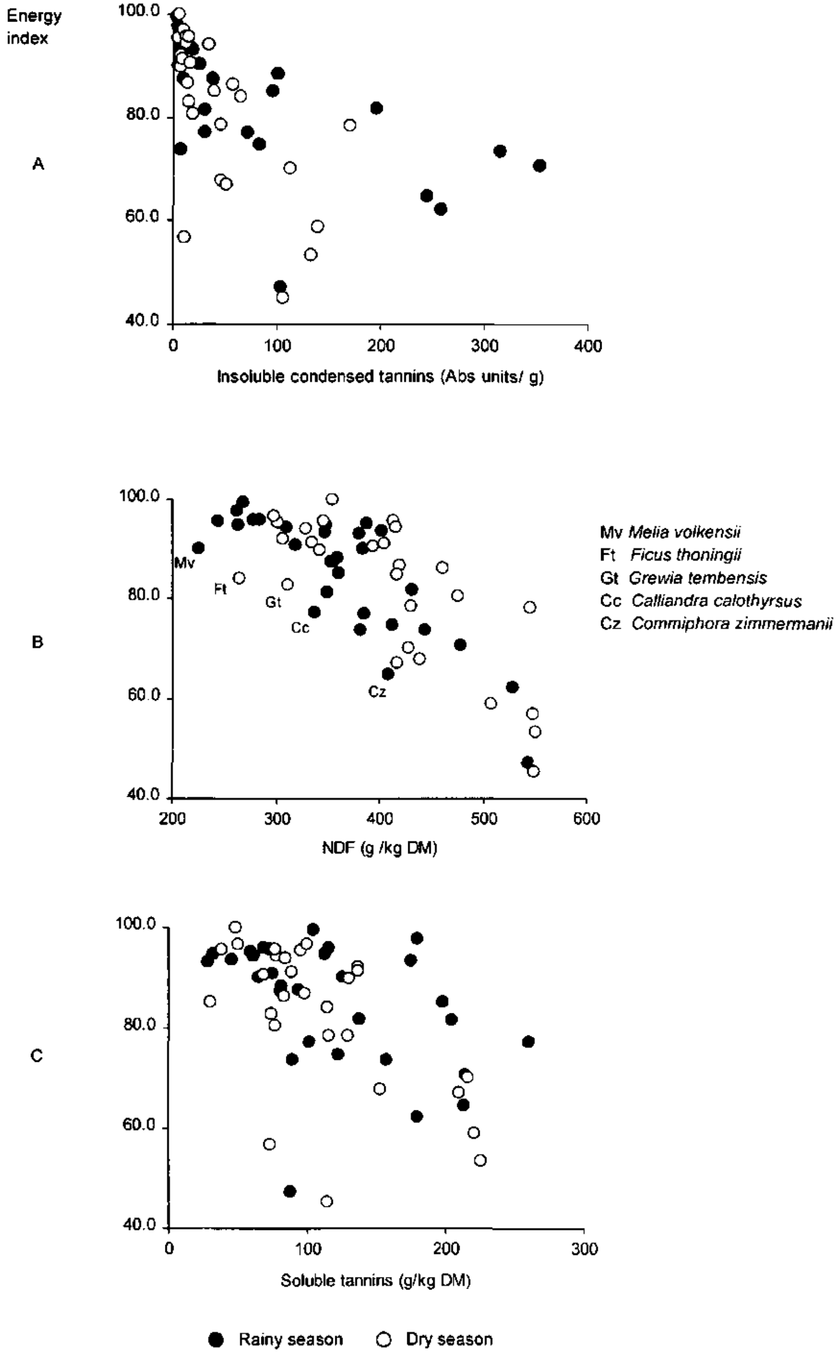

Figure 1. Relationship between energy index and anti-nutritive factors.

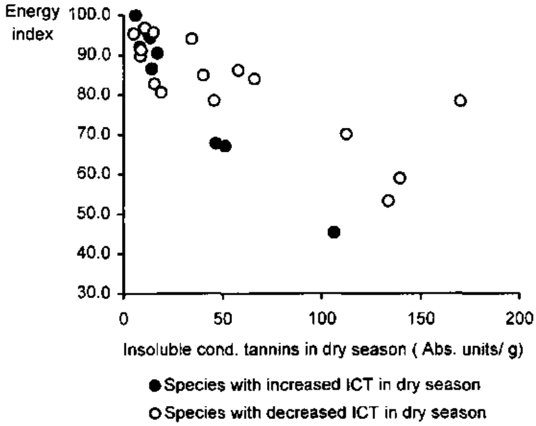

Figure 2. Effect of species category on the relationship between insoluble condensed tannins and energy index.

dry season. During the dry season the relationship between ICT and energy index was stronger in category one than in category two (Fig. 2). During the rainy season there was no difference. For the other anti-nutritive factors there was no difference between these categories either, during any season. ICT, soluble tannins and NDF had a significant negative relationship with half time of gas production, with p values of < 0.001, 0.002 and 0.002, respectively, and adjusted R^2 of 0.40, 0.27 and 0.26, respectively.

The analyses in this experiment show that energy value of IFTS is more related to NDF than any tannin, supporting the conventional relationship between energy and NDF for forages. Nevertheless, the impact of tannins cannot be denied. *M. volkensii, F. thoningii, G. tembensis, C. calothyrsus* and *C. zimmermanii* were relatively far below the imaginary trend line in Fig. 1b, suggesting that tannins are responsible for this deviation. An attempt was made to detect the responsible tannins through the HPLC fingerprints. Similar peaks occurred between 1 and 2 minutes and between 15.5 and 17 minutes after the start of the HPLC procedure. These peaks also occurred with many other species though. If these species are selected for improved fodder technologies, improvements on nutritive value could be obtained by selecting provenances with lower tannin concentrations, and more specifically lower soluble tannin concentration.

Exclusions from regression

In Table 6 the adjusted R^2 is given for the regression coefficients between quality parameters defined by farmers and laboratory analyses. Some farmer parameters have been left out from the table because they had no significant correlation ($p > 0.10$). These parameters were: compatibility of IFTS with crops, health of the animal after eating IFTS and drought resistance of IFTS.

C. zimmermanii was removed from the analysis as presented in Table 6. Inclusion of this species increased the p value to above 0.10 for regression coefficients between growth and regrowth on the one hand and energy index, protein index, gas, and ash on the other. Farmers had rated growth and regrowth very high for this species, but this did not correspond with favourable laboratory parameters. Reasons for this disparity are not clear.

Some species were excluded from the calculation of the regression coefficients only for specific parameters, since their presence increased the p value to above 0.10. For instance, in the medium and dry zone, *G. tembensis* had received a high rating for milk production by farmers. However, for the calculation of the regression coefficient between milk production and protein index, its presence increased the p value to 0.27 and reduced the R^2 to 0.08. It was therefore excluded. *A. ataxacantha* was excluded for the calculation of the regression coefficients between milk production on the one hand, and gas production and soluble tannins on the other, during the rainy season. Gas production was lower and soluble tannins higher for this species than what could be expected from the regression equation. Other farmer factors, such as fodder availability, might be responsible for the outlying nature of *G. tembensis* and *A. ataxacantha*. For the calculation of the regression coefficient between palatability for cattle and energy index, *Acalypha fruticosa* was excluded in the rainy season. Some secondary compounds within the relatively high soluble tannin concentration of this species could have been responsible for the low rate of palatability it received from the farmers. The low ash concentration of *C. goodiiformis* caused high p values for regression coefficients with palatability and fattening, and the ash value for this species was therefore excluded from the regression calculations during the dry season. Similarly, low soluble tannin levels in *M. putterlickioides* caused high

Table 6 Significance and adjusted R^2 of linear regression coefficients, between quality parameters determined by farmers (vertical) and laboratory analyses (horizontal). Zonal sub groups: subhumid (Sh), and medium and dry (Dry). Seasons: rainy (R) and dry (D). The negative sign before the R^2 value indicate negative regression coefficient.

	Zone [a]	Season	Energy $index_{rel}$		Protein $index_{rel}$		Total gas		Ash		NDF		Soluble tannins		Insoluble cond.tannins		Half time gas	
			p	R^2	p	R^2	p	R^2	p	R^2	p	R^2	p	R^2	p	R^2	p	R^2
Growth after establishment	Sh	R	0.016	0.85	ns		0.011	0.88	0.019	0.84	ns		ns		ns		0.012	-0.88
		D	0.033	0.77	0.032	0.77	na		0.011	0.89	0.008	-0.91	ns		ns		na	
	Dry	R	ns		0.011	0.58	ns		ns		ns		ns		ns		ns	
		D	ns		ns		na		ns		ns		0.003	0.76	ns		ns	
Regrowth after pruning	Sh	R	0.067	0.64	ns		0.015	0.86	0.022	0.82	ns		ns		ns		0.074	-0.61
		D	ns		0.046	0.71	na		0.018	0.84	0.017	-0.85	ns		ns		na	
	Dry	R	ns		0.072	0.35	ns		ns		ns		ns		ns		na	
		D	ns		ns		na		ns		ns		ns		ns		na	
Palatability for cattle	Sh	R/D	ns		ns		ns		ns		ns		ns		ns		ns	
	Dry	R	0.002	0.80 [b]	ns		0.010	0.58	ns		0.075	-0.30	0.105	-0.24	ns		0.082	-0.28
		D	0.002	0.87	0.037	0.47	na		0.016	0.67 [e]	0.085	-0.37	0.027	-0.59 [f]	<0.001	-0.84	na	
Palatability for goats	Dry	R	ns		ns		0.007	0.63	ns		ns		0.086	-0.27	ns		ns	
		D	ns		0.010	0.65	na		0.037	0.54 [e]	0.087	-0.37	0.016	-0.67 [f]	ns		na	
Fattening of animals	Dry	R	0.047	0.38	ns		0.001	0.77	ns		ns		0.011	-0.58			ns	
		D	0.004	0.74	0.042	0.45	na		0.047	0.49 [e]	0.014	-0.68	0.023	-0.61 [f]	0.005	-0.72	ns	
Milk prod. for goats	Dry	R	ns		0.032	0.66 [c]	0.037	0.63 [d]	ns		ns		0.018	-0.74 [d]	ns		ns	
		D	ns		ns		na		ns		0.039	-0.74	ns		ns		na	

[a] IFTS species included in subhumid zone are: *Bridelia micrantha, Lantana camara, Tithonia diversifolia, Triumfetta tomentosa* and *Vernonia lasiopus*. Species in the dry zone are: *Acacia ataxacantha, Acalypha fruticosa, Aspilia mossambicensis, Crotalaria goodiiformis, Indigofera lupatana, Grewia tembensis, Lantana camara, Maytenus putterlickioides* and *Melia volkensii*. [b] Excluding *Acalypha fruticosa*, [c] excluding *Grewia tembensis*, [d] excluding *Acacia ataxacantha*, [e] excluding *Crotalaria goodiiformis*, [f] excluding *Maytenus putterlickioides*.
ns: not significant, na: not applicable.

p values for several regression coefficients. The value for soluble tannins in this species was therefore excluded in the dry season. The thorny nature of this species is probably an additional negative factor. For the same reason, this species was excluded in the dry season for the calculation of the regression coefficient between palatability for cattle and energy index.

Relationships

Growth after establishment had more relationships with laboratory parameters in the subhumid zone than in the medium and dry zones. This reflects the observation from the previous study that farmers in the subhumid zone are more used to planting trees than in the other zones. Regrowth after cutting had more significant regression coefficients in the subhumid zone than in the drier ones, which reflects the more active harvesting in this zone as opposed to browsing in the other zones. Palatability for cattle had no significant regression coefficients in the subhumid zone, but it did in the other zones. Palatability of feed in the subhumid zone might have been influenced strongly by other factors, such as training animals to eat certain feeds and lack of alternative feeds, since most animals there are kept in zero-grazing systems. In these described aspects the zones were complementary to each other in terms of information retrieved, in an unforeseen way. There was a particularly high significance between energy index and palatability for cattle in the drier zones. In the dry season, ICT had a strong influence on palatability for cattle. Palatability for goats in the drier zones had relationships with all factors except energy index and ICT. Fattening of animals had a strong link with gas production in the rainy season, and negatively with ICT in the dry season. Milk production for goats was strongly negatively related to soluble tannins in the rainy season and NDF in the dry season. Two of the factors which were negatively related to farmers assessments, ICT and NDF, manifested mostly during the dry season. The other factor, soluble tannins, showed relationships during both seasons. Rate of rumen degradability, indicated by half time of gas production, does not seem to have a large relationship with farmers' assessments, apart from growth of trees after establishment.

Finding relationships between palatability and laboratory determined parameters has proved to be difficult in other experiments, where palatability of 40 species was determined through indices including DM intake and quantity offered to sheep and goats (Kaitho *et al.*,1997a). The highest R^2 values that were achieved in that study for degradability, protein, gas production, fibre and tannin related parameters were 0.22 for effective degradability, 0.14 for N concentration, 0.14 for asymptotic gas production, 0.31 for NDF and 0.11 for acetone soluble phenolics. Looking at the higher R^2 values derived from our study it can be suggested that farmers' assessment of palatability of IFTS seems to be more reliable than palatability determined through feed intake trials using sheep and goats.

Conclusion

It was possible to screen IFTS through laboratory analysis indicating consistent differences in nutritive value. Although nutritive value was generally higher during the rainy season than during the dry season, it was still high enough during the dry season to provide high quality fodder supplements, with a large scope for selection of superior species. There are strong relationships between farmers assessments of IFTS and laboratory nutritive analyses. However, some species stand out from these relationships. It is important to identify these outlying species, as they could be overlooked in selection programmes if only either farmers assessments or laboratory tests were used as criteria. Identifying the properties that determine a species' outstanding performance is important to determine its applicability as energy- or protein supplement, or as high quality basic feed.

Chapter 6

Feed intake and selection of tree fodder by dairy heifers

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Animal Feed Science and Technology (1999) 79:1-13

Chapter 6

Feed intake and selection of tree fodder by dairy heifers

Abstract

A trial was conducted in the central Kenyan highlands to determine the dry matter intake (DMI) by dairy heifers for napier grass (*Pennisetum purpureum*) plus supplements of either fresh *Calliandra calothyrsus*, fresh *Morus alba* (mulberry), dried *Manihot glaziovii* (cassava tree), fresh *Leucaena diversifolia* (leucaena) or dairy meal. Five Ayrshire heifers were stall fed and exposed to each diet in a latin square design, providing five replicates in five periods. Napier grass was supplied *ad libitum* and supplements at 25 % of estimated daily DMI. Plant parts, twig diameters and crude protein (CP) content, *in vitro* digestibility and, *in sacco* rumen degradability of consumed material were determined. DMI for supplements and napier were significantly different at $p < 0.05$; intake of digestible crude protein, rumen degradable dry matter and digestible dry matter were significantly different at $p < 0.001$. Animals were able to select parts of the tree fodder with higher contents of CP, higher *in vitro* digestibility and higher rumen degradability than the average of the offered supplement. Ash content, condensed and soluble tannins were higher but neutral detergent fibre and acid detergent fibre contents were lower in offered than left over tree fodder. Thickness of consumed branches increased with rainfall figures and measured up to 5 mm for leucaena, 9 mm for mulberry and 12 mm for calliandra. Studies such as this one will enable researchers to estimate the feeding values of different fodder trees and enable them to recommend optimum rations including these fodders. Through comparison of DMI, indications of palatability of tree fodders can be obtained. Of the fodder tree species tested in this experiment, mulberry and cassava tree had the highest potential in terms of milk production levels. Experiments are needed feeding these two species to lactating cows.

Keywords: Fodder trees; dairy cows; feed intake; feed selection; nutritive value

Introduction

Dairy farming is an important source of income for the small scale farmer in the central highlands of Kenya. During the dry seasons the nutritive value of the basal cattle diet, napier grass, drops below a required level for sustained milk production. Tree fodder can be a good supplement, because of its high nutritive value and because it retains this high value during the dry season.

Luecaena leucocephala has been the most widely known fodder tree in the world for decades (Shelton and Brewbaker, 1994). In Kenya, however, farmers abandoned this tree after the pest *Heteropsylla cubana* (leucaena psyllid) broke out in 1992. Farmers have been using alternative fodder tree species such as *Manihot glaziovii* (cassava tree), *Morus alba* (mulberry) and *Calliandra calothyrsus* (Roothaert and Paterson, 1997). Many species which farmers use have high nutritive value, illustrated by cassava tree leaves which have a crude protein (CP) level of 395 g kg^{-1} DM and *in vitro* organic matter digestibility (IVOMD) of 855 g kg^{-1} DM (Thijssen *et al.*, 1993a). The information that is missing is the optimum amounts of these fodders in the ration.

Tree fodder offered to cows often consists of a combination of leaves, petioles, twigs, flowers and pods but feeding value of different parts of a tree varies (Salawu *et al.*, 1997a). The hypothesis tested in this study was: "The type of tree fodder that is fed as a protein supplement to dairy cattle in the tropics which are fed a low quality basal grass diet, determines the growth rate or level of milk production. The different effects of fodder trees are caused by their nutritive value, voluntary intake and ability of cattle to select the most nutritive parts within one type of tree fodder." The objectives of the study were to compare the voluntary feed intake of tree fodder supplements, fed to heifers with a basal diet of napier grass; to estimate the feeding value of the actual eaten part of tree fodder; to determine the thickness of the twigs that are consumed; and to extrapolate the findings to milk production of mature cows.

Materials and methods

The experiment was carried out at the Regional Research Centre of the Kenya Agricultural Research Institute (KARI) in Embu, in the central Kenyan highlands. The Research Centre is situated 1490 meters above sea level, 00°30' South latitude and 37°27' East longitude. The soils in the area are humic nitosol (FAO classification) or typic palehumult (USDA classification) (FURP, 1987) of moderate to high fertility. The experiment was conducted from January to April 1995, starting in the dry season and ending in the rainy season. The total monthly rainfalls were: January 7 mm, February 119 mm, March 167 mm and April 349 mm.

Animals

Five Ayrshire heifers were used with initial ages ranging from 13 to 15 months, and initial live weights ranging from 143 to 180 kg. Before the start of the experiment they were dewormed with Wormicid Plus®, 1.5 % w/v Levamisole HCl B.P. Vet, 8.0 % w/v Bithionol Sulfoxide. During third week of March 1995 the animals were vaccinated with an attenuated live vaccine of East Coast Fever. Every week they were sprayed against ticks with Triatix®, 12.5 % w/v Amitraz, a diamidid. The animals were kept in individual pens of 2.7 m x 1.9 m and were allowed to exercise together in a paddock of 16 m x 10 m every day from 11.00 am to 4.00 pm. They were fed twice a day at 9.00 am and 4.00 pm. Individual feeding troughs were designed such that spilling of feed was minimised. Commercial mineral licks were provided and water was offered *ad libitum*.

Diets

Napier grass was unfertilised and allowed to grow 1.5 to 2 m tall before it was cut. In this way napier was providing a low quality basal diet representing farmers situation in the dry season. The grass was chopped with a hand chopper to pieces of about two cm length. *Calliandra calothyrsus, Leucaena diversifolia* and *Manihot glaziovii* (cassava tree) were planted at a density of 20,000 trees per ha, *Morus alba* (mulberry) at 30,000 trees per ha. Calliandra and leucaena were planted with seedlings while mulberry and cassava tree were planted with cuttings. Cutting height of all trees was 50 cm. The first harvest for the experiment started nine months after planting date, when all species had shown good growth. The fodder of calliandra, mulberry and leucaena that was offered to the heifers consisted of leaves and succulent twigs, and was fed fresh. During the last months, the fodder also included green pods of calliandra and leucaena. The leaves of cassava tree were harvested together with one third of the petioles. This fodder of cassava tree was then detoxified through sun drying, a process that destroys the precursors of HCN (Devendra, 1977). One batch of commercial dairy meal was bought that lasted throughout the experiment.

Experimental design and procedures

The experimental design was a Latin Square with five heifers, five periods and five treatments. In one period all heifers were on a different treatment. Each heifer was allocated a different treatment every period, in order to obtain five replicates per treatment. Napier grass was fed *ad libitum* to all heifers throughout the experiment at 10 % above the average consumption. The treatments were different fodder supplements: calliandra, mulberry, leucaena, cassava tree and a control of dairy meal. The amount of DM of supplement offered was calculated for each animal at a rate of 0.625 % of the live weight (25 % of the total DM intake, which was estimated at 2.5 % of live weight). The amounts were revised every two weeks. Each treatment period lasted three weeks. Although leucaena contains the toxin mimosine, dietary inclusion level was below the safe threshold of 30 %, and the species used, *L. diversifolia*, is known to contain less mimosine than the more often used *L. leucocephala* (Hughes, 1998). The amounts of feeds offered were recorded every feeding time, the amounts left over were weighed and recorded every morning at 8.00 am. Grass and tree fodder left overs could easily be separated. Samples of offered and left over feeds were taken weekly and dried at 60 °C. Voluntary intake of the different tree supplements was measured through mean DM intake of supplement. The heifers were weighed weekly.

Table 1 Chemical composition of offered (O), left over (L) and consumed (C) fodder.

Species		DM (as fed)		CP ($g\ kg^{-1}$ DM)		Ash ($g\ kg^{-1}$ DM)		NDF ($g\ kg^{-1}$ DM)		ADF ($g\ kg^{-1}$ DM)	
		mean	sed	mean	sed	mean	sed	mean	sed	mean	sed
Calliandra	O	342	20.9	189	7.0	55.5	3.1	528	30.0	412	35.5
calothyrsus	L	387	22.2	141	11.9	50.7	1.2	664	23.4	530	25.4
	C			212							
Morus alba	O	272	19.1	151	3.1	106	5.2	468	13.3	238	11.4
	L	354	36.7	67.5	8.2	54.9	7.1	720	17.1	292	41.9
	C			166							
Manihot	O	843	13.5	187	12.7	81.8	3.7	485	29.0	347	24.1
glaziovii	L	806	26.2	76.8	11.0	68.4	4.0	714	16.6	559	17.3
	C			239							
Leucaena	O	310	21.4	190	7.6	62.8	3.2	519	19.8	205	10.0
diversifolia	L	398	25.4	108	6.4	48.4	2.5	725	19.1	199	31.4
	C			223							
Pennisetum	O	286	24.9	67.1	6.2	98.6	7.4	782	23.5	488	17.4
purpureum	L	331	28.1	53.4	5.0	86.6	7.3	815	9.3	510	23.2
	C			68.4							
Dairy meal	O	858		162		69.3		627		280	

Chemical analysis

The ability of cattle to select the most nutritious parts of tree fodder was determined through comparing the chemical composition of offered, consumed and left over material. After drying, fodder samples were ground by a hammer mill and passed through a 2mm sieve. All nutritive value parameters as shown in Table 1 and 2 were determined after the completion of the trial, with the dried samples. Contents of DM, ash and crude protein (CP) were analysed for all samples following the procedures of the Association of Official Analytical Chemists (Helrich, 1990). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Van Soest and Robertson (1985). *In vitro* digestibility of DM for all samples was determined through the Tilley and Terry method (1963); the same method was used to determine the *in vitro* digestibility of CP for one sample per feed stuff. This CP digestibility was calculated with the formula:

Table 2 *In vitro* dry matter digestibility (IVDMD, g kg^{-1}), *in sacco* rumen dry matter degradability (g kg^{-1}), soluble tannins (g kg^{-1} DM) and condensed tannins (absorbency units per g fibre) of offered (O), left over (L) and consumed (C) fodder.

Species		IVDMD		Degradability		Soluble tannins		Condensed tannins	
		mean	sed	mean	sed	mean	sed	mean	sed
Calliandra	O	423	16.8	430	19.9	202	35.1	31.9	2.90
calothyrsus	L	357	15.1	416	17.6	156	24.6	20.8	3.37
	C	455		437					
Morus alba	O	721	31.9	636	24.1	88.7	14.9	6.51	0.44
	L	505	41.3	375	27.7	30.2	12.0	5.45	0.89
	C	760		683					
Manihot	O	603	31.5	646	17.2	50.4	11.7	17.1	2.22
glaziovii	L	408	20.0	440	23.2	16.2	6.6	5.55	1.29
	C	695		743					
Leucaena	O	472	18.0	513	12.4	87.2	8.7	38.0	4.33
diversifolia	L	300	17.9	369	15.2	44.9	7.1	22.8	1.86
	C	545		570					
Pennisetum	O	405	17.3	393	9.9				
purpureum	L	378	19.6	369	12.7				
	C	408		395					
Dairy meal	O	794		639		34.0		2.92	

$$D = 1 - ((N\ \%\ residue \times g\ residue) / (N\ \%\ sample \times g\ sample))$$

In sacco rumen degradability of DM for all samples was determined by the method of Orskov, DeB Hovell and Mould (1980), with 24 hours incubation in rumen fluid derived from a bull fed on napier grass. The relatively short incubation time of 24 hours was chosen because the supplements were expected to be highly degradable. More over, the animals were fed at maximum intake levels which would imply a high rate of passage. Soluble tannins and condensed tannins were analysed for all samples except napier according to the methods of Reed *et al.* (1985). To calculate the CP percentage, *in vitro* digestibility and rumen degradability for the actual consumed fodder, the total amount of the nutrients in left over of a particular feed stuff was subtracted from the total amount offered, and the outcome divided by the total DM intake of that feed stuff.

Branch diameter studies

In order to assess physical characteristics of selected tree fodder by heifers, a special study was undertaken to determine the diameters of eaten twigs and branches. This special study was conducted during the last two or three days of each period. Tree stems of about 90 cm length with fodder attached were given to the heifers in their troughs. The stems were divided in to two groups: the top 90 cm growth of a tree and the 90 to 180 cm growth below the top, leaving stems of up to 50 cm above the ground uncut. After the usual feeding time, the diameters of the twigs at the places where the fodder was browsed were measured. A DM allowance was added to the usual ration to compensate for the inedible woody parts.

Statistical analysis

Every feeding period lasted 22 days; the first eight days were considered as an adaptation period for the animal to the new treatment; the following nine days were used to determine the DM intake of the feeds and the last five days were used for branch diameter studies. The data of the experiment were subjected to analysis of variance using the computer package Genstat 5.3 (Genstat Five Committee, 1993). Reported means were adjusted for missing values.

Results

Condition of the heifers

One heifer developed fever after the East Coast Fever vaccination. This occurred during period 5 when she was on a diet treatment of leucaena. As a result of the fever, feed intake by this cow during this period was far below normal and these data were excluded and treated as missing values. The heifers grew well during the experiment, with an average weight gain of 303 g per day.

Chemical analysis and nutritive value

Dry matter (DM) percentage of the offered napier and tree fodder dropped as the rains proceeded, whereas their CP content generally increased over time. The range of DM content during the experimental period for napier, calliandra, mulberry and leucaena was 125 to 437, 235 to 474, 115 to 354 and 247 to 397 g kg^{-1} DM respectively. The average CP contents for napier, calliandra, mulberry, leucaena and cassava tree were 67, 189, 151, 190 and 187 g kg^{-1} DM respectively (Table 1); the range of CP content was 49 to 85, 145 to 226, 132 to 166, 146 to 222 and 124 to 250 g kg^{-1} DM respectively.

The percentage of CP, *in vitro* digestibility, rumen degradability, ash percentage, soluble and condensed tannin content were all higher in the offered than in the left over fodder while NDF and ADF were higher in the left over than in the offered fodder (Table 1 and 2). Consequently, CP percentage, *in vitro* digestibility and rumen degradability were higher in the actual consumed feed than in the offered feed. (Table 1 and 2). Differences in CP percentage among feeds were more pronounced in ingested than in offered material. As napier was chopped there was very little room for selection, which resulted generally in small differences of nutrient concentrations between offered and left over material. Rumen degradability did not vary much for offered, left over and ingested calliandra. There was no left over dairy meal. Concentrations of condensed tannins were at least twice as high for calliandra and leucaena than for other feeds. Concentration of soluble tannins was twice as high for calliandra as for other feeds (Table 2).

Voluntary intake

Dry matter intake (DMI) of all tree fodder supplements was much lower during period one than the following periods, most likely due to the fact that the heifers were not exposed to tree fodder before and the adaptation period was short. In order to

Table 3 Adjusted means of daily dry matter intake (DMI) of supplements, napier, total dry matter; left over dry matter of supplements, napier; total *in vitro* digestible crude protein (DCP), total *in sacco* rumen degradable dry matter (DegDM) and total *in vitro* digestible dry matter (DigDM); per kg metabolic live weight (g/kg $LW^{0.75}$) for dairy heifers (n=4).

Species	DMI supple-ment	DMI napier	Total DMI[1]	Left supple ment DM[2]	Left napier DM	Total DCP intake	Total Deg DM intake	Total Dig DM intake
Calliandra calothyrsus	16.4	89.2	105.6	5.36	8.05	6.7	42.0	43.2
Morus alba	19.0	87.6	106.5	3.38	8.89	7.9	47.4	50.0
Manihot glaziovii	13.9	90.3	104.0	7.27	7.66	8.4	46.4	46.7
Leucaena diversifolia	15.8	87.9	103.5	7.23	8.02	7.5	43.1	43.6
Dairy meal	20.9	86.6	107.6	-0.08	9.74	8.0	47.6	51.9
significance level (p)	0.015	0.044	0.192	<0.001	0.748	<0.001	<0.001	<0.001
sed	1.49	0.98	1.70	0.90	1.71	0.18	0.78	0.83

[1] Total DMI differs slightly from the sum of the previous two columns because of the adjustment of means.
[2] Negative value caused by adjustment of means.

present data that reflect the potential DMI of the treatments, period one was excluded from the results that are presented in Table 3. Data were analysed through analysis of variance with incomplete latin square. The exclusion of period one did increase the significance level for differences for napier intake.

Selection within tree fodder and thickness of eaten twigs and branches

The leaves and twigs of calliandra, mulberry and leucaena were eaten throughout the experiment. Calliandra flowered during two periods; the flowers were eaten by one heifer but not by the other. Foliage of leucaena was severely infested with psyllids (*Heteropsylla cubana*), but this did not seem to affect the consumption by animals. Leucaena and calliandra produced pods during one period; those of

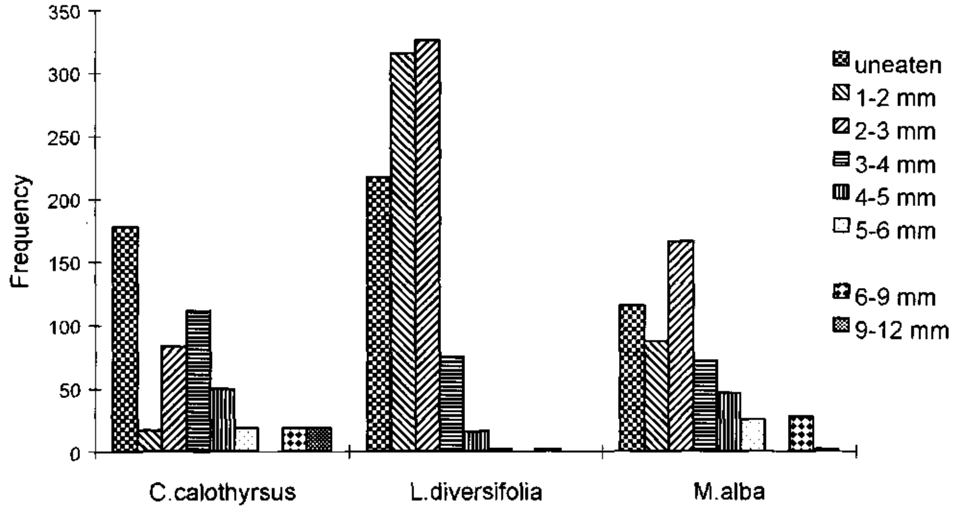

Figure 1. Number of times (frequency) that branches had been eaten up to a certain diameter for different fodder trees.

leucaena were eaten but those of calliandra were not. The bark of uneaten mulberry branches was stripped off by two animals.

The thickest branches consumed were of calliandra, then mulberry and last leucaena (Figure 1). During the rainy season, branches became more succulent. Period one and two could be considered dry season, period three was a transition between seasons, and in period four and five growth of the trees were representing high rainfall. The diameters of consumed branches increased during the rainy season, represented by period four and five (Figure 2). From the bottom part of the stems (90 - 180 cm from top), twigs were eaten up to 7 mm diameter. Consumed branches thicker than 7 mm came all from the top 90 cm.

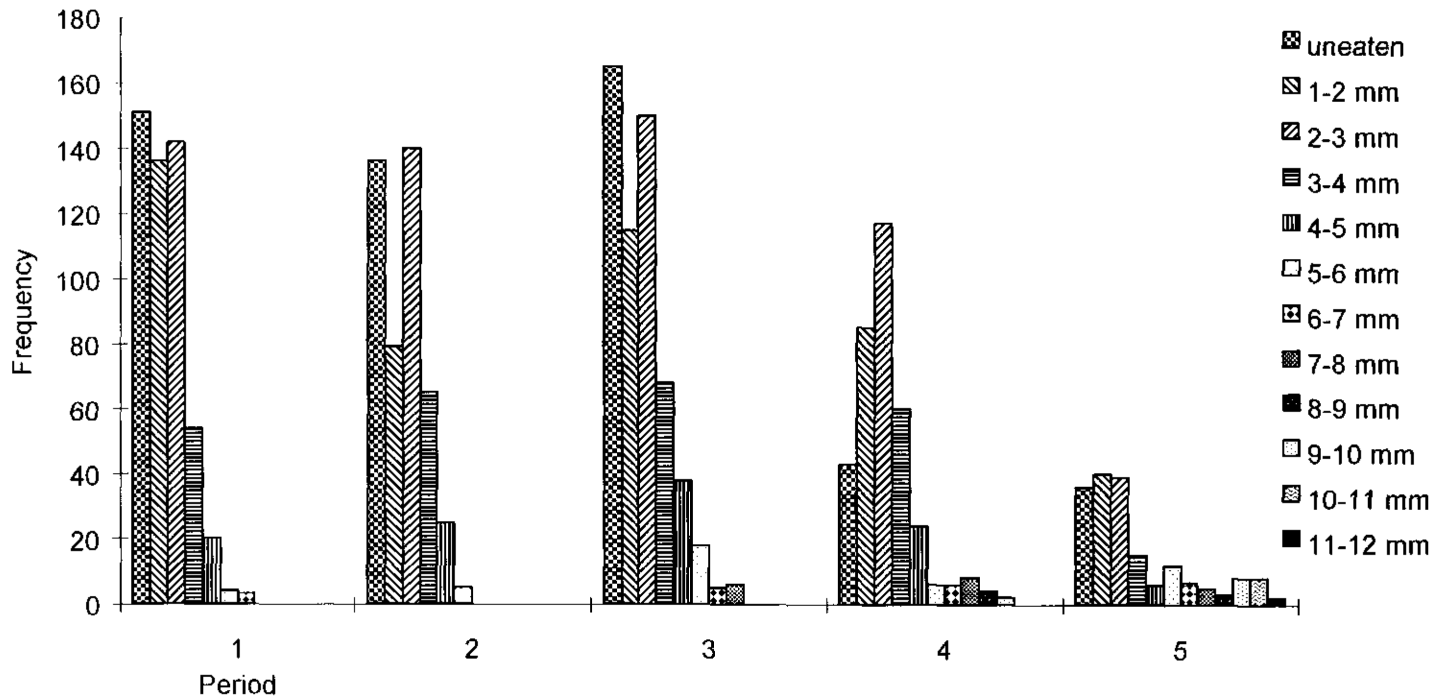

Figure 2. Number of times (frequency) that branches had been eaten up to a certain diameter, for all fodder trees combined in different periods (dry season = period 1 and 2, transitional = period 3, rainy season = period 4 and 5).

Discussion

Palatability of tree fodder has often been attempted to assess through short term cafeteria type intake trials. These trials do not take in to consideration the fact that animals can be trained to consume fodder which they do not like the first day they are exposed to it. Zero-grazing units, the common dairy management system in central Kenya, offer excellent opportunities for such a diet adaptation process. Palatability can be an important factor for the voluntary intake of fodder, such as the supplements used in this trial. Of the tree fodder, mulberry had the highest voluntary intake, comparable to dairy meal (Table 3). The high voluntary intake and the fact that the bark was eaten are indications of high palatability of mulberry.

Table 1 and 2 show that consumed tree fodder has a higher nutritive value than offered material. Heifers are able to select the most nutritious parts from the fodder. A selectivity index can be obtained for the tree fodders from the amount left over divided by the amount offered. A high selectivity index indicates sharp selection by heifers. Similarly, a nutrient index can be obtained through dividing nutrient concentration in consumed material by concentration in offered material (Table 4). Selectivity index and the nutrient indices are highly correlated; $R = 0.94$, 0.98, and 0.93 for CP, IVDMD and rumen degradability respectively ($p < 0.021$). The highest selectivity for tree fodder in this trial was able to increase CP content of ingested material with 28 %, IVDMD and rumen degradability each with 15 % compared to offered material. Therefore, when diets with fodder trees are formulated, it is important that feeding value of ingested food is used. If not, feeding value of the fodder tree supplement will be underrated and uneconomical high quantities of it will be used. Basal diets of grass are generally cheaper to produce than protein rich fodder because of higher biomass production of grass.

The heifers selected parts that were higher in soluble and condensed tannins than the offered material, for all tree supplements. Condensed tannins are generally considered to decrease organic matter digestibility (Lowry, 1990) but in this trial the higher levels of condensed tannins in consumed tree fodder were accompanied by higher IVDMD and rumen degradability. Other factors such as CP, NDF or ADF might have had a stronger influence on IVDMD and rumen degradability. Selection

Table 4 Selectivity index (left over DM/ consumed DM) and nutrient index (nutrient concentration in consumed DM/ nutrient concentration in offered DM) for CP, *in vitro* dry matter digestibility (IVDMD), *in sacco* rumen dry matter degradability of fodder.

Species	Selectivity index	Nutrient index		
		CP	IVDMD	Degradability
Calliandra calothyrsus	0.248	1.121	1.076	1.100
Morus alba	0.153	1.100	1.054	1.074
Manihot glaziovii	0.342	1.278	1.153	1.150
Leucaena diversifolia	0.315	1.174	1.155	1.111
Pennisetum purpureum	0.091	1.019	1.007	1.005

of younger material within the tree fodder might have caused higher tannin levels (Lowry, 1990) although this contradicts observations of Salawu *et al.*, (1997b) who found increasing condensed tannin levels with increasing age of leaves of *C. calothyrsus*.

From Figure 1 a generalisation can be made for the thickness of consumed twigs. Twigs for calliandra are mostly consumed with diameters up to 4 mm, for leucaena and mulberry up to 3 mm. Some woody twigs with smaller diameters are also not consumed. However, when rains are continuous, branch diameters of calliandra and mulberry increase rapidly. During the rainy season, when weekly rainfall exceeds 40 mm, succulent branches of calliandra are consumed up to 12 mm, mulberry up to 9 mm and leucaena up to 4 mm. Consumption of other parts of fodder trees than leaves and twigs might depend on a cow's individual preference.

The average DMI for all heifers was higher than expected. The mean for the whole experimental period was 105.4 g/kg $LW^{0.75}$ which corresponds with 2.8 % of the mean final live weights or 3.0 % of the mean initial live weights. As napier was fed *ad libitum*, the proportion of fodder tree or dairy meal supplement in the diets was less than planned, 16.2 in stead of 25 %. The average *in vitro* digestibility of ingested supplements was 650 g kg^{-1} DM and of napier 405 g kg^{-1} DM, which corresponds with metabolizable energy (ME) values of 9.93 and 6.18 MJ per kg DM respectively. Thus the calculated average ME intake for the average live weight

(173 kg) was 34.2 MJ, whereas the requirement for heifers (McDonald *et al.*, 1981) of this weight with live weight gains of 303 g per day is 28 MJ ME. DCP intake for the average weighed heifer was 367 g, whereas the requirement was 290 g. These calculations show that the diets were well balanced in terms of ME and DCP.

If the rations that were used in the experiment were fed to lactating cows of 350 kg live weight, and if the intake per kg metabolic live weight would have been the same, ME supply would have been the limiting factor for milk yield. The milk yields for diets with calliandra, mulberry, cassava tree, leucaena or dairy meal would have been 2.5, 3.9, 3.3, 2.6 and 4.5 kg respectively. The digestible protein levels in the diets would have been enough for 5.8, 7.5, 8.2, 6.9 and 7.6 kg milk respectively. The lower DMI of cassava tree compared to other supplements was compensated by an increased napier consumption of 2.0 g kg^{-1} live weight (Table 3). A cow weighing 350 kg live weight would therefore eat 162 g DM or 566 g fresh napier more when supplemented with cassava tree than when supplemented with the other feed stuffs.

The quality of napier used in the experiment was below normal because of the stage of growth at which it was harvested. The figure for digestibility used to calculate milk production was 40.5 %. Anindo and Potter (1994) report digestibilities of napier ranging from 56 % in the dry season to 72 % in the wet season with 8 week cutting intervals. If such quality of napier were used, milk yields would be considerably higher than in the above made calculations.

The outcome of the experiment has shown that the first hypothesis stated in the introduction of this paper was correct; the type of tree fodder can influence the growth rate and milk production of cattle. The second hypothesis proved partly correct. The determining animal productivity effect for cassava tree, leucaena and calliandra appears to be selectivity and nutritive value but for mulberry it appears to be voluntary intake. The combination of nutritive value , voluntary intake and selectivity determined the amounts of nutrients consumed. As a result, cattle would produce more milk when given mulberry or cassava tree than when given calliandra or leucaena. The extend farmers use mulberry and cassava tree as fodder for dairy cattle is comparable to calliandra. However, most research in Kenya is currently focused on calliandra. The findings of this experiment would therefore justify more research on mulberry and cassava tree.

Conclusions

The type of tree fodder given to dairy animals has an effect on amounts of nutrients consumed and potential milk production. In this trial, mulberry and cassava tree had the highest potential. Dairy heifers select parts of tree fodder, within a species, with high digestibility, CP content but also high tannin content. Stem diameters that are eaten vary for different fodder tree species. These factors should be taken in to consideration when tree fodder samples are taken and when they are analysed for nutritive value.

As milk production was not actually measured in this experiment, there is a need for on station feeding trials with lactating cows fed on mulberry and cassava tree, to more accurately determine milk production responses. At the same time, on farm feeding trials with lactating cows are necessary to ensure farmers involvement, which will provide a way to assess farmers' acceptability for wider use of these unconventional fodder trees.

Acknowledgement

The author wishes to thank the members of the National Agroforestry Research Project in Embu for their support and Richard Coe for his advice on the statistical analysis. The work has been made possible through financial support from Swedish International Development Co-operation Agency (Sida), Kenya Agricultural Research Institute, Natural Resources Institute (UK), and Directoraat Generaal Internationale Samenwerking (DGIS, the Netherlands).

Chapter 7

Feed intake and selection of Kenyan fodder trees by dairy heifers

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Tropical Grasslands (Submitted)

Chapter 7

Feed intake and selection of Kenyan fodder trees by dairy heifers

Abstract

A trial was conducted in the central Kenyan highlands to determine the dry matter intake (DMI) by dairy heifers for napier grass (*Pennisetum purpureum*) plus supplements of either *Calliandra calothyrsus*, *Tithonia diversifolia*, *Lantana camara*, *Ficus sp*. or dairy meal. Five Ayrshire heifers were stall fed and exposed to each diet in a latin square design, providing five replicates in five periods. Napier grass was supplied ad libitum and supplements at 30 % of estimated daily DMI. Plant parts, twig diameters and crude protein (CP) content, in vitro digestibility and, in sacco rumen degradability of consumed material were determined. Selection and nutrient indices were calculated in order to assess the effect of selectivity on nutrient concentration of consumed material. The proportion of uneaten branches, irrespective of consumed leaves, was 98 % for ficus, 72 % for tithonia, 17 % for lantana and 12 % for calliandra. Selection indices were different for the treatments ($p<0.001$, LSD = 0.074) with adjusted means of 0.18 for calliandra, 0.49 for tithonia, 0.27 for lantana and 0.31 for ficus. The voluntary intake of the supplements were significantly different; dairy meal had the highest; calliandra, ficus and lantana were within a close range; and tithonia had the lowest voluntary intake. Rumen degradable protein was insufficient in all diets including dairy meal. Higher inclusion levels of mulberry, calliandra, tree cassava and lantana are likely to increase energy supply and RDP levels in the rumen, and indirectly increase energy availability through better fermentation efficiency.

Keywords: Tropics; Dairy cattle; Browse; Small scale; Rumen degradable protein

Introduction

In the highlands of central Kenya dairy farming is predominantly small scale with exotic dairy breeds. Basal feeds consist of napier grass (*Pennisetum purpureum*), banana pseudo stems and maize stovers. As rainfall follows a bimodal pattern there are two dry seasons per year, during which there is a shortage of feed. The available feed is of low quality especially lacking protein. Fodder trees are known to provide green foliage with high protein concentrations and high concentrations of other nutrients during the dry season, which make them good supplements to low quality basal diets. There are many indigenous or naturalized fodder trees that are used by farmers but of which little is known in terms of quality (Roothaert and Franzel, in press). *Calliandra calothyrsus,* an exotic tree from Latin America, has been used extensively in Kenya (Franzel *et al.*, 1996a). Calliandra, however, has a relatively low digestibility of dry matter and crude protein, probably due to high levels of condensed tannins (Palmer *et al.*, 1994; Ahn *et al.*, 1989). This stresses the need to diversify the use of tree species for fodder, as over reliance on one species can lead to severe loss by farmers (Roothaert and Paterson, 1997).

Not only the type of fodder is important in animal nutrition but also the way in which it is fed. It is known that small ruminants are very capable to select most nutritious parts of a fodder through their small mouth structure, even when the fodder is chopped (e.g. Wahed *et al.*, 1990; Osafo *et al.*,1997). Osafo *et al.* (1997) demonstrated that cattle are also able to select more nutritious parts of stall fed sorghum stover, both chopped and unchopped, but that only in unchopped material this resulted in a substantial increase in dry matter intake. Selective behaviour of browsing cattle has been demonstrated several times in terms of plant species selection (e.g. Backlund and Bellskog, 1991; Mnene *et al.*, 1996; Winder *et al.*, 1996). However, cattle are also able to select within fodder tree species, as demonstrated in a feeding trial with dairy heifers in Kenya (Roothaert, 1999). Dairy heifers consumed more digestible protein when fed a diet including *Morus alba* (mulberry) or *Manihot glaziovii* (cassava tree) than calliandra or *Leucaena diversifolia*, not only because of differences of digestible crude protein concentration in the material but also because of the ability of cattle to select the parts with the highest concentration.

The hypothesis tested in this study is that several indigenous fodder trees would have higher nutritive value than calliandra and result in better animal performance, when fed as a supplement to a basal diet of napier grass and allowing a certain degree of selection. The species tested in this study, *Tithonia diversifolia, Lantana camara* and *Ficus spp.*, are among the nine most popular indigenous and naturalized fodder trees in the subhumid zone of central Kenya, and the latter two are also much used in the slightly drier zones (Roothaert and Franzel, in press). The objectives of the study are to quantify selection within tree fodder species by heifers in terms of consumed twig diameters and in terms of differences of nutritive value of selected and unselected fodder; and to determine differences of animal responses among diets with different fodder tree species.

Materials and methods

The experiment was carried out at the Regional Research Centre of the Kenya Agricultural Research Institute (KARI) in Embu, in the central Kenyan highlands. The Research Centre is situated 1490 meters above sea level, 00°30' S and 37°27' E. The soils in the area are humic nitosol (FAO classification) or typic palehumult (USDA classification) (FURP, 1987) of moderate to high fertility. The experiment was conducted from 9 January to 24 April 1998, divided into 5 periods of 3 weeks each. Although this would normally be the dry season in this region, due to excessive rains of *el Niño*, monthly rainfall for the months of January, February, March and April was 166, 165, 163 and 213 mm, respectively. There were peaks of rainfall in period 2 and period 4, and there was a no rain in period 3.

Animals

A feeding trial was conducted with five Ayrshire heifers with initial ages ranging from 9 to 11 months, and initial live weights ranging from 85 to 124 kg. Before the start of the experiment they were dewormed with Wormicid Plus®, 1.5 % w/v Levamisole HCl B.P. Vet, 8.0 % w/v Bithionol Sulfoxide. The first week of March 1999 the animals were vaccinated with a combined vaccine of black quarter and anthrax. Every week they were sprayed against ticks with Triatix®, 12.5 % w/v Amitraz, a diamidid. The animals were kept in individual pens of 2.7 m x 1.9 m and were allowed to exercise together in a paddock of 16 m x 10 m every day from 8.00 am to 9.00 am and from 1.00 pm to 4.30 pm. They were fed twice a day at 9.00 am and 4.30 pm. Individual feeding troughs were designed such that spilling of feed was minimised. Commercial mineral licks were provided and water was offered ad libitum.

Fodder

Pennisetum purpureum (napier grass) was fertilized with CAN fertilizer (27 % N) at a rate of 100 kg per ha, before the start of the experiment. The grass was harvested at ground level when it had reached a height of 1.5 m. In case it had grown taller, only the top 1.5 m was used for fodder, and the remaining returned used as mulch. The grass was hand chopped to 2 cm length. The fodder trees used were *Calliandra calothyrsus, Tithonia diversifolia, Lantana camara*, and *Ficus thonningii*. Calliandra was planted in April 1994 with seedlings at 20 000 trees ha^{-1}, tithonia in April 1996 with cuttings at 30 000 trees ha^{-1}. Both calliandra and tithonia had been harvested regularly at 50 cm above the ground, when tree height had reached 150 to 250 cm. Lantana was harvested from abundantly available wild growth along pathways and roads of the KARI Research Centre, which had been slashed yearly at approximately 30 cm above the ground. Ficus was harvested from four mature trees, 7 to 12 m tall, growing along the boundary of the KARI office complex. The tree fodder of all species that was fed to the heifers consisted of leaves, petioles, succulent twigs, figs in case of ficus, and flowers in case of tithonia. One batch of commercial dairy meal with 160 g CP kg^{-1} DM was bought that lasted throughout the experiment.

Experimental design and procedures

The experimental design was a Latin Square with 5 heifers, 5 periods and 5 treatments. In one period all heifers were on a different treatment. Each heifer was allocated a different treatment every period, in order to obtain 5 replicates per treatment. The basal diet was napier grass and the treatments were different supplements: calliandra, tithonia, lantana, ficus and a control of dairy meal. Total daily dry matter (DM) intake was predicted to be 3 % of live weight in kg (Roothaert, 1999). An extra DM allowance of 0.6 % of live weight was given to supply feed ad libitum. The offered feed ratio napier grass to supplement was 70 to 30 % on a DM basis, resulting in 2.52 and 1.08 % of live weight, respectively. The amounts offered were revised weekly according to the amounts left over by the individual heifers. Each treatment period lasted three weeks. Although period 1 started with 5 heifers, the 2 smallest (both 67 kg live weight) were replaced with bigger heifers halfway through the period. The 2 small ones had been weaned only a short time before and lost weight because they could not adapt easily to a rigid basal diet of napier grass. They were on treatments of ficus and dairy meal, the data of which were subsequently excluded from analyses in the first period.

The amounts of the feeds offered were recorded every feeding time, the amounts left over were weighed and recorded every morning at 8.00 am. Grass and tree fodder left overs could easily be separated. Daily samples were taken of offered and left over napier grass and supplements, and were frozen within 1 hour. At the end of each period, the frozen samples were pooled into groups of type of supplement and napier grass, and subdivided into offered and left over feed. These frozen sample groups were then divided into 2 replicates. One replicate was dried in an oven at 60°C, ground and passed through a 1 mm sieve. The oher replicate was freeze dried, ground and passed through a 1 mm sieve. Another sampling of offered napier grass and supplements was carried out twice weekly in order to determine

Table 1 In vitro dry matter digestibility (IVDMD, g kg^{-1} DM), in vitro crude protein digestibility (IVCPD, g kg^{-1} CP) and in sacco dry matter degradability (ISDMD, g kg^{-1} DM) of tree fodder and dairy meal.

Species	IVDMD	IVCPD	ISDMD
Calliandra calothyrsus	595	763	662
Ficus thonningii	555	650	747
Lantana camara	645	683	895
Tithonia diversifolia	704	892	945
Pennisetum purpureum	598	833	
Dairy meal	764	903	

DM content. These samples were dried immediately in an oven at 100°C and discarded after weighing. Voluntary intake of the different tree supplements was measured through mean DM intake of supplement. Selection was expressed as indices calculated through the amount of supplement left over divided by the amount consumed. Before and after the experiment, body fat and muscle condition of the heifers was visually assessed, through use of scores possibly ranging from 1 (emaciated, outstanding spine, sunken back) to 5 (too fat, spine not visible, rounded back). The heifers were weighed weekly.

Chemical analysis

DM, ash and crude protein (CP) concentrations were analysed for all samples following the procedures of the Association of Official Analytical Chemists (AOAC, 1990). Neutral detergent fibre (NDF) was determined according to Van Soest and Robertson (1985). Soluble tannins and condensed tannins were analysed according to the methods of Reed *et al.* (1985) and Reed *et al.* (1982), respectively. In vitro digestibility and in sacco rumen degradability of DM and CP were determined on all samples but the results were unreliable. The in vitro and in sacco analysis were therefore repeated on other samples from representative edible fractions of fodder trees (Table 1). The method of Tilley and Terry (1963), modified by Van Soest and Robertson (1985), was used for in vitro digestibility of both DM and CP. CP digestibility was calculated with the formula:

$$D = 1 - ((N\ \%\ \text{residue} \times g\ \text{residue}) / (N\ \%\ \text{sample} \times g\ \text{sample})).$$

In sacco rumen degradability of DM was determined by the method of Ørskov *et al.*, (1980), with 48 hours incubation in the rumen of cross bred cattle fed on Rhodes grass hay ad libitum and 2 kg cotton seed cake supplement per head.

The analyses of CP, NDF, in vitro digestibility and in sacco degradability were carried out with samples oven dried at 60°C; tannins were analysed with freeze dried samples. Analysis of tannins, in vitro and in sacco digestibility were carried out at the International Livestock Research Institute in Debre Zeit, Ethiopia. To calculate the amounts of in vitro digestible CP (IVDCP) of the actual consumed fodder, the total amount of the nutrients in left over feeds was subtracted from the total amount offered.

Branch diameter studies

A special study was conducted during the last two days of each period to determine the diameters of eaten twigs and branches. Tree branches and stems of about 60 to 100 cm length with fodder attached were given to the heifers in their troughs during the evening feeding session. At 8.00 am the next morning, the diameters of the twigs at the places where the fodder was browsed were measured. A DM allowance was added to the usual ration to compensate for the inedible woody parts. The eaten branches were counted and divided into groups with diameters of 1 to 2, 2 to 3, 3 to 4 mm etc.

Selection and nutrient indices

A selection index (SI) was determined for every supplement to quantify selectivity for each individual heifer. The effect of selection on nutrients consumed was expressed in a nutrient index (NI) for every supplement and napier. The indices were calculated as follows:

SI = (amount supplement DM left over) / (amount of suppl. DM offered)

NI = (nutrient concentration in consum. DM) / (nutr. conc. in offered DM)

Selectivity increases when SI increases. Effect of selection on nutrient concentration is positive when NI is bigger than 1. This effect intensifies, positive or negative, as NI increases from 1 or moves to 0 from 1, respectively.

Statistical analysis

Every feeding period lasted 21 days; seven days of adaptation to the new treatment, twelve days to determine the DM intake of the feeds, and the last two days to determine diameters of branches consumed. The data for intake and diameter of eaten branches were subjected to analysis of variance using the computer package Genstat 5.3 (Genstat Five Committee, 1993). Reported means were adjusted for missing values.

Results

Condition of the heifers

Body conditions of the animals were quite uniform both at the beginning and at the end of the trial, but the average score dropped from 3.2 at the beginning to 2.4 at the end. The heifers grew well during the experiment with an average growth of 376 g per day. During period 5, the heifer which fed on lantana developed problems in swallowing. On examination, a big lump of fodder was found stuck between her teeth. After it was removed with some force the swallowing improved, but the heifer remained salivating excessively for about a week. As this problem happened during the period of data collection of DM intake, and because her intake figures were exceptionally low during this period, her data were excluded from the analysis.

Dry matter fluctuation and variability of nutritive value

DM content of grass and supplements varied over time. Only napier grass and lantana showed a pattern following rainfall, containing less DM when rainfall increased. DM content of tithonia decreased when harvesting interval became shorter. CP concentration dropped during the experiment for calliandra, lantana, ficus and napier grass, whereas it increased for tithonia. Ash concentration increased for tithonia and remained constant for other feeds, during the trial. Nutritive value varied among offered tree fodder supplements (Table 2). CP concentration of offered tithonia was 1.9 times higher than of ficus. Ficus had the highest NDF concentration and tithonia the lowest. Soluble tannins were 3.8 times higher in calliandra than in tithonia. Condensed tannins were at least five times higher in ficus than in all other feeds.

Branch diameters

The proportion of uneaten branches, irrespective of consumed leaves, was 98 % for ficus, 72 % for tithonia, 17 % for lantana and 12 % for calliandra (Fig. 1). Succulent twigs of ficus were only 20 – 50 mm long, much shorter than succulent twigs of other fodder tree species. Sessile, unripe figs of 10 –20 mm diameter were often present in the offered material but they were not consumed by any heifer. Leaves including petioles, however, were readily consumed, often up to 95 % of available foliage. Flowers were sometimes present in material of calliandra, tithonia and lantana. In calliandra and lantana these were eaten. In tithonia they were eaten by one heifer, refused by another, and another heifer only ate the petals leaving the big receptacles of the flowers. During period one, lantana fodder contained fruits, which were also eaten. Because ficus branches were hardly eaten, differences of diameters of consumed branches were tested only for calliandra, tithonia and lantana. Diameters were different ($p=0.005$); means were 3.7 mm for calliandra, 3.6 mm for tithonia and 2.1 mm for lantana. Period had no significant effect on diameter ($p = 0.26$), although diameters were 0.7 mm smaller during the dry period 3, compared with the overall mean.

Table 2 Chemical composition (g kg^{-1} DM), soluble tannins (g kg^{-1} DM), and condensed tannins (absorbency units per gram fibre) of offered (O), left over (L) and consumed (C) fodder, n=5.

Species		DM (as fed)		CP		Ash		NDF		Soluble tannins		Cond. tannins	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Calliandra calothyrsus	O	308	10.4	229	10.4	62	1.4	662	23.2	255	12.2	26.3	2.89
	L	349	27.2	121	6.7	59	2.5	733	17.8	112	8.8	15.5	1.17
	C			255	17.0	63	1.2	648	22.4	289	20.3	28.7	3.28
Tithonia diversifolia	O	146	13.4	266	7.0	135	6.9	529	8.4	66	5.3	15.8	0.56
	L	167	26.1	218	9.2	140	11.1	577	17.4	69	2.9	11.5	1.52
	C			317	21.0	122	6.6	490	22.6	62	13.3	19.1	1.18
Lantana camara	O	223	4.8	177	5.0	97	2.2	625	23.3	141	21.8	14.0	0.73
	L	376	2.7	105	6.8	76	1.5	752	24.5	75	17.1	11.3	1.28
	C			227	7.9	115	7.8	531	46.9	175	27.4	15.9	1.44
Ficus thonningii	O	285	14.5	140	9.8	92	3.6	680	11.4	185	21.8	141.0	31.40
	L	310	11.5	123	12.5	86	2.6	687	4.8	198	7.3	151.5	32.56
	C			147	8.1	95	3.7	681	14.0	176	39.3	133.3	59.13
Pennisetum purpureum	O	178	17.3	119	2.5	143	6.9	728	8.5	74	7.1	4.4	0.33
	L	177	17.9	79	3.4	134	11.5	795	9.9	28	6.7	8.0	1.93
	C			127	3.1	145	6.2	714	9.6	82	8.4	3.8	0.64
Dairy meal	O	902	1.7	164	1.9	61	5.4		11.8	46	0.5	8.90	0.28

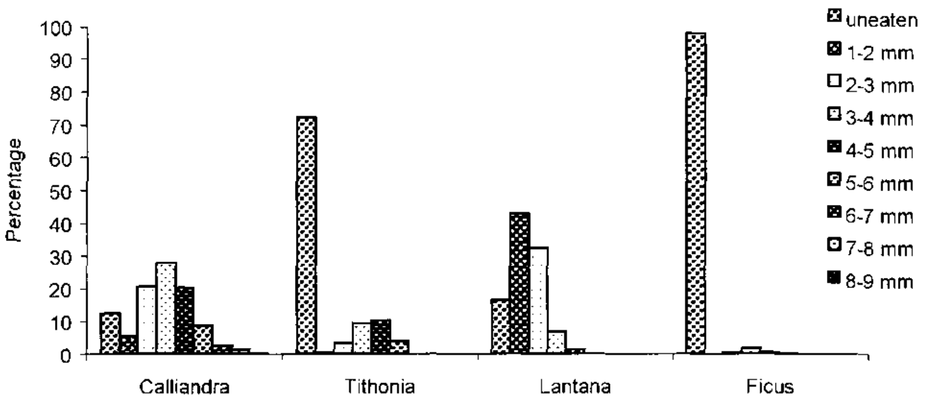


Fig. 1. Percentage of branches which had been eaten up to a certain diameter, for different fodder trees.

Selection and effect of selection on nutritive value

Selection indices were different for the treatments ($p<0.001$, LSD = 0.074) with adjusted means of 0.18 for calliandra, 0.49 for tithonia, 0.27 for lantana and 0.31 for ficus (Table 3). Nutrient indices were > 1 for CP and ash, except for ash in tithonia (Table 2 and 3). Nutrient indices for NDF were < 1, or almost equal to 1 in case of ficus. In ficus there were many unripe figs in the left over feed which might have contributed to the low fibre concentration of this fraction. Nutrient indices for soluble tannins were > 1 for calliandra and lantana, shrubs with high soluble tannin concentration in the offered material. Nutrient indices for condensed tannins were > 1 for all shrubs except ficus. The biggest difference between nutrients in offered and consumed material was found in lantana, even though the selection index was not the highest for this shrub.

Voluntary intake

The voluntary intake of the supplements were significantly different (Table 3); dairy meal had the highest; calliandra, ficus and lantana were within a close range;

Table 3 Selection index (left over DM/consumed DM) and nutrient index (nutrient concentration in consumed DM/ nutrient concentration in offered DM) for CP, ash, NDF, soluble tannins (Soltan), condensed tannins and (Contan) of fodder.

Species	Selection index		Nutrient index				
	Supple-ment	*P.purp.*	CP	Ash	NDF	Soltan	Contan
Calliandra calothyrsus	0.23	0.25	1.114	1.006	0.979	1.133	1.091
Tithonia diversifolia	1.17	0.16	1.192	0.904	0.926	0.932	1.209
Lantana camara	0.38	0.20	1.282	1.186	0.850	1.241	1.136
Ficus thonningii	0.53	0.19	1.050	1.033	1.001	0.951	0.943
Pennisetum purpureum			1.067	1.014	0.981	1.115	0.865

and tithonia had the lowest voluntary intake. DMI of napier grass was not different among treatments although low intake of tithonia seemed to have been compensated for by higher intake of the basal diet of napier grass. Total DMI was highest for dairy meal and lowest for tithonia. IVDDM intake was similar for all fodder tree supplements but dairy meal scored significantly higher.

Discussion

The distribution pattern of diameters of eaten branches of calliandra in this study was similar to that of calliandra displayed in the earlier study (Roothaert, 1999), where it was concluded that twigs of calliandra were mostly eaten up to a diameter of 4 mm. Contrary to the previous study, there were no eaten twigs of 9 – 12 mm diameter, probably due to maturity of branches. From the two studies a recommendation can be made to farmers and researchers about the thickness of twigs to select for fodder. For tithonia it would be up to 5 mm, for calliandra up to 4 mm, for lantana, leucaena and mulberry up to 3 mm. For future nutritive analysis, no twigs should be included for ficus fodder. Farmers, however, might find it more practical to supply whole branches of this species. During months of heavy rainfall (more than 300 mm) diameters of succulent consumable branches of calliandra and mulberry increase.

Protein concentration of consumed feed increases as the opportunity for selection increases. Zemmelink *et al.*, (1972) found increasing CP concentrations in consumed hay by cattle, with increasing levels of offered hay, although differences were not significant. In the previous experiment with heifers by Roothaert (1999), selection indices were positively related to levels of nutrients in consumed feed, expressed as nutrient indices. In this study, however, there was no high correlation between selection index and nutrient indices; R values for CP, ash, NDF, soluble and condensed tannins in the tree fodder were 0.30, -0.48, -0.26, -0.71 and 0.60, respectively (Table 4). In Figure 2 the relationship between selection index and CP index is depicted, including data from both this and the previous experiment. Ficus was excluded since there was no variability in the parts selected; the consumed parts always consisted of leaves and petioles only. The regression was defined asymptotic, as there are limits to selectivity of cattle; at a certain point physical nature of both plant parts and mouth structure of cattle prevents the nutrient index to increase. The fitted curve in Figure 2 represents the following regression equation:

$$\text{CP index} = 1.31 - 0.31 * (0.056)^{SI}, \; R^2 = 0.48, \; p = 0.023$$

where SI = selection index

This equation suggests that the maximum CP index is 1.29, as the selection index approaches 1. Zemmelink (1986) found that the type of fodder species affects the effect of selectivity on digestible DM intake. It is likely that the type of tree species also influences the relationship between selection index and CP index. The maximum CP index for tithonia would probably be lower than 1.29, whereas for lantana and cassava tree it would be higher than 1.29.

When animals are fed napier grass and supplements ad libitum, it is difficult to predict the intake ratio. However, in this experiment the ratio was close to the desired one of 70 % napier grass and 30 % supplement. The proportions of consumed supplement in the total diet were 31.1, 18.6, 24.5, 27.0 and 32.5 % for calliandra, tithonia, lantana, ficus and dairy meal, respectively. Only the intake of tithonia was much lower than expected. Because of the high amount of left over

Table 4 Adjusted means of daily dry matter intake (DMI) of supplements, napier grass, total dry matter; left over dry matter of supplements, napier grass; total intake in vitro digestible crude protein (IVDCP); and total intake in vitro digestible dry matter (IVDDM); per kg metabolic live weight (g kg $^{-1}$ LW$^{0.75}$) for dairy heifers (n=5).

Species	DMI supplement	DMI napier	Total DMI	Left supplement DM	Left napier DM	Total IVDCP intake	Total IVDDM intake
Calliandra calothyrsus	32.0	71.0	103.0	6.6	16.8	11.5	61.5
Tithonia diversifolia	18.5	81.1	99.6	16.3	12.9	10.5	61.5
Lantana camara	25.5	78.3	103.8	9.9	14.2	9.5	63.3
Ficus thonningii	28.4	76.3	105.0	12.8	14.5	8.6	61.5
Dairy meal	36.9	76.8	113.6	-2.1	16.6	11.4	74.0
Significance level (p)	<0.001	0.145	0.035	<0.001	0.165	0.006	<0.001
SED	2.60	3.49	3.63	2.48	1.63	0.65	2.16

one can conclude that approximately 19 percent of total DMI is the maximum proportion that heifers will consume of tithonia. The lowest intake and highest amount of left over are also indications of the relatively low palatability of tithonia.

Potential milk production can be calculated for cows fed the diets of this experiment. A cow of 350 kg live weight would need 40 MJ metabolisable energy (ME) and 220 g DCP per day for maintenance (McDonald *et al.*, 1981). Average gross energy per kg DM is 18.4 MJ and conversion from digestible to metabolisable energy is 0.83. DCP consumption would allow a daily production of 12.7, 11.2, 9.8, 8.5 and 12.5 kg milk for calliandra, tithonia, lantana, ficus and dairy meal, respectively. Metabolisable energy is the limiting factor though; in diets with calliandra, tithonia, lantana, ficus and dairy meal energy would allow a milk production of 6.8, 6.8, 7.2, 6.8 and 9.7 kg, respectively. Because the IVDDM intake was not significantly different among different types of tree fodder, milk production differences as a result of energy intake are not significant either. One can conclude that the type of tree fodder has no effect on milk production at these feeding rations. Rations with dairy meal, however, provide about 3 kg more milk per day. The DMI

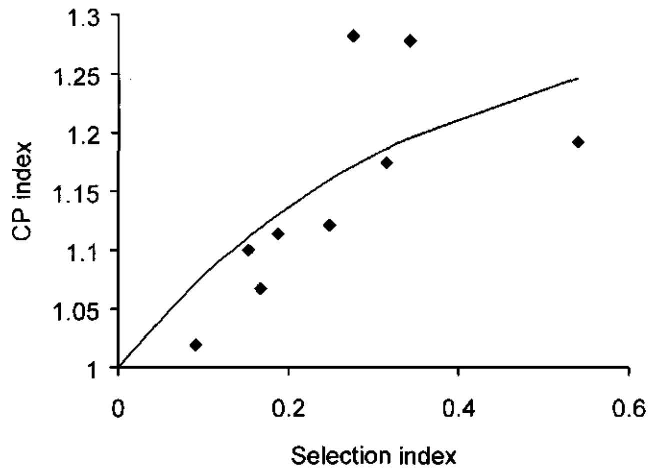


Fig. 2. Relationship between selection index and crude protein index.

figures used for lactating cows were based on metabolic live weight, which corresponds with an average of 2.43 % of live weight. If a more common figure of 3 % was used (Kariuki *et al.*, 1998; Anindo and Potter, 1986), predicted milk production would range from 10.2 to 13.8 kg per day. In the latter case dairy meal consumption would be 3.7 kg per day. However, most farmers use only about 2 kg of concentrates per day for various reasons such as lack of cash and variability of quality of the concentrates (Minae *et al.*, 1988; NDDP, 1994).

Fodder can only be digested properly if the micro flora and fauna in the rumen are well supplied with fermentable energy and nitrogen. The majority of a cow's energy requirement is supplied through volatile fatty acids which are produced in the rumen by microbes. At an optimal fermentation process, 24 to 30 g N is used by microbes for every kg of fermentable organic matter (McDonald *et al.*, 1988; Tamminga *et al.*, 1994). This corresponds with 176 to 221 g rumen degradable protein (RDP) per kg rumen degradable organic matter (RDOM), if the efficiency of conversion of RDP into microbial protein (MP) is 85 %. Several authors (Kamatali *et al.*,1992, Kaitho *et al.*, 1997a, Kariuki *et al.*, in press) have studied CP and OM degradability of calliandra with the in sacco technique described by Ørskov *et al.* (1980) using the following formulas:

$Rt = U + (1000\text{-}W\text{-}U)e^{-kd*t}$ (Robinson *et al.*, 1986)

where

Rt = residue at time t

U = truly indigestible residue (336 hour incubation)

W = water soluble fraction (0 hour incubation)

k_d = rate of degradation (fraction per hour)

ROMD (g kg^{-1} DM) = $[W + (D*k_d/(k_p + k_d))] * OM$ (Van Vuren *et al.*, 1991)

where

k_p = rate of passage from rumen (fraction per hour)

D = potentially degradable proportion (1000-W-U)

$RDP = W + (D * k_d/(k_p + k_d))$ (Perera *et al.*, 1992)

Using the above mentioned formulas, the amount of RDP per kg RDOM in calliandra were 129, 168 and 279 g in the studies of Kamatali *et al.* (1992), Kaitho *et al.* (1998) and Kariuki *et al.* (in press), respectively. The material of calliandra they used was quite uniform with CP concentration within the range of 219 to 225 g kg^{-1} DM. One can therefore conclude that calliandra as a fodder itself has sufficient or almost sufficient RDP for efficient rumen fermentation. Although these values are not readily available for the other fodder tree supplements used in this experiment, they can be estimated using coefficients. In Table 5 coefficients are given of ISDMD of supplements divided by ISDMD of calliandra. RDOM is calculated by multiplying these coefficients by RDOM of calliandra, an average value derived from experiments by authors mentioned earlier. In a similar way RDP is determined for the supplements. The amount of RDP is divided by the RDOM, for the total diet including napier grass. An RPD value of 460 g kg^{-1} CP was used for napier grass, according to Kariuki *et al.* (in press). Napier grass alone had an RDP/ RDOM ratio of 110 g kg^{-1}. All treatments have a RDP ratio bigger than napier grass, but lower than

Table 5 Rumen degradable organic matter and rumen degradable crude protein, derived from in sacco DM degradability, ROMD of calliandra and rumen protein degradability of calliandra.

Species	ISDMD[a] (g kg^{-1} DM)	ISDMD coeff.	ROMD suppl. (g kg^{-1} DM)	Proportion suppl.[b]	ROMD total[c] (g kg^{-1} DM)	RPD suppl. (g kg^{-1} CP)	CP suppl. ingested (g kg^{-1} DM)	RDP suppl. (g kg^{-1} DM)	RDP total[d] (g kg^{-1} RDOM)
C. calothyrsus	662	1	401[e]	311	486	339[f]	255	86	137
T. diversifolia	945	1.43	572	186	534	484	317	153	142
L. camara	895	1.35	542	245	529	458	227	104	131
F. thoningii	747	1.13	452	270	505	383	147	56	114
M. alba	940	1.42	569	348	540	481	166	80	121
M. glaziovii	880	1.33	533	260	527	451	239	108	135
Dairy meal	770	1.16	547	325	532	601	164	99	134

[a] Values derived from 48 hours rumen incubation of representative edible fraction of tree fodder.
[b] g DM of supplement per kg total DMI. *M. alba* and *M. glaziovii* figures from Roothaert (1999), multiplied by factor 1.95
[c] ROMD rumen degradable OM from total diet, using an average ROMD value for napier grass of 525, calculated by Kariuki *et al.* (1998) and Anindo and Potter (1994).
[d] Combination of napier grass and supplements.
[e,f] Average of values calculated by Kaitho *et al.* (1997a), Kariuki *et al.* (in press) and Kamatali *et al.* (1992), at a rate of passage of 4 % per hour.

the minimum of 176. Tithonia, calliandra, tree cassava and lantana would be the best tree fodder for increasing available N for microbes in the rumen and they are comparable to dairy meal in this aspect. Mulberry and ficus would be less efficient. It is interesting to note that even dairy meal does not seem to provide enough RDP for optimal rumen fermentation of the total diet. This is caused by the low RDP of the basal diet, even though a good quality napier grass was used in this experiment. More RDP could increase fermentation and therefore increase available energy for the cows. Therefore, higher levels of tree fodder in the diet are necessary. The shortage of energy from tropical pastures for dairy cattle has also been recognised by Stobbs and Thompson (1975), although they had not identified the role of RDP. It is likely that the intake proportion of mulberry, calliandra, tree cassava, and lantana can still increase. Intake levels of tithonia are unlikely to increase whereas increased levels of leucaena would expose cattle to too high levels of the toxin mimosine, which becomes a problem at inclusion levels higher than 30 % for extended periods (Shelton and Brewbaker, 1994).

Conclusion

The hypothesis that supplements used in this experiment would cause higher intake of nutrients than calliandra and therefore result in better animal production has to be rejected. Available energy is likely to be the limiting factor for predicted milk production, caused by a lack of rumen degradable protein. Rumen degradable protein is insufficient in all diets including dairy meal. Higher inclusion levels of mulberry, calliandra, tree cassava and lantana are likely to increase energy supply and RDP levels in the rumen, and indirectly increase energy availability through better fermentation efficiency.

Chapter 8

General Discussion

Chapter 8

General discussion

East African experiences

Research on fodder trees has been carried out in East Africa in the context of different livestock production systems. There is scope for increased use of fodder trees in intensive systems (Chapter 2). Planting fodder trees is only possible in places where the seedlings are protected from browsing during the establishment phase.

Very little is known about the biomass production potential of indigenous fodder trees and shrubs (IFTS) in East Africa. Tuwei *et al.* (1998) compared the fodder production of 21 indigenous and exotic tree species and accessions in an on-station randomized block experiment at the Regional Research Centre in the subhumid zone of Embu District, central Kenya (Table 1). The trees were planted in rows, intercropped with sweet potato, and harvested 1 m above the ground every 3 months. Fodder production of the indigenous species was lower than the mean of the exotic species. In terms of useful energy yield, differences between *C. calothyrsus* and the indigenous trees are therefore relatively small. Assuming a high correlation between digestibility of DM and CP (Kaitho *et al.*, 1997a), *T. orientalis* would yield a similar amount of digestible CP per ha as *C. calothyrsus*. In the semi- arid zone in Mbeere District, an on-station experiment has recently been

Table 1. Comparison of dry matter yields and digestible nutrients yields of some fodder trees.

Species	Fodder yield [a] t ha^{-1} yr^{-1}	In vitro DM digestibility [b] g kg^{-1} DM	CP concentration [b] g kg^{-1} DM	Digestible dry matter t ha^{-1}	In vitro digestible CP [c] t ha^{-1}
Calliandra calothyrsus	6.0	379	217	2.27	0.49
Trema orientalis	3.0	590	232	1.77	0.41
Sapium ellipticum	2.6	645	146	1.68	0.25

[a] Tuwei *et al.*, 1998, [b] Tuwei, 1997, [c] IVDCP = IVDMD x CP

started comparing the on-station fodder production of the indigenous species *Crotalaria goodiiformis* and *Indigofera lupatana* with *Gliricidia sepium* and several *Leucaena spp.*, but conclusive results are not available as yet at the time of writing.

Farmers' knowledge

The most important factors that determined the differences in the farming systems are climate and farming intensity, and these have played an important role throughout the study. At the most intensive and most humid side of the range, IFTS were used most intensively in terms of harvesting management and sometimes propagation (Chapter 3). The consumers of the fodder differed among zones, reflecting the different roles of livestock in the system. The role of gender was more pronounced in the drier areas, as division of labour was less clear in the subhumid zone. Choice of species was in the first place determined by ecological adaptation.

Framers' criteria to assess quality of IFTS were related to the farming system and therefore differed among agroecological zones (AEZ). The roles of parameters such as palatability of IFTS for goats, compatibility of IFTS with other crops, health of the animals after eating IFTS, fattening potential of IFTS, and milk production of goats after eating IFTS, are different between the subhumid and the drier zones. The method of rating fodder tree species according to farmers' own criteria resulted in accurate differences among species. Farmers had specific knowledge about pests which affected IFTS; acknowledging that these pests occur is important for the final selection of IFTS for further research and development. *Trema orientalis* is a clear example of a tree which has almost all the desired characteristics of an ideal fodder tree, apart from the fact that its leaves are badly eaten by caterpillars during the time when it is needed most as a livestock feed. The incidence of caterpillars is an indication, however, of low tannin concentration of the fodder, which was also shown in Chapter 5.

Farmers knew the distinction between local and exotic species (Chapter 3). In the first instance it was not entirely clear whether farmers also knew the difference between indigenous and naturalized tree species, since the word for both terms in the local language is *míti ya gúkú*. However, at some follow up visits the old farmers could indicate some species which were considered local but which had come to Kenya a hundred years or more ago, and which were defined in this study as naturalized. These were *Lantana camara, Morus alba* and *Manihot glaziovii*. However, *Tithonia diversifolia* was classified as local by farmers but nobody knew that it was originally introduced into Kenya from South America. Other knowledge with important implications for IFTS is toxicity. Two *Acacia* species were associated with toxicity by farmers and did therefore not rank high in preference. *L. camara* remains a controversial species since it was sometimes mentioned as causing digestive problems and in other parts of the world it causes death of livestock, but in the study area it ranked high in preference, and adverse effects were hardly mentioned by farmers.

Adoption prospects

The feasibility of intensive use of IFTS was tested on-farm (Chapter 4). In the subhumid zone the question of whether IFTS have a chance for intensive use is not so much depending on the management aspect, but it is a species specific issue, determined by ease of propagation and compatibility with crops. In the drier zones, compatibility with crops is less important since there is relatively much land available at the potential planting niches of IFTS which are the soil conservation structures, the divisions between agricultural plots and the external farm boundaries. Propagation is not a major problem for intensive use of IFTS in the dry zones. Most species there are propagated by seeds, which are relatively abundant, and which easily germinate. Species such as *Indigofera lupatana*, and possibly others, germinate quicker when the seeds are scarified between two pieces of sand paper.

Slightly more complicated is the propagation of *Melia volkensii*; it requires extraction of seeds from the endocarp followed by sterile germination (Kidundo, 1997.). This process would be feasible for group nurseries, taking into account the great demand for these seedlings. Alternatively, wildings of this species are collected and transplanted in the farm. A major determinant for the adoption of intensive use of IFTS in the dry zones is the process of intensification of the livestock component of the farming system, indicated by practices such as tethering, fencing of grazing land, and upgrading of cattle and goat breeds. There is an indication that in the semi-arid zone the role of women in fodder tree technology development is more important than in the subhumid zone, as women's involvement in the on-farm experiment increased as it went on (Chapter 4).

The multi-purpose nature of most trees is another important factor for the adoption of fodder tree species. In the subhumid zone, negative impact of fodder trees on crops through competition for sunlight, water and nutrients, is compensated not only by the production of fodder but also by the provision of many other products as specified in Chapter 3. In all zones the type of other uses also seems to result in gender specific preferences. For instance, one can produce beehives from or hang beehives in *Cordia africana,* while men harvest the honey and produce *múratina*, an alcoholic drink mainly consumed by men.

Laboratory and farmers' assessment of nutritive value

It was possible to select IFTS on the basis of nutritive value through both laboratory and farmers' assessments, and there were strong relationships between the two methods (Chapter 5). Nutritive value has many aspects. Farmers' defined criteria related to nutritive value are palatability for cattle or goats, effect on health of the animal, milk production and fattening. Laboratory assessments of nutritive value are related to the predicted course of nutrients through the alimentary tract, the interactions among these nutrients, and the effect of anti-nutrients in this process. Criteria of farmers' assessment could, therefore, be seen as parameters resulting from nutritive value, as determined by laboratory analyses. Although farmers' assessment of palatability is strongly related to many laboratory parameters, in some individual cases other factors have a stronger influence, such as thorniness or yet undefined secondary compounds, which are not or cannot be analysed in the laboratory. Farmers' assessment of palatability is more accurate than assessments through feeding trials, probably because a long term evaluation is involved. Length of evaluation in palatability trials was also stressed by Kaitho *et al.* (1996).

Fodder intake and selection and its implications

In the first feeding trial, naturalized fodder species such as *M. alba* and *M. glaziovii* showed better results in terms of DM and nutrient intake than *C. calothyrsus* (Chapter 6). In the second trial, however, indigenous and naturalized species showed similar results as *C. calothyrsus* (Chapter 7). There is therefore potential for IFTS which can be fed to dairy heifers. The results would also apply to mature dairy cows, bearing in mind that animals need to be introduced to IFTS at an early age to maximize acceptance at a later age. There seems to be a limitation of the palatability of *T. diversifolia*, however, affecting nutrient intake for optimum milk production. At an approximately 30 % inclusion level of IFTS in the diet of dairy cows, milk production can reach 10.2 kg milk per day or more. At this feeding level milk production is 46 % higher than the average milk production recorded in the subhumid zone by Murithi *et al.* (1993) or 59 % higher than the production recorded by Minae *et al.* (1988) in the same zone. Higher levels of milk production are expected when the proportion of IFTS in the diet increases (Chapter 7).

The maximum nutrient index obtained in the experiments for CP was 1.28. This value is close to the asymptote of 1.29, derived from the regression equation between selection index and CP index. One could conclude that 29 % is the maximum potential increase of CP concentration in consumed tree fodder obtained through selection. However, there is a variability among tree species and one would need to increase experimental left over levels for forages with high CP indices, such as *L. camara* and *M. glaziovii*, to confirm this conclusion. Diameters of consumed fodder trees vary per species and increase during the rainy season for some species. This has an important implication on sampling procedures to assess and compare nutritive value of tree fodder consumed by cattle.

Biodiversity

The development of technologies with IFTS contributes to increased biodiversity on-farm, therefore reducing the risk of depending on too few fodder tree species (Chapter 2). Although it is questionable whether IFTS produce less in terms of useful fodder per unit land area than exotic species, even if they do, growing these trees does not necessarily cause a loss of opportunity. As trees are highly integrated in the farming system, a lower biomass production of these trees would probably mean less competition for associated crops, resulting in better crop yields. Research with *C. calothyrsus* and *L. leucocephala* has shown that intercropping these trees with the grass *P. purpureum* results in increased dry matter production per ha, and total dry matter production is similar for combinations (Nyaata et al., 1998). Similar effects are to be expected with the incorporation of IFTS in the farming system. There might also be advantages in mixing species within a line, but farmers mostly planted species grouped within the line (Chapter 4).

Role of IFTS

Shortage of CP in the diets of cattle has been recognized as a constraint to milk production in stall fed systems with basal feeds of napier grass (Snijders, 1991). The same constraint applies to intensive systems in the drier zones, as grasses which form the basal feeds there have similarly insufficient CP concentrations (Kariuki, in press). The species with CP concentrations ranking in the top half have a minimum value of 175 g kg^{-1} DM in the subhumid zone and 138 g kg^{-1} DM in the two drier zones together, during the dry season (Chapter 5). These values are high enough to formulate productive rations with grass and crop residues. Effective protein degradability still needs to be determined for the promising IFTS in this study, because there is a large variability among species (Kaitho *et al.*, 1998). For calculation of rumen fermentation in Chapter 7 the relatively low CP degradability value for *C. calothyrsus* has been applied to all tree forages, at a risk of under estimating the true value of IFTS.

As there is a general shortage of fodder during the dry season (Minae *et al.*, 1988; Sutherland *et al.*, 1995), incorporating more IFTS in the farming system can relieve this problem, providing high quality feed. During the rainy season, the role of IFTS would be to improve the nutritive value of rations rather than to provide the bulk of feed.

Promising IFTS for central Kenya

In Chapter 2 a framework of activities was shown for the screening of IFTS. Activities were carried out to determine farmers' preference and knowledge, nutritive analysis, and animals' selection and intake. Some information was obtained about agronomic performance and propagation methods. On the basis of these selection criteria, a list of promising IFTS can be presented. Promising species for the subhumid zone are: *Ficus thoningii, L. camara, M. alba, M. glaziovii, S. ellipticum, T. diversifolia, T. orientalis, Triumfetta tomentosa* and *Vernonia lasiopus*. According to farmers' preferences, *F. thoningii, S. ellipticum* and *T. orientalis* would be best left to grow big and harvested through pollarding; other species would be harvested as hedges. All these species provide high quality fodder during both rainy and dry season, although digestible protein levels in *F. thoningii* are generally too low to classify as a protein supplement. A limitation of *T. diversifolia* as a supplement would be its low maximum intake. Low palatability of this species was also reported by Zemmelink *et al.* (1999). However, in Colombia, cattle, sheep, goats, rabbits and pigs readily consume *T. diversifolia* (Katto, 1997). There is a possibility that the accession from Colombia is more palatable. Adoption of *T. orientalis* might be hindered by pest incidence. *T. tomentosa* and *V. lasiopus* are much appreciated but not planted, probably because they germinate spontaneously at many sites on-farm.

Because of a large overlap of species, and in order to increase accuracy of comparison among species, the evaluation of species in the medium and semi-arid zones were grouped together. The most promising species here, for the same reasons as mentioned above, are: *A. ataxacantha, A. mossambicensis, C. goodiiformis, G. tembensis, I. lupatana, L. camara* and *M. volkensii*. Only *M. volkensii* would be pollarded, the other species would be harvested as hedges. All these species have a potential as high quality fodder supplement, although *A. ataxacantha, A. mossambicensis* and *G. tembensis* have some obvious limitations. *A. ataxacantha* does not provide enough energy, *G. tembensis* does not provide enough protein and *A. mossambicensis* is less nutritious during the dry season.

Future research

The ultimate productof fodder trees is increased animal production. Hardly any trials feeding IFTS to lactating cattle have been carried out in central Kenya, for practical reasons such as costs to run the trials and the difficulty to acquire the required quantity of fodder. On-farm feeding trials with lactating cattle would be needed as this type of research could reduce costs and provide direct farmers' participation. However, accurate milk yield responses would only be obtained through on-station feeding trials.

In order to be able to assess economic profitability of fodder tree technologies, agronomic performance data are required of IFTS. Although IFTS are grown in linear arrangements by farmers on a variety of niches, bordering a variety of crops, quick useful information would be obtained by solid agronomic experiments in a controlled environment, applying a cutting height and planting density commonly practiced by farmers. It would be advisable to let time of harvesting depend on the time needed per species to produce reasonable amounts of coppice shoots, e.g. 50 cm length, possibly resulting in different harvest frequencies among species. Reasons why farmers apparently do not like to mix different species within a line need to be assessed.

There is still a lack of information about protein quality of IFTS. Effective degradability of CP needs to be assessed of promising IFTS according to the methods of Robinson *et al.* (1986) and Perera *et al.* (1992). Protein concentration of consumed feed also depends on selectivity of animals. Asymptotic values of CP index as a function of selection index need to be determined for the promising IFTS.

Some issues remain unclear about individual IFTS species. For instance for *L. camara*, it needs to be investigated which role detoxifying rumen organisms, *Bos indicus* versus *Bos taurus*, physical immunity against the toxic triterpene acids lantadene A and B, plant provenance, and toxic threshold play in the absence of toxic cases in central Kenya. For *T. diversifolia* it would be useful to assess differences of dry matter intake among accessions of Kenya and Colombia. For *T. orientalis* it needs to be examined whether and how cutting regime can reduce incidence of caterpillars which consume the foliage.

References

Ahn, J.H., Robertson, B.M., Elliot, R., Gutteridge, R.C and Ford, C.W. 1989. Quality Assessment of Tropical Browse Legumes: Tannin Content and Protein Degradation. Animal Feed Science and Technology 27:147-156.

Akkasaeng, R., Gutteridge, R.C. and Wanapat, M., 1989. Evaluation of trees and shrubs for forage and fuelwood in Northeast Thailand. The International Tree Crops Journal, 5:209-220.

Akyeampong, E. and Muzinga, K., 1994. Cutting management of *Calliandra calothyrsus* in the wet season to maximize dry season fodder production in the central highlands of Burundi. Agroforestry Systems 27:101-105.

Alfonso, H.A., Figueredo, J.M. and Merino, N. 1982. Photodynamic dermatitis caused by *Lantana camara* in Cuba. A preliminary study. Revista de Salud Animal 4(2):141-150.

Anindo, D.O. and Potter, H.L. 1986. Milk production from Napier grass (*Pennisetum purpureum*) in a zero-grazing feeding system. East African Agricultural and Forestry Journal 52(2): 106-111.

Anindo, D.O. and Potter, H.L., 1994. Seasonal variation in productivity and nutritive value of Napier grass at Muguga, Kenya. East African Agricultural and Forestry Journal, 59(3): 177-185.

Antilla, L.S., Johansson, G.M. and Johansson, S.G. 1994. Browse preference of Orma livestock and chemical composition of *Prosopis juliflora* and nine indigenous woody species in Bura, Eastern Kenya. East African Agricultural and Forestry Journal, Special Issue 58: 83-90

AOAC (Association of Official Analytical Chemists). 1990. Official methods of analysis. 15th Edition. AOAC Inc., Arlington, Virginia, USA.

Atta-Krah, A.N. and Sumberg, J.E. 1987. Studies with *Gliricidia sepium* for crop-livestock production systems in West Africa. In: *Gliricidia sepium* (Jacq.) Walp.: Management and Improvement. Proceedings, Workshop held at CATIE, Turrialba, Costa Rica, June, 1987. Special Pub. 87-01 p. 20-28. Nitrogen Fixing Tree Association, Hawaii, USA.

Atta-Krah, K. 1996. From research plots to farmer adoption: an approach for agroforestry research and development interaction. In: Mugah, J.O. (Ed.) People and Institutional Participation in Agroforestry for Sustainable Development. Proceedings of the First Kenya National Agroforestry Conference. 25-29 March, 1996. Kenya Forestry Research Institute, Muguga, Kenya.

Backlund, M. and Bellskog, J. 1991. The role of trees and shrubs in livestock production in central Tanzania - A survey of their nutritive value during the dry season. *Working Paper 175.* Swedish University of Agricultural Sciences. International Rural Development Centre. Uppsala, Sweden. 27 pp.

Baggio, A. and Heuveldop, J. 1984. Initial performance of *Calliandra calothyrsus* Meissm. in live fences for the production of biomass. Agroforestry Systems 2: 19-29.

Bayer, W. 1990. Use of browse by Fulani cattle in central Nigeria. Agroforestry Systems 12: 217-228.

Bennison, J.J., and Paterson, R.T., 1993. Use of Trees by Livestock 3: Gliricidia. Natural Resource Institute, Chatham, U.K., 18pp.

Blair, G.J., Masud Panjaitan, D.A., Palmer, B. and Sudjad, M., 1988. An evaluation of tree legumes on an acid ultisol in South Sumatra, Indonesia. Journal of Agricultural Science Camb., 111:435-441.

Borel, R. and Romero, F. 1991. On-farm research in a silvopastoral project: a case study. Agroforestry Systems 15(2-3): 245-257.

Buttler, W.G., Flux, D.S., Peterson, G.B., Wright, E.W., Glenday, A.C. and Johnson, J.M., 1957. Goitrogenic effect of white clover (*Trifolium repens* L.). *N.Z.* Journal of Science Technology Sect. A. 38:793-802.

DAREP, 1994. First Six Monthly Report (for the period August '93 to March '94). Kenya Agricultural Research Institute, Regional Research Centre, Embu.

Devendra, C. 1977. Cassava as a feed source for ruminants. In: Nestel, B. and Graham, M. (Editors), Cassava as Animal Feed. Proceedings of a workshop held at the University of Guelph, 18-20 April 1977. International Development Research Centre, Ottawa, Canada.

Devendra, C. 1990. The use of shrubs and tree fodders by ruminants. In: Devendra, C. (Ed.), Shrubs and Tree Fodders for Farm Animals. Proceedings of a Workshop in Denpasar, Indonesia, 24-29 July 1989. International Development Research Centre, Ottawa.

Dicko, M.S. and Sikena, L.K. 1992. Feeding behaviour, quantitative and qualitative intake of browse by domestic ruminants. In: A. Speedy and P. Pugliese (Eds.) Legume trees and other fodder trees as protein sources for livestock. FAO Animal Production and Health Paper No. 102, p. 129-144.

Djogo, A.P.Y. 1994. The Use of Forage Tree Legumes in Timor. In: R. C. Gutteridge and H.M. Shelton (Eds.) Forage Tree Legumes in Tropical Agriculture. CAB International, Wallingford, Oxon, UK, p. 374-380.

Dzowela, B.H., Mafongoya, P.L. and Hove, L., 1994. SADC-ICRAF Agroforestry Project, Zimbabwe 1994 Progress Report.

FAO 1997. Production yearbook 1996. Food and Agriculture Organization, Rome.

Fourie, N., Lugt, J.J. van der, Newsholme, S.J. and Nel, P.W., 1987. Acute *Lantana camara* toxicity in cattle. Journal of the South African Veterinary Association 58(4): 173-178

Francis, P.A. and Atta-Krah, A.N. 1989. Sociological and ecological factors in technology adoption: fodder trees in Southeast Nigeria. Experimental Agricultural 25: 1-10.

Franzel, S., Hitimana, L. and Akyeampong, E. 1995. Farmer participation in on-station tree species selection for agroforestry: a case study from Burundi. Experimental Agriculture 31:27-38

Franzel, S., Arimi, H., Murithi, F. and Karanja, J. 1996a. Boosting milk production and income for farm families: The adoption of *Calliandra calothyrsus* as a fodder tree in Embu District, Kenya. In: Mugah, J.O. (ed) Proceedings of the First Kenya National Agroforestry Conference on People and Institutional Participation in Agroforestry for Sustainable Development, pp 421-438. Kenya Forestry Research Institute, Muguga, Kenya

Franzel, S., Holding, C., Ndufa, J.K., Obonyo, O.C. and Weru, S.M. 1996b. Farmers and trees -- linking research and extension. Agroforestry Today 8(3)19-21

Franzel, S. Coe, R. Cooper, P., Place, F. and Scherr, S.J., in press. Assessing the adoption potential of agroforestry practices: ICRAF's experiences in subsaharan Africa. Paper presented at the International Symposium of the Association for Farming Systems Research-Extension, 29/11 – 4/12, Pretoria, South Africa. Accepted for Agricultural Systems

FURP, 1987. Fertilizer Use Recommendation Project (Phase I). Final Report, Annex III, Volume 24, Embu District. Trial Site 24.3. KARI Regional Research Centre. Embu, Kenya.

Genstat Five Committee, 1993. Genstat Five Release Three Reference Manual. Statistics Department, Rothamsted Experimental Station. Oxford University Press Inc., New York, 796 pp.

Gichuru, M.P. and Kang, B.T., 1989. *Calliandra calothyrsus* (Meissn.) in alley cropping systems with sequentially cropped maize and cowpea in Southwestern Nigeria. Agroforestry Systems 9:191-203.

Gondwe, A.T.D., 1974. Studies on the hydrocyanic acid contents of some local varieties of cassava (*Manihot esculenta* Crantz) and some traditional cassava food products. East Afr. Agricultural For. J. 40:161-167.

Haugerud, A. and Collinson, M.P., 1990. Plants, genes, and people: Improving the relevance of plant breeding in Africa. Experimental Agriculture 26: 341-362

Heering, J.H., Reed, J.D. and Hanson, J. 1996. Differences in Sesbania sesban accessions in relation to their phenolic concentration and HPLC fingerprints. Journal of the Science of Food and Agriculture 71(1): 92-98.

Heineman, A.M., Mengich, E.K., Olang, A.D. and Otieno, H.J.O., 1990. AFRENA Project Maseno, Kenya Progress Report for the Period January 1988 to January 1990. AFRENA Report No. 27, ICRAF, Nairobi.

Helrich, K. (Editor), 1990. Official Methods of Analysis of the Association of the Official Analytical Chemists, 82 pp.

Herrington, M.D., Elliot, R.C. and Brown, J.E., 1971. Diagnosis and treatment of thyroid dysfunction occurring in sheep fed on *Cynodon plectostachyus*. Rhodesian Journal of Agricultural Research 9:87-93.

Hoekstra, D.A., 1988. Summary of Zonal Agroforestry Potentials and Research across Land-use Systems in the Highlands of Eastern and Central Africa. AFRENA Report No. 15, ICRAF, Nairobi.

Hughes, C.E., 1998. Leucaena, A Genetic Resources Handbook, Tropical Forestry Papers 37. Oxford Forestry Institute, UK, 274 pp.

Humphreys, L.R. 1991. Tropical Pasture Utilisation. Cambridge University Press, New York.

ICRAF, 1992. Annual Report 1991. International Centre for Research in Agroforestry, Nairobi.

ICRAF, 1993. Annual Report 1992. International Centre for Research in Agroforestry, Nairobi.

ICRAF, 1994. Annual Report 1993. International Centre for Research in Agroforestry, Nairobi.

Ivory, D.A., 1990. Major characteristics, agronomic features, and nutritional value of shrubs and tree fodders. In: Devendra C. (Ed) Proceedings of a Workshop on Shrubs and Tree Fodders for Farm Animals, pp. 22- 38, International Development Research Centre, Ottawa, Canada

Jabbar, M.A., Gobbina, J. and Reynolds, L. 1992. Optimum fodder-mulch allocation of tree foliage under alley farming in southwest Nigeria. Agroforestry Systems 20(3): 187-198.

Jones, R.J. and Lowry, J.B. 1984. Australian goats detoxify the goitrogen 3-hydroxy-4(1H) pyridone (DHP) after rumen infusion from an Indonesian goat. Experienta 40: 1435-1436

Kaitho, R.J., Tamminga, S. and Bruchem, J., 1993. Rumen degradation and in vivo digestibility of dried *Calliandra calothyrsus* leaves. Animal Feed Science and Technology, 43:19-30.

Kaitho, R.J., Umunna, N.N., Nsahlai, I.V., Tamminga, S., Bruchem, J. van, Hanson, J. and Wouw, M. van de 1996. Palatability of multipurpose tree species: effect of species and length of study on intake and relative palatability by sheep. Agroforestry Systems 33(3): 249-261.

Kaitho, R.J., Nsahlai, I.V., Williams, B., Umunna, N.N., Tamminga, S. and van Bruchem, J. 1997a. Relationships between preference, rumen degradability, gas production and chemical composition of browses. Agroforestry Systems 39(2): 129-144.

Kaitho, R.J., Umunna, N.N., Nsahlai, I.V., Tamminga, S. and van Bruchem, J. 1997b. Utilization of browse supplements with varying tannin levels by Ethiopian Menz sheep: 1. Intake, digestibility and live weight changes. Agroforestry Systems 39(2): 145-159.

Kaitho, R.J., Umunna, N.N., Nsahlai, I.V., Tamminga, S. and van Bruchem, J. 1998. Nitrogen in browse species: rumen degradability and post-ruminal digestibility measured by mobile nylon bag and *in vitro* techniques. Journal of the Science of Food and Agriculture 76 (4): 488-498.

Kamatali, P., Teller, E., Vanbelle, M., Collignon, G. and Foulon, M., 1992. *In situ* degradability of organic matter, crude protein and cell wall of various tree forages. Animal Production, 55:29-34.

Kamau, I. and Odra, J., 1988. A Blueprint for Agroforestry Research in the Unimodal Upland Plateau of Tanzania. AFRENA Report No. 6, ICRAF, Nairobi.

Kanzila, M., 1994. Survey of browse trees in Burundi, Rwanda and Zaire. Revue d'elevage et de Medecine Veterinaire des Pays Tropicaux. 47(4): 415-424.

Karachi, M. and Zengo, M., 1997. Foliage of legumes pigeon pea leucaena and sesbania as supplements to growing goats grazing natural herbage. Agroforestry Systems 39(1): 13-21.

Kariuki, I., Karanja, J. and Murithi, N. 1998. The performance of dairy cattle in an agroforestry based zero-grazing unit. In: M. O'Neill (Ed.) National Agroforestry Research Project, KARI - Regional Research Centre - Embu, Annual Report: March 1997 - March 1998. AFRENA Report No. 120. International Centre for Research in Agroforestry, Nairobi, Kenya.

Kariuki, J.N., Boer, H., Tamminga, S., Gitau, G.K., Gachuiri, C.K. and Muia, J.M. (in press). Rumen degradation and intestinal digestion of protein in napier grass and other Kenyan forages. Animal Feed Science and Technology.

Karki, M.B. and Gold, M.A. 1994. Growth, forage content, and biomass yield response to on-farm fodder tree species trials in Nepal. Journal for Farming Systems Research Extension 4(3): 61-73.

Katto, C.I.R. 1997. Boton de oro *Tithonia diversifolia* (Hemsl.) Gray. In: Gomez, M.E., Rodrigeuz, L., Murgueitio, E., Rios, C.I., Mendez, M.R., Molina, C.H., Molina, C.H., Molina, E. and Molina, J.P. (Eds.), Arboles y arbustos forrajeros utilizados en alimentacion animal como fuente proteica: Matarraton (*Gliricidia sepium*), Nacedero (*Trichanthera gigantea*), Pizamo (*Erythrina fusca*) y Boton de oro (*Tithonia diversifolia*). Centro para la Investigacion en Sistemas Sostenibles de Produccion Agropecuaria, Cali, Colombia, pp. 115-126.

Kehar, N.D. and Goswami, M.N.D., 1956. Research in Animal Husbandry. A Review, 1929-54. Indian Council for Agricultural Research, New Delhi, 34p.

Kidd, T. J. and Taogaga, T., 1984. Survival and herbage yield of six nitrogen-fixing trees intercropped with Taro in Western Samoa. Nitrogen Fixing Tree Research. Reports. 2:22-23.

Kidundo, M. 1997. Key informants as a diagnostic tool for propagation of *Melia volkensii* - a potential agroforestry tree in semi-arid Kenya. In: Kang'ara, Sutherland and Gethi (Eds.), Proceedings of the Conference on on Participatory Dryland Agricultural Research East of Mount Kenya, 21-24 January, 1997. KARI: Kitale, Kenya, p. 205 – 213.

Kidundo, M., Ochieng, D. and Karichu, M. 1997. Termite damage on young trees – screening some indigenous control practices. In: Kang'ara, Sutherland and Gethi (Eds.) Proceedings of the Conference on Participatory Dryland Agricultural Research east of Mount Kenya, January 21-24, 1997. KARI, Kitale, Kenya.

Lamprey, H.F., Herlocker, D.J. and Field, C.R. 1980. Report on the state of knowledge on browse in East Africa in 1980. In: Le Houérou, H.N. (Ed.) 1980. Browse in Africa - the Current State of Knowledge, pp 33-54. International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Le Houérou, H.N. 1980a. Chemical composition and nutritive value of browse in tropical west Africa. In: H.N. Le Houérou (Ed.) Browse in Africa - the current state of knowledge. Papers presented at the International Symposium on Browse in Africa, Addis Ababa, April 8-12, 1980, and other submissions. International Livestock Centre for Africa, Addis Ababa, Ethiopia, p. 261-289.

Le Houérou, H.N. 1980b. Report on the state of knowledge on browse in east Africa in 1980. In: H.N. Le Houérou (Ed.) Browse in Africa - the current state of knowledge. Papers presented at the International Symposium on Browse in Africa, Addis Ababa, April 8-12, 1980, and other submissions. International Livestock Centre for Africa, Addis Ababa, Ethiopia, p. 33-54.

Le Houérou, H.N. 1980c. Browse in northern Africa. In: H.N. Le Houérou (Ed.) Browse in Africa - the current state of knowledge. Papers presented at the International Symposium on Browse in Africa, Addis Ababa, April 8-12, 1980, and other submissions. International Livestock Centre for Africa, Addis Ababa, Ethiopia, p. 55-82.

Le Houérou, H.N. 1989. An assessment of the economic feasibility of fodder shrubs plantation (with particular reference to Africa). In: C.M. MacKell (Ed.) The Biology and Utilization of Shrubs. Academic Press, San Diego, p. 603-630.

Leakey, R. 1996. Definition of agroforestry revisited. Agroforestry Today 8(1): 5-7.

Leloup, S.J.L.E. and Mannetje, L.'t 1996. Relationships between yield, chemical composition and reported palatability of browse in southern Mali. Tropical Grasslands 30(2): 282-288.

Lowry, J.B. 1990. Toxic factors and problems: methods of alleviating them in animals. In: Devendra, C. (Ed.), Shrubs and Tree Fodders for Farm Animals. Proceedings of a Workshop in Depasar, Indonesia, 24-29 July 1989. International Development Research Centre, Ottawa, pp 76-88..

McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D., 1981. Animal Nutrition 3rd ed, Longman, London, 479 pp.

McLennan, M.W. and Amos, M.L. 1989. Treatment of lantana poisoning in cattle. Australian Veterinary Journal 66(3): 93-94.

Milimo, P.B. 1994. Chemical composition of *Melia volkensii* Gurke: an unrealised browse potential for semi-arid agroforestry systems. Journal of the Science of Food and Agriculture 64: 365-370.

Minae, S., Kaumi, S., Avila, M., Okorio, J., Kaboneka, S. and Ghahamanyi, A. 1988. Agroforestry Research Project Proposal for the Coffee Based System in the Bimodal Highlands, Central and Eastern Provinces, Kenya. AFRENA Report No. 16, ICRAF, Nairobi.

Mnene, W.N., Stuth, J.W. and Lyons, R.K. 1996. Effects of herbage and bush level on diet selection and nutrient intake of cattle in Commiphora savanna. Tropical Grasslands 30: 378-388.

Morrison, B.J., Gold, M.A. and Lantagne, D.O. 1996. Incorporating indigenous knowledge of fodder trees into small-scale silvopastoral systems in Jamaica. Agroforestry Systems 34: 101-117.

Munyua, S.J.A., Njenga, M.J., Karitu, T.P., Kimoro, C., Kiftoon, J.E. and Buoro, I.B.J. 1990. A note on clinical-pathological findings and serum enzyme activity in sheep, goats and Fresian calves with acute *Lantana camara* poisoning. Bulletin of Animal Health and Production in Africa 38: 275-279.

Murithi, F.M., Thijssen, H.J.C., Mugendi, D.N., Mwangi, J.N, O'Neill, M.K. and Nyaata, O.Z. 1993. Report of a Survey on Agroforestry Technologies for Fodder Production and Soil Fertility Improvement in Meru District, Kenya. AFRENA Report no. 73. ICRAF, Nairobi, Kenya.

Murithi, F.M. 1998. Economic evaluation of the role of livestock in mixed smallholder farms of the Centtral Highlands of Kenya. Ph.D. thesis, Department of Agriculture, Veterinary Epidemiology and Economics Research Unit, The University of Reading, UK, 289 pp.

NDDP 1994. Results of the farm surveys in all Districts. Survey 1994. National Dairy Development Project of the Ministry of Agriculture, Livestock Development and Marketing, Nairobi.

Niang, A., 1994. Coppicing heights and frequencies of MPTs. Presented at a Training Course on Multipurpose Tree Improvement and Management, Maseno, Kenya.

Niang, A., Styger, E., Gahamanyi, A., and Ugeziwe, J., 1994. Comparative growth performance of some fifteen exotic species and provenances at high elevation acidic soils of Rwanda. Presented at the International Workshop on Nitrogen-Fixing Trees for Acidic Soils, Turrialba, Costa Rica. July 1994.

Niang, A., Styger, E., Gahamanyi, A., Hoekstra, D. and Coe, R., 1998. Fodder-quality improvement through contour planting of legume-shrub/grass mixtures in croplands of Rwanda highlands. Agroforestry Systems 39(3): 263-274.

Niang, A.I., Ugeziwe, J., Cooper, P., Styger, E. Coe, R. and Gahamanyi, A., 1996. Forage potential of eight woody species: intake and growth rates of local young goats in the highland region of Rwanda. Agroforestry Systems 34(2): 171-178.

Nochebuena, G. and O'Donovan, P.B., 1986. The nutritional value of high protein forage from *Gliricidia sepium*. World Animal Review 57: 48-49.

Norton, B.W. 1994. Anti-nutritive and toxic factors in forage tree legumes. In: R. C. Gutteridge and H.M. Shelton(Eds.) Forage Tree Legumes in Tropical Agriculture. CAB International, Wallingford, Oxon, UK, p. 202-215.

Nyaata, O.Z., O'Neill, M.K. and Roothaert, R.L. 1998. Comparison of *Leucaena leucocephala* with *Calliandra calothyrsus* in napier (*Pennisetum purpureum*) fodder banks. In: H.M. Shelton, R.C. Gutteridge, B.F. Mullen and R.A. Bray (Eds.) Leucaena – Adaptation, Quality and Farming Systems, Proceedings of a workshop held in Hanoi, Vietnam, 9 – 14 February 1998, Australian Centre for International Agricultural Research, p. 257 - 260.

Odenyo, A.A., Osuji, P.O., Karanfil, O. and Adinew, K. 1997. Microbiological evaluation of *Acacia angustissima* as a protein supplement for sheep. Animal Feed Science and Technology 65: 99-112

O'Neill, M., Murithi, F., Nyaata, Z., Gachanja, S., Mugendi, D., Tuwei, P. and Thijssen, R., 1993. KARI Regional Research Centre-Embu Annual Report: March 1992-April 1993. AFRENA Report No. 69, ICRAF, Nairobi.

O'Neill, M.K., Murithi, F.M., Mwangi, J., Nyaata, Z., Paterson, R.T., Roothaert, R.L. and Kihanda, F. 1995. National Agroforestry Research Project, KARI - Regional Research Centre - Embu, Annual Report: March 1994 - March 1995. AFRENA Report No. 92, International Centre for Research in Agroforestry, Nairobi, Kenya.

Ørskov, E.R., DeB. Hovell, F.D and Mould, F., 1980. The use of the nylon bag technique for the evaluation of feedstuffs. Tropical Animal Production, 5: 195-213.

Osafo, E.L.K., Owen, E., Said, A.N., Gill, M. and Sherington, J. 1997. Effects of amount offered and chopping on intake and selection of sorghum stover by Ethiopian sheep and cattle. Animal Science 65: 55-62.

Otsyina, R., Hanson, J. and Akyeampong, E., 1995. Leucaena in East Africa. In: H.M. Shelton, C.M Piggin and J.L. Brewbaker (Eds.), Leucaena - Opportunities and Limitations. Proceedings of a Workshop held in Bogor, Indonesia 24 - 29 January 1994. ACIAR Proceedings No. 57, 241pp.

Otsyina, R., Msangi, R., Gama, B. Nyadzi, G and Madulu, J., 1994. SADC-ICRAF Agroforestry Research Project Tumbi, Tabora, Tanzania. Annual Progress Report. AFRENA Report No. 83, ICRAF, Nairobi.

Palmer, B. and Schlink, A.C., 1992. The effect of drying on the intake and rate of digestion of the shrub legume *Calliandra calothyrsus.* Tropical Grasslands 26: 89-93.

Palmer, B., Macqueen, D.J and Gutteridge, R.C. 1994. Calliandra calothyrsus – a Multipurpose Tree Legume for Humid Locations. In: C. Gutteridge and H.M. Shelton(Eds.) Forage Tree Legumes in Tropical Agriculture. CAB International, Wallingford, Oxon, UK, pp. 65-74.

Paterson, R.T. 1993. Use of Trees by Livestock 4: Anti-nutritive Factors. Natural Resources Institute, Chatham, UK.

Paterson, R.T., Kiruiro, E. and Arimi, H.K. 1999. *Calliandra calothyrsus* as a Supplement for Milk Production in the Kenyan Highlands. Tropical Animal Health and Production 31(2): 115-126.

Perera, A.N.F., Yaparathe, V.M.K. and van Bruchem, J. 1992. Characterisation of protein in some Sri Lankan tree fodders and agro-industrial by-products by nylon bag degradation studies. In: M.N.M. Ibrahim, R. de Jong, J van Bruchem and H. Purnomo (Eds.) Livestock and Feed Development in the Tropics. Brawijaya University, Malang, Indonesia, pp. 171-177.

Reed, J.D. McDowel, R.E., van Soest, P.J. Horvath, P.J. 1982. Condensed tannins: A factor limiting the use of cassava forage. Journal of the Science of Food and Agriculture, 33: 213-220.

Reed, J.D., Horvath, P.J., Allen, M.S. and Van Soest, P.J., 1985. Gravimetric determination of soluble phenolics including tannins from leaves by precipitation with trivalent ytterbium. Journal of the Science of Food and Agriculture, 36: 255-261.

Reynolds, L. and Bimbuzi, S., 1993. The leucaena psyllid in Coast Province, Kenya. Nitrogen Fixing Tree Research Reports. 11:103.

Riley, B.W. and Brokensha, D. 1988. The Mbeere in Kenya Volume II – Botanical Identities and Uses. Institute for Development Anthropology, University Press of America, London, 348 pp.

Robinson, P.H. Fadel, J.G. and Tamminga, S. 1986. Evaluation of mathematical models to describe neutral detergent residue in terms of its susceptibility to degradation in the rumen. Animal Feed Science and Technology 15: 249-271.

Rocheleau, D., Wachira, K. Malaret, L. and Wanjohi, B.M. 1989. Local knowledge for agroforestry and native plants. In: Chambers, Pacey and Thrupp (Eds.) Farmers First – Farmer Innovation and Agricultural Research. Intermediate Technology Publication, London, UK, pp. 14-23

Roothaert, R., Karanja, G.M., Kariuki. I., Paterson, R., Tuwei, P., Kiruiro, E., Mugwe, J. and Franzel. S. 1998. Calliandra for livestock. Technical Bulletin No. 1. National Agroforestry Research Project. International Centre for Research in Agroforestry, Nairobi, 14 pp.

Roothaert, R.L. 1999. Feed intake and selection of tree fodder by dairy heifers. Animal Feed Science and Technology 79:1-13.

Roothaert, R.L. and Franzel, S. , in press. Farmers' preferences and use of indigenous fodder trees and shrubs in Kenya. Agroforestry Systems.

Roothaert, R.L. and Paterson, R.T. 1997. Recent work on the production and utilization of tree fodder in East Africa. Animal Feed Science and Technology 69: 39-51.

Roothaert, R.L., Franzel, S. and Kiura, J.M. (in press). On-farm evaluation of farmer preferred indigenous fodder trees and shrubs. Agricultural Systems.

Ross, G.J.S. 1987. Maximum Likelihood Program (a manual). Rothampsted Experimental Station Harpender, Hertfordshire.

Rusten, E.P. and Gold, M.A. 1991. Understanding an indigenous knowledge system for tree fodder via multi-method on-farm research approach. Agroforestry Systems 15: 139-165.

Salawu, M.B., Acamovic, T., Stewart, C.S., DeB. Hovell, F.D. and Roothaert, R.L., 1997a. Chemical composition and *in vitro* degradability of different parts of *Calliandra calothyrsus* from Kenya. Annual Meeting 1997 Book of Summaries, British Society of Animal Science, p 72.

Salawu, M.B., Acamovic, T., Stewart, C.S. and DeB. Hovell, F.D. 1997b. Proanthocyanidin (PA) content of *Calliandra* leaves and the effect of polyethylene glycol and pH on complexes formed between *Calliandra* tannins and Bovine serum albumin (BSA). Annual Meeting 1997 Book of Summaries, British Society of Animal Science, p 70.

Salawu, M.B., Acamovic, T., Stewart, C.S. and Roothaert, R.L. 1999. Composition and degradability of different fractions of *Calliandra* leaves, pods and seeds. Animal Feed Science and Technology 77: 181-199.

Sampet, C. and Pattaro, V., 1987. *Sesbania grandiflora, Gliricidia maculata* and *Leucaena leucocephala* as fodder crops. Thai Journal of Agricultural Science, 20:303-313.

Sen, K.C., 1938. Bulletin No. 25. Indian Council of Agricultural Research.

Shelton, H.M. and Brewbaker, J.L. 1994. *Leucaena leucocephala* – the most widely used forage tree legume. In: C. Gutteridge and H.M. Shelton (Eds.) Forage Tree Legumes in Tropical Agriculture. CAB International, Wallingford, Oxon, UK, pp. 65-74.

Shelton, M., Gutteridge, R.C., Mullen, B.F. and Bray, R.A. (Eds.) 1998. Leucaena – Adaptation, Quality and Farming Systems. Proceedings of a workshop held in Hanoi, Vietnam 9 – 14 February 1998. Australian Centre for International Agricultural Research, Canberra, 358 pp.

Shepherd G (1989) Putting trees into the farming system: land adjudication and agroforestry on the lower slopes of Mount Kenya. Network Paper 8a, Overseas Development Institute, London

Sileshi, Z., Owen, E., Dhanoa, M.S. and Theodorou, M.K. 1996. Prediction of in situ dry matter disappearance of Ethiopian forages from an in vitro gas production technique using a pressure transducer, chemical analysis or in vitro digestibility. Animal Feed Science and Technology 61: 73-87.

Snijders, P.J., 1991. Fodder management and the protein gap on zero-grazing farms based on Napier grass. In: ETC-Kenya Consultants B.V. (Eds). The Protein Gap-The Fodder Tree Option. Proceedings of a Seminar Organized to Discuss the Bridging of the Protein Gap through Fodder Trees Held in Nakuru 26th- 28th August 1991. Ministry of Livestock Development, Nairobi.

Staples, R.R., Hornby, H.E. and Hornby, R.M. 1942. Comparative effects of goats and cattle on a mixed grass-bush pasture. East African Agricultural and Forestry Journal 8: 62-80.

Stewart, C., Lamberton, J.A., Fairclough, R.J., Pass, M.A. 1988. Vaccination as a possible means of preventing lantana poisoning. Australian Veterinary Journal 65(11): 349-352

Stewart, J.L., Allison, G.E. and Simons, A.J. (Eds.) 1996. *Gliricidia sepium* – Genetic resources for farmers. Tropical Forestry Papers No. 33. Oxford Forestry Insititute, University of Oxford, UK, 125 pp.

Stobbs, T.H. and Thompson P.A.C. 1975. Milk production from tropical pastures. World Animal Review 13: 27-31.

Sutherland, A., Ouma, J. and Ndubu, J. 1995. Farming in Mbeere. Report of an Informal Diagnostic Survey of the Farming Systems of Lower Embu, Kenya. Volume 1. Kenya Agricultural Research Institute, Regional Research Centre - Embu, Kenya.

Tamminga, S., Van Straalen, W.M., Subnel, A.P.J., Meijer, R.G.M., Steg, A., Wever, C.J.G. and Blok, M.C. 1994. The Dutch protein evaluation system: the DVE/OEB system. Livestock Production Science 40:139-155.

Thapa, B., Walker, D.H. and Sinclair, F.L. 1997. Indigenous knowledge of the feeding value of tree fodder. Animal Feed Science and Technology 67: 97-114.

Theodorou, M.K., Williams, B.A. Dhanoa, M.S. McAllan, A.B. and France, J. 1994. A simple gas production method using a pressure transducer to determine the fermentation kinetics of ruminant feeds. Animal Feed Science and Technology 48(3-4): 185-197.

Thijssen, H.J.C., Murithi, F.M., Nyaata, O.Z., Mwangi, J.N., Aiyelaagbe, I.O.O. and Mugendi, D.N. 1993a. Report on an ethnobotanical survey of woody perennials in the coffee zone of Embu District, Kenya. AFRENA Report No. 62, ICRAF, Nairobi, 37pp.

Thijssen, H.J.C., Murithi, F.M. and Nyaata, O.Z., 1993b. Existing Hedges on Farms in the Coffee Based Land Use System of Embu District, Kenya. AFRENA Report No. 65, ICRAF, Nairobi.

Tilley, J.M.A. and Terry, R.A., 1963. A two-stage technique for *in vitro* digestion of forage crops. Journal of the British Grassland Society, 18:104-111.

Toruan-Mathius, Nurita and Suhendi, D., 1992. Potential of six cultivars of diploid *Leucaena diversifolia* as animal feed. Leucaena Research Reports, 13:56-58.

Tuwei, P., O'Neill, M. and Kanga, L. 1998. Species and provenance diversification for fodder production in central Kenya. Paper presented at the National Agroforestry Research Project Symposium, held at Embu, 9 - 11 December 1998. Kenya Agricultural Research Institute, Regional Research Centre, Embu, Kenya.

Tuwei, P.K. 1997. An evaluation of tree/ shrub species and provenances for fodder production, Embu, Kenya. M.Sc. dissertation, Sokoine University of Agriculture, Tanzania.

Van Soest, P.J. and Robertson, J.B., 1985. Analysis of Forage and Fibrous Foods. A Laboratory Manual for Animal SC. 613. Cornell University, pp. 98-110.

Van Vuuren, A.M., Tamminga, S. and Ketelaars, R.S. 1991. In sacco degradation of organic matter and crude protein of fresh grass (*Lolium perenne*) in the rumen of grazing dairy cows. Journal of Agricultural Science (Camb) 116: 429-436.

Veen, W. van der, 1993. Economic Analysis of Fodder Trees for Dairy Cows on Farms in Western Kenya. Msc thesis, Wageningen Agricultural University, The Netherlands.

Wahed, R.A., Owen, E., Naate, M. and Hosking, B.J. 1990. Feeding straw to small ruminants: effect of amount offered on intake and selection of barley straw by goats and sheep. Animal Production 51(2): 283-289.

Webster, C.C. and Wilson, P.N. 1968. Agriculture in the Tropics. Longmans, Green and Co Ltd, London, 488 pp.

Whyte, R.O. 1947. The use and misuse of trees and shrubs as fodder. Commonwealth Agricultural Bureau. Publication No. 10.

Winder, J.A., Walker, D.A. and Bailey, C.C. 1996. Effect of breed on botanical composition of cattle diets on Chihuahuan desert range. Journal of Range Management 49: 209-214.

Winrock International 1991. Assessment of Animal Agriculture in Sub-Saharan Africa. Winrock International Institute for Agricultural Development, Morrilton, USA, 125 pp.

Woodward, A. and Reed, J.D. 1989. The influence of polyphenolics on the nutritive value of browse: A summary of research conducted at ILCA. ILCA Bulletin 35. International Livestock Centre for Africa, Addis Ababa, Ethiopia, 11 pp.

Zemmelink, G. 1986. Measuring intake of tropical forages. In: Balch, C.C. and Es, A.J.H. van (Eds.) Recent advances in feed evaluation and rationing systems for dairy cattle in extensive and intensive production systems. International Dairy Federation Bulletin No. 196, p. 17-21.

Zemmelink, G., Haggar, R.J. and Davies, J.H. 1972. A note on the voluntary intake of *Andropogon Gayanus* hay by cattle, as affected by level of feeding. Animal Production 15: 85-88.

Zemmelink, G., Premaratne, S., Ibrahim, M.N.M., Leegwater, P.H. 1999. Feeding of Dairy Cattle in the Forest-Garden Farms of Kandy, Sri Lanka. Tropical Animal Health and Production 31(5): 307-319.

Summary

There will be an increasing demand for livestock products in Africa in the near future. This demand creates opportunities for small scale farmers to increase their income. In the subhumid zone of Embu District, central Kenya, milk production is already a big source of farm income, but there is vast room for improvement. In the drier zones, Mbeere District, livestock is economically less important now but its importance is increasing, triggered by a general intensification of the farming system in those zones. Constraints to livestock production in both Districts are low quality of animal feeds and shortage of feed during the dry season. Basal diets consisting of grass are of low quality, especially during the dry season. Fodder trees have much higher nutrient concentrations and keep these throughout the year. They can be used to increase animal production, when fed as supplements to low quality diets. A disadvantage of fodder trees is the presence of anti-nutrients in the forage. They can have toxic effects on ruminants, or interfere with the digestibility of nutrients in the feed.

Most research on fodder trees has been carried out on a few genera such as *Leucaena, Sesbania, Gliricidia* and *Calliandra*. These are exotic in most parts of the world where they are used, and sometimes accompanied by pest problems resulting from the fact that they are exotic. Many local fodder tree species are used in central Kenya. Their advantage is that they are well adapted to the climate and soil, farmers know them well and are less likely to be affected by pests. Indigenous and naturalized fodder trees and shrubs (IFTS) need to be screened for their usefulness for intensive utilization. In order to increase the chance of adoption of new technologies developed with these trees, the screening has to de done in a participatory way, involving farmers in all research steps.

Fodder trees are generally high in dietary minerals, except for phosphorous. Although not many economic data are available, use of tree fodder has proved to be economical in central Kenya and other parts of Africa. In Chapter 2, research on fodder trees in East Africa was reviewed. *Leucaena leucocephala* was a popular fodder species until it was attacked by the leucaena psyllid (*Heteropsylla cubana*) to which other species such as *L. diversifolia, L. esculenta* and *L. pallida* have shown some degree of tolerance. *Sesbania spp.* showed early promise but did not

withstand intensive cutting management. In Kenya, when *Calliandra calothyrsus* is grown in 4:1 and 1:1 grass:legume combinations the fodder yields are higher than for pure hedgerows. For dairy cows 1 kg of concentrates can be successfully replaced by 3 kg of fresh *C. calothyrsus*. At altitudes above 2300 m supplementation with *Mimosa scabrella* enabled local goats to gain 50 g/day compared with 31 g/day for grass alone.

The objectives of this study were to identify IFTS species in central Kenya with potential for intensive use for cattle. Additional objectives were to assess the role of farmers, feeding trials and laboratory analyses in the screening process.

A participatory survey was conducted in three agroecological zones (AEZ) along the altitudinal gradient of Mount Kenya (Chapter 3). The objective was to find out farmers' ranking of indigenous fodder tree species of their choice, their criteria for assessing fodder trees, how the most preferred species rated on each criterion, and species' uses, management, niches and ways of establishment. Improved, stall-fed dairy animals were the dominant livestock types in the subhumid zone whereas communally-grazed, local-breed cattle and goats were common in the dry zone. Farmers in the three zones used a total of 160 different IFTS. In the subhumid zone, the most frequently mentioned criteria were the ability of the fodder to satisfy hunger and contributions to animal health. Palatability and drought resistance of the tree were the most important criteria in the medium zone and, effect on the condition of the animal and palatability were most important in the semi-arid zone. There were significant differences among tree and shrub species ($p<0.05$).

Farmers who had participated in the survey chose seedlings of indigenous, naturalized and some exotic fodder trees and shrubs, from a nursery during feedback meetings (Chapter 4). They planted them on-farm, where the planting niches, management, biomass production, and animal response were evaluated, and compared with the results of an earlier survey. Data were collected two months, one year and 16 months after planting. The percentage of female farmers during the feedback meeting, when species were chosen, were 41, 65 and 41 %, for the subhumid, medium and semi-arid zones, respectively. The choice of species and planting niches generally reflected the information from the survey but the feedback meetings proved important to understand discrepancies between the survey results and farmers' practices. Survival of seedlings was affected by an extremely dry spell, but some species in the semi-arid zone still showed remarkable growth. Manure was only applied to *S. ellipticum* in the subhumid zone and to *Crotalaria goodiiformis* in the semi-arid zone, stressing farmers' appreciation for these species. In the subhumid zone there were significant differences ($P < 0.001$) of the percentage of trees which had been pruned to feed cattle and goats. Farmers showed a strong interest to intensify the use of IFTS. The study method was useful to test the willingness of farmers to plant trees.

Fodder samples were collected from 29 woody species, in two seasons. The species were screened for nutritive value through laboratory analysis and this was compared with farmers' assessment. There was a large variability in chemical composition and nutritive value parameters among species and between seasons. Except in the case of soluble tannins, season had either a significant positive or negative effect on nutritive parameters. Regrowth after cutting had more significant regression coefficients ($p < 0.05$) in the subhumid zone than in the drier ones, which reflects the more active harvesting in this zone as opposed to browsing in the other zones. Palatability for cattle had no significant regression coefficients in the subhumid zone, but it did in the other zones. It was concluded that there are strong relationships between farmers' assessments and laboratory nutritive analyses. It is important to identify the properties of individual species, which cause a large deviation from the regression.

A trial was conducted to determine the dry matter intake (DMI) by dairy heifers for napier grass (*Pennisetum purpureum*) plus supplements of either fresh *C. calothyrsus*, fresh *Morus alba* (mulberry), dried *Manihot glaziovii* (cassava tree), fresh *Leucaena diversifolia* (leucaena) or dairy meal (Chapter 6). Five Ayrshire heifers were stall fed and exposed to each diet in a latin square design, providing five replicates in five periods. Napier grass was supplied ad libitum and supplements at 25 % of estimated daily DMI. Plant parts, twig diameters and crude protein (CP) content, in vitro digestibility and, in sacco rumen degradability of consumed material were determined. DMI for supplements and napier were significantly different at $p < 0.05$; intake of digestible crude protein, rumen degradable dry matter and digestible dry matter were significantly different at $p < 0.001$. Animals were able to select parts of the tree fodder with higher contents of CP, higher in vitro digestibility and higher rumen degradability than the average of the offered supplement. Ash content, condensed and soluble tannins were higher but neutral detergent fibre and acid detergent fibre contents were lower in offered than left over tree fodder. Thickness of consumed branches increased with rainfall. Through comparison of DMI, indications of palatability of tree fodders can be obtained. Of the fodder tree species tested in this experiment, mulberry and cassava tree had the highest potential in terms of milk production levels.

A second feeding trial with dairy heifers was conducted similar to the first one. The diets were napier grass plus supplements of either *C. calothyrsus*, *Tithonia diversifolia, Lantana camara, Ficus sp.* or dairy meal. Supplements were supplied at 30 % of estimated daily DMI. Selection and nutrient indices were calculated in order to assess the effect of selectivity on nutrient concentration of consumed material. The proportion of uneaten branches, irrespective of consumed leaves, was 98 % for ficus, 72 % for tithonia, 17 % for lantana and 12 % for calliandra. Selection indices were different for the treatments ($p<0.001$, LSD = 0.074) with adjusted means of 0.18 for calliandra, 0.49 for tithonia, 0.27 for lantana and 0.31 for ficus. The voluntary intake of the supplements were significantly different; dairy meal had the highest; calliandra, ficus and lantana were within a close range; and tithonia had the lowest voluntary intake. Rumen degradable protein was insufficient in all diets including dairy meal. Higher inclusion levels of mulberry, calliandra, tree cassava and lantana are likely to increase energy supply and RDP levels in the rumen, and indirectly increase energy availability through better fermentation efficiency.

Although there is little information on biomass production of IFTS, it was concluded that in terms of useful energy and protein production per land unit, IFTS were not inferior to exotic species. Farmers' knowledge, practices and selection criteria for IFTS differed among AEZ. The involvement of farmers through surveys, feed back meetings and on-farm experiments has been an indispensable tool to assess the potential of IFTS species for intensive use. Gender related preferences of species are important for technology development. Superior IFTS species in terms of nutritive value were identified. Promising species for the subhumid zone are: *Ficus thoningii, L. camara, M. alba, M. glaziovii, S. ellipticum, T. diversifolia, T. orientalis, Triumfetta tomentosa* and *Vernonia lasiopus*. The most promising species in the two drier zones are: *A. ataxacantha, A. mossambicensis, C. goodiiformis, G. tembensis, I. lupatana, L. camara* and *M. volkensii*. Many of these species compare favorably with the popular exotic species *C. calothyrsus* in terms of animal response. There is a potential for intensive use of IFTS in all zones, for the improvement of the quality of the diet of cattle and other ruminants, and to provide feed during times of shortage. As a follow up, feeding trials with dairy cattle are needed both on-farm and on-station, using the identified superior fodder species. To enable economic assessment, agronomic performance data are required of IFTS. On a more fundamental research note, protein quality needs to be assessed, the effect of selectivity on nutrient concentration of consumed feed, and toxic resistance mechanisms in *L. camara*.

Samenvatting

Het potentieel van inheemse en genaturaliseerde voederbomen en -struiken voor intensief gebruik in centraal Kenya.

Er zal in de nabije toekomst een toenemende vraag zijn naar dierlijke produkten in Afrika. Deze vraag opent mogelijkheden voor kleinschalige boeren om hun inkomen te vergroten. In de subhumide zone van Embu District, centraal Kenya, is melkproduktie reeds een grote bron van inkomsten, maar er is ruimte voor verbetering. In de drogere zones in Mbeere District is veehouderij in economisch opzicht minder belangrijk nu, maar de belangrijkheid neemt toe, veroorzaakt door een algemene intensivering van de landbouwbedrijfssystemen. De belemmeringen voor veehouderij in beide Districten zijn lage kwaliteit van de voedermiddelen en een tekort aan voer tijdens het droge seizoen. Het basisvoer gras heeft een lage kwaliteit, vooral tijdens het droge saizoen. Voederbomen hebben een veel hogere concentratie van voedingsstoffen het hele jaar door. Als ze als suplement worden gevoerd voor laagwaardig voeder kunnen zij de dierlijke produktie verhogen. Een nadeel van voederbomen is de aanwezigheid van anti-nutrienten in het eetbaar materiaal. Deze kunnen giftig zijn voor herkauwers of de vertering negatief beïnvloeden.

Het meeste onderzoek is gedaan naar slechts enkele genera zoals *Leucaena, Sesbania* en *Calliandra*. Deze zijn uitheems voor de meeste plaatsen ter wereld waar ze worden gebruikt, en worden soms door plagen geteisterd door het feit dat zij uitheems zijn. Er worden in centraal Kenya vele inheemse voederboomsoorten gebruikt. Het voordeel van deze is dat zij goed aangepast zijn aan het klimaat en de bodem, ze zijn bekend bij de boeren en worden minder gauw aangetast door plagen. De inheemse en genaturaliseerde voederbomen en –struiken (IVBS) moeten worden getest op hun bruikbaarheid voor intensief gebruik. Om de kansen op adoptie van nieuw ontwikkelde technologieën met deze bomen te vergroten, moet het testen op een participatieve manier uitgevoerd worden, waarbij boeren in alle fasen worden betrokken.

Voederbomen hebben over het algemeen een hoge concentratie van mineralen, behalve fosfor. Uit de weinige economische gegevens die beschikbaar zijn, blijkt dat het gebruik van voederbomen economisch rendabel is in centraal Kenya en andere delen van Afrika. In Hoofdstuk 2 wordt een overzicht gegeven van het onderzoek over voederbomen in Afrika. *Leucaena leucocephala* was een populaire boomsoort totdat het werd geteisterd door the leucaena psyllid (*Heteropsylla cubana*), waartegen andere soorten zoals *L. diversifolia, L. esculenta* en *L. pallida* een zekere mate van tolerantie hebben. *Sesbania spp.* waren veel belovend, maar overleefden geen intensief oogstbeleid. In Kenya is de totale voederopbrengst hoger wanneer *Calliandra calothyrsus* in mengteelt word verbouwd met gras dan wanneer het alleen wordt verbouwd. Voor melkvee kan 1 kg krachtvoer succesvol worden vervangen door 3 kg vers *C. calothyrsus*. Op hoogtes boven 2300 m kunnen geiten 50 g per dag groeien met een suplement van *Mimosa scabrella*, vergeleken met 31 g per dag voor gras alleen.

Het doel van deze studie was om IVBS in Kenya te identificeren die potentieel hebben voor intensief gebruik voor rundvee. Bijkomende doelen waren om de rol van boeren, de rol van voederexperimenten en van laboratorium analyses te bepalen in het selectieproces.

Een participatieve enquete werd uitgevoerd in drie agroecologische zones (AEZ) langs de hoogte gradient van Mount Kenya (Hoofdstuk 3). Het doel was de rangschikking door boeren van IVBS van hun keuze te bepalen, volgens hun eigen criteria; en de wijze van benutting, plantniches en vermeerderingsmethoden te bepalen. Boeren gebruikten een lokaal houten spelbord, *bao*, om de soorten te waarderen. In de subhumide zone waren verbeterde melkkoeien, op stal gevoerd, de voornaamste veesoort, terwijl in de dogere zones lokale koeien- en geitenrassen, op communale gronden grazend, de meest voorkomende waren. Boeren in het studiegebied bebruikten in totaal 160 verschillende IVBS. In de subhumide zone waren de meest genoemde criteria de capaciteit van het voer om de honger van het dier te stillen en het effect op de diergezondheid. In de midden zone waren smakelijkheid en droogte resistentie van de bomen de belangrijkste criteria, en in de semi-aride zone waren het effect van het voer op de conditie van het dier en smakelijkheid van het voer de belangrijkste criteria. Er waren significante verschillen tussen de soorten ($p < 0.05$).

Aan de boeren die hadden deelgenomen aan de enquete werden zaailingen van inheemse, genaturaliseerde en exotische voederboom en -struiken gegeven die zij selecteerden uit kwekerijen tijdens terugkoppelingsbijeenkomsten (Hoofdstuk 4). Zij plantten deze op de boerderij, waar de plant niches, het management, de biomassa produktie en dierlijke resultaten werden geëvalueerd, en vergeleken met resultaten uit de eerdere enquete. Het percentage van boerinnen tijdens de terugkoppelingsbijeenkomsten, waarop de soorten gekozen werden, was 41, 65 en 41 %, voor de subhumide, midden en semi-aride zones respectievelijk. De keuze van soorten en plant niches reflecteerde over het algemeen de informatie van de enquete, maar de terugkoppelingsbijeenkomsten waren belangrijk om de verschillen te begrijpen tussen de uitkomsten van de enquete en de boerenpraktijken. De overleving van zaailingen was laag door de extreme droogte, maar sommige soorten in de semi-aride zone groeiden toch behoorlijk. Er werd alleen mest toegediend aan *Sapium ellipticum* in de subhumide zone en *Crotalaria goodiiformis* in de semi-aride zone, hetgeen de voorkeur van boeren voor deze soorten duidelijk aangaf. In de subhumide zone bestonden significante verschillen ($p < 0.001$) tussen de percentages bomen die werden gesnoeid voor het voeren aan rundvee en geiten. Boeren toonden veel interesse om het gebruik van IVBS te intensiferen. De studiemethode was nuttig om de wil van boeren om bomen te planten te testen.

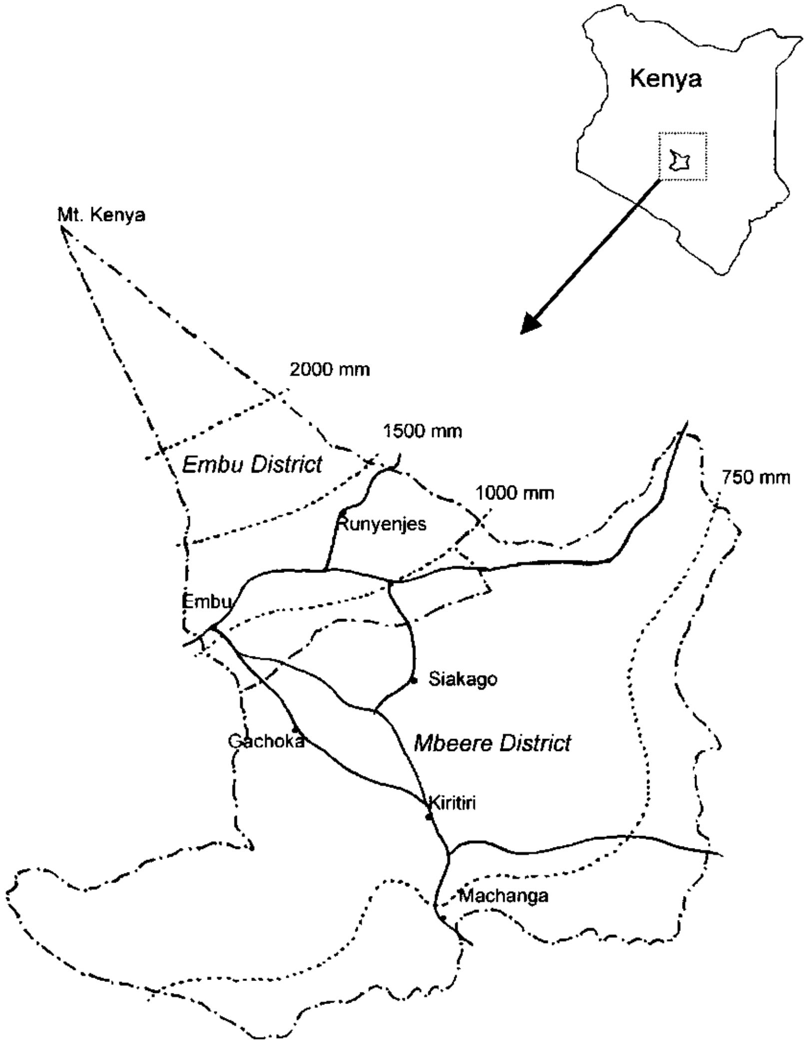
Van 29 houtige plantensoorten werden monsters genomen, tijdens twee seizoenen. De soorten werden onderzocht op voedingswaarde door laboratorium technieken en dit werd vergeleken met waarderingen door boeren. Er bestonden grote verschillen in chemische samenstelling en voedingswaarde tussen soorten en tussen seizoenen. Behalve voor oplosbare tanninen had seizoen òf een significant positief òf een significant negatief effect op voedingsparameters. Regressiecoëfficiënten tussen laboratoriumanalyses en boerenwaarderingen toonden verschillen tussen de zones, hetgeen veroorzaakt werd door de verschillen in veehouderijsystemen. Desalnietemin bestonden er sterke relaties tussen boerenwaarderingen en laboratorium voedingsanalyses. Het is belangrijk om de eigenschappen van individuele soorten te identificeren die grote afwijkingen van de regressie veroorzaken.

Een voedingsproef werd uitgevoerd om de droge-stofopname te bepalen door vaarzen van olifantsgras (*Pennisetum purpureum*) plus suplementen van verse *C. calothyrsus*, verse *Morus alba*, gedroogde *Manihot glaziovii*, verse *L. diversifolia* of krachtvoer Hoofdstuk 6). Vijf Ayrshire vaarzen werden op stal gevoerd en kregen elk rantsoen in een latijns blok ontwerp, met vijf herhalingen in vijf perioden. Olifantsgras werd *ad libitum* gevoerd en suplementen voor 25 % van de geschatte dagelijkse droge-stofopname. De plantendelen, twijgdiameters, ruw-eiwitgehalte, *in vitro* verteerbaarheid en *in sacco* degradering van geconsumeerd materiaal werd bepaald. Droge-stofopname van suplementen en olifantsgras waren significant verschillend ($p < 0.05$); opname van verteerbaar ruw eiwit, in de pens afbreekbare droge stof en verteerbaar droge stof waren significant verschillend ($p < 0.001$). De dieren waren in staat om delen van het boomvoer te selecteren met hogere concentraties ruw eiwit, hogere in vitro verteerbaarheid en hogere in-pens afbreekbaarheid dan het gemiddelde van het aangeboden supplement. Concentratie van mineralen, gecondenseerde en oplosbare tanninen waren hoger, maar NDF en ADF concentraties waren lager in aangeboden dan in overgebleven boomvoer. Dikte van geconsumeerde takken nam toe bij hogere regenval. Door vergelijking van droge-stofopname verkrijgt men indicaties van smakelijkheid van het boomvoer voor het vee. Van de geteste boomsoorten in dit experiment, toonden *M.alba* en *M. glaziovii* het grootste potentieel met betrekking tot melkproduktieniveaus.

Een tweede voedingsproef werd uitgevoerd met vaarzen, vergelijkbaar met de vorige proef. The rantsoenen bestonden uit olifantsgras met suplementen van *C. calothyrsus, Tithonia diversifolia, Lantana camara, Ficus sp.* of krachtvoer. De suplementen werden gevoerd op 30 % van de geschatte dagelijkse droge-stofopname. Selectie- en voedingsstoffenindexen werden berekend om het effect van selectiviteit op concentratie van voedingsstoffen te bepalen in het geconsumeerde materiaal. De proportie van ongegeten takken, onafhankelijk van de gegeten bladeren, was 98 % voor *Ficus sp.*, 72 % voor *T. diversifolia*, 17 % voor *L. camara* en 12 % voor *C. calothyrsus*. Selectie-indices waren verschillend voor de behandelingen ($p < 0.001$, LSD = 0.047) met gemiddelden van 0.18 voor *C. calothyrsus*, 0.49 voor *T. diversifolia*, 0.27 voor *L. camara* en 0.31 voor *Ficus sp.* de vrijwillige opname van suplementen was significant verschillend; krachtvoer had de hoogste; *C. calothyrsus, Ficus sp.* en *L. camara* zaten dicht bij elkaar; en *T. diversifolia* had de laagste vrijwillige opname. Er was een tekort aan in de pens afbreekbaar eiwit in alle rantsoenen inclusief krachtvoer. Hogere voedingsniveau's met *M. alba, C. calothyrsus, M. glaziovii* en *L. camara* zullen waarschijnlijk de energietoevoer en afbreekbaar eiwitconcentraties in de pens verhogen, en indirect de beschikbare energie verhogen door hogere efficiëntie van de fermentatie.

Hoewel er weinig informatie beschikbaar is over biomassaproductie van IVBS, werd er geconcludeerd dat met betrekking tot de productie van bruikbare energie per eenheid landoppervlak, IVBS niet onder doen voor uitheemse boomsoorten. Boerenkennis, gebruiken en selectie criteria voor IVBS waren verschillend voor de AEZ. De betrokkenheid van boeren door enquetes, terugkoppelingsbijeenkomsten en onderzoeken op boerderijen is een onmisbaar middel om het potentieel van IVBS te beoordelen voor intensief gebruik. Vrouw gerelateerde voorkeuren voor soorten zijn belangrijk voor ontwikkeling van technologieën. Superieure IVBS soorten met betrekking tot voederwaarde werden geïdentificeerd. Veelbelovende soorten voor de subhumide zone zijn: *Ficus thoningii, L. camara, M. alba, M. glaziovii, S. ellipticum, T. diversifolia, T. orientalis, Triumfetta tomentosa* and *Vernonia lasiopus*. De veelbelovende soorten voor the twee drogere zones zijn: *A. ataxacantha, A. mossambicensis, C. goodiiformis, G. tembensis, I. lupatana, L. camara* and *M. volkensii*. Veel van deze soorten tonen vergelijkbare resultaten met *C. calothyrsus* op het gebied van voederopname. Er is een potentieel voor intensief gebruik van IVBS in alle zones, voor de kwaliteitsverbetering van rantsoenen van rundvee en andere herkauwers, en om extra voer te verschaffen tijdens droge perioden. Als vervolg zijn voederproeven met melkvee nodig, zowel op onderzoekstations als op boerderijen, gebruik makend van de geïdentificeerde superieure voedersoorten. Om tot economische evaluaties te komen zijn agronomische proeven met IVBS nodig. Op het gebied van fundamenteel onderzoek moeten eiwit kwaliteit, het effect van selectiviteit op nutrienten concentraties in geconsumeerd voer, en toxische resistentie mechnismen in *L. camara* onderzocht worden.

Appendix 1. Map of Embu and Mbeere Districts.



_._._ District boundary

.... Mean annual precipitation

—— Roads

Curriculum vitae

Ralph Leonard Roothaert was born on 6 April 1964 in Maastricht, the Netherlands. He grew up in Oisterwijk and completed the secondary school, Gymnasium-β, at the Maurick College, Vught. After that, he then went to the National Agricultural College, Deventer, where he obtained his B.Sc. degree in tropical and sub-tropical agriculture, with specialization in tropical animal production, in 1987. He had spent his one year practical attachment for this study at the Sri Lanka Technical Institute and Diyagala Boys' Town, Ragama. His thesis was entitled "The role of *Leucaena leucocephala* in the small scale integrated farming systems in South-East Asia". Through the London based Voluntary Service Overseas he was sent to Birnin Kudu, Nigeria, where he worked for the Kano State Agricultural and Rural Development Authority, for two and half years. He co-ordinated extension and training activities of the livestock programme in the zone, and carried out adaptive research. After he had returned to Europe, he studied at the Centre for Tropical Veterinary Medicine, Edinburgh University, Scotland, where he obtained an M.Sc. degree in Tropical Animal Production and Health, 1991. For his thesis he conducted a trial feeding poultry wastes to goats. He worked at the same centre for three months as a research associate, carrying out experiments on the energy expenditure of draft animals. In 1992, he became a lecturer at the Larenstein International Agricultural College. He taught tropical animal nutrition, tropical grassland and physiology of growth to regular Dutch B.Sc. students and mature international diploma students. In 1993, he started working for the Directorate General International Co-operation of the Ministry of Foreign Affairs, The Hague, and was seconded to the International Centre for Research in Agroforestry (ICRAF). For ICRAF he worked at Embu, Kenya, where he carried out research on the production and utilization of fodder trees, as an associate animal scientist in an international team, till 1999. In April 1999 he came to the Netherlands to finish his Ph.D. thesis at the Agronomy location of Wageningen University. He married his Kenyan wife during his study in September 1999.