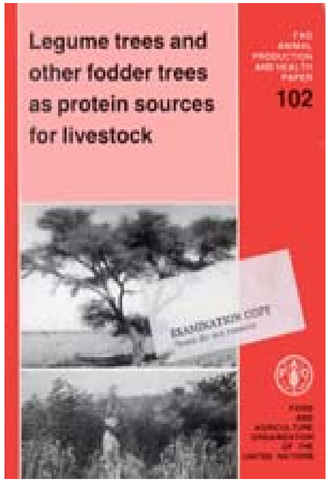

FAO ANIMAL PRODUCTION AND HEALTH PAPER 102

Legume trees and other fodder trees as protein sources for livestock

Contents

Proceedings of the FAO Expert Consultation held at the Malaysian Agricultural Research and Development Institute (MARDI) in Kuala Lumpur, Malaysia, 14–18 October 1991

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M-23
ISBN 92-5-103203-3

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS Rome, 1992

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Contents

Introduction

***The FAO Expert Consultation on Legume Trees and Other Fodder Trees as Protein Sources for Livestock was held at the Malaysian Agricultural Research and Development Institute (MARDI) in Kuala Lumpur, Malaysia, from 14 to 18 October 1991*.**

BACKGROUND

Fodder trees and fodder shrubs have always played a significant role in feeding domestic animals. In fact, trees and shrubs are increasingly recognized as important components of animal feeding, particularly as suppliers of protein and especially in harsh environmental conditions. In such situations, the available grazing is not generally sufficient to meet the maintenance requirements of animals, at least for part of the year. This occurs, for example, in some mountainous regions and in the dry tropics where the grazing is also sometimes very degraded. Thus, in extensive, animal production systems in the dry areas of Africa, it is generally estimated that ligneous materials contribute up to 90% of rangeland production and account for 40–50% of the total available feed. Such figures illustrate the existing and urgent need not only for better knowledge but also for better use of such potential, particularly in the present context of environmental degradation which is affecting our planet.

On the other hand, in the humid tropics of Latin America, the Caribbean, South-east Asia and Africa, fodders from trees and shrubs -especially from leguminous species - are beginning to

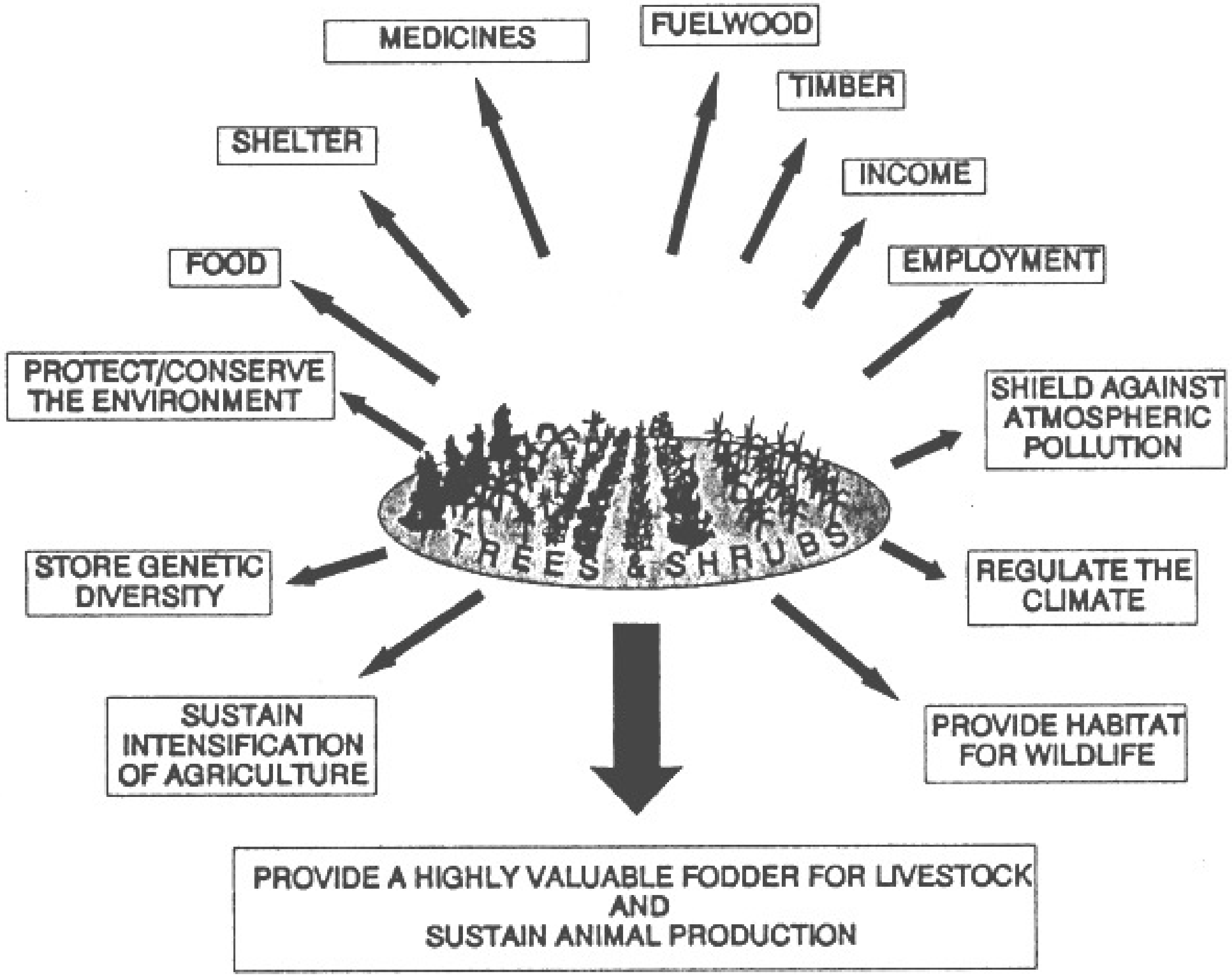
be utilized more widely as dietary nitrogen supplements for ruminants. In this respect, there is now a significant move to look for new sources of protein from trees and shrubs. However, given the increasing demand for forage and the extensive availability of low quality basal feed materials which require protein supplementation, high protein fodders from leguminous trees and shrubs could have a much more significant role in animal feeding systems throughout the developing world. In this respect, there is a need for more research to develop technically viable solutions. These solutions must also be economically and socially acceptable; they must preserve natural resources and protect the environment. In other words, the challenge is the sustainable development of fodder trees and shrubs.

Broadly speaking, it seems that collaborative efforts among scientists must be particularly directed towards integrated patterns of use by ruminants and non-ruminants and towards the establishment and development of innovative feeding systems, both intensive and extensive, using high protein fodders from promising species of trees and shrubs. In this respect, some research themes of major importance are: productivity, feeding behaviour of animals, real nutritive value, ecological adaptation and natural regeneration ability. The objectives are to improve the availability of feed resources for livestock throughout the year and to provide an adequate strategic feed supplementation to animals over critical periods.

It must also be kept in mind that, apart from their potential role in animal feeding, trees and shrubs are valuable sources of fuelwood, shelter, timber, herbal medicines and food for people and have been since the first civilizations of hunter-gatherers. Later on, humans also learnt that trees and shrubs could help to maintain soil fertility and to control erosion. We now know that our planet cannot hope to survive very long without a drastic global policy to control the use of natural resources. Undoubtedly, trees and shrubs, whether or not they provide fodder for animals, do offer a partial but adequate response to desertification problems, to environmental degradation and to changes in climate, problems which have begun to be

observed with some anxiety in the last few years. This is irrespective of their role as a source of income and employment, as a means to sustain the intensification of agriculture, to maintain biodiversity and to enable livestock to be kept as essential sources of meat, milk, fibre or draught power for the rural poor.

FIGURE 1. The different roles of trees and shrubs.



PURPOSE

The proposed objectives of this interdisciplinary Expert Consultation on Fodder trees and fodder shrubs as protein sources for livestock were:

- **a global review of the utilization of these species in the developing countries;**
- **a review of promising species already utilized by farmers and breeders in the field or investigated by scientists in different countries and agro-climatic zones (basic and applied research);**
- **a short up-to-date list of species with a likely future;**
- **a synthesis, related to the main fodder trees and shrubs, either effectively utilized today in animal feeding or with a likely future, looking at the current state of knowledge, particularly with respect to:**
    - **their geographical and ecological distribution;**
    - **their main botanical characteristics;**
    - **their main agronomic characteristics, particularly including quantity and quality of fodder, pods and seed production, as well as timber, fuelwood or, if appropriate, parts of plants used in human nutrition;**
    - **their main nutritional characteristics for ruminants and non-ruminants: palatability, voluntary intake, chemical composition, mineral and amino-acid composition, apparent digestibility, feeding value, toxic or anti-nutritional factors, etc.**

- **the main results of feeding trials using fodder shrubs and fodder trees as parts of rations for meat or milk production;**

- **investigations of conservation techniques and/or simple technological ways to enhance their utilization (silages, meals, seed soaking, etc.)**

- **reports on how, in practice, farmers and breeders cultivate and utilize such ligneous materials in extensive and intensive feeding systems.**

- **an analysis of the main results of animal feeding systems developed all over the world utilizing fodder trees and fodder shrubs, also taking into account socio-economic parameters;**

- **practical recommendations at the present stage of knowledge, in order to develop the cultivation and utilization of fodder shrubs and fodder trees, particularly in harsh environmental conditions as a means of improving animal feeding in developing countries and of matching livestock production systems to available and potential feed resources;**

- **an identification of the main research fields for the future.**

In conclusion, in a situation where feeds remain the major constraint for livestock development and the major component of the cost of animal production, FAO, as an advisory and executive agency of the UN system, considers this Expert Consultation on fodder trees as a key event towards coordinated efforts all over the world to promote fodder trees and fodder shrubs as a means of improving livestock feeding and also of moving towards sustainable agriculture.

OPENING SESSION AND INTRODUCTORY STATEMENT

The first address at the opening ceremony was delivered by Mr. Carl Erik Wiberg, Regional Representative of the United Nations Development Programme (UNDP). First of all, he expressed his great pleasure to be at MARDI for the opening of the Consultation and declared how impressed he was with MARDI's successes and achievements in hosting and undertaking local and regional research programmes, many of which are under UNDP or FAO sponsorship.

In his speech, he reminded the participants of the fact that, although UNDP had no direct involvement in the Consultation, the subject matter was not without interest to UNDP. UNDP is currently financing a number of projects and assisting many institutions in the region in developing and applying new technologies and techniques in animal production and health. Collectively, the outcome of these efforts and the attendant Expert Consultations will, according to Mr. Wiberg, have a far-reaching effect on research and development policies and practices as well as on the farming community and farm-level practices.

Mr. Wiberg then took the opportunity to stress the main roles of UNDP and specialized agencies of the UN system in building up national capabilities, in technical cooperation matters and in facilitating technical cooperation among developing countries. He insisted on the imperative necessity to establish as perfectly as possible a true understanding of the real purpose of the particular assistance, between developing countries and the donor or development aid agency concerned, in order to help adopt the appropriate technologies and make the right choices in imported and domestic technologies. From this point of view, he stressed the fact that the UN system has a role to play in the enhancing of interactions between developing countries towards harmonization and standardization of new technologies and their application.

Mr.Pierre-Luc Pugliese, FAO technical Officer in charge of the Consultation and on behalf of the Director General of FAO, welcomed the participants and thanked the Director General of

MARDI and his staff for so generously welcoming the Consultation and for the active participation in the preparation of the meeting. He also thanked Mr. Carl Erik Wiberg for the highly appreciated help given by his bureaux in Kuala Lumpur.

He then explained that the Consultation fell within the overall framework of meetings organized by the Animal Production and Health Division of FAO in the last ten years, to review the possible feed resources present in the developing world and to promote a better utilization of these local feed resources in such countries. He also pointed out that, as a major output of this Consultation, FAO was expecting practical recommendations on the cultivation and use of fodder trees and shrubs as a means of improving animal feeding in developing countries and of matching available feed resources to sustainable livestock production, particularly under harsh environmental conditions.

Yang Berbahagia, Dató Dr. Hj. Mohd. Yusof Hashim, Director General of MARDI, gave the opening speech and welcomed all the participants. He pointed out the prediction that self-sufficiency in meat would drop by 33 per cent in South East Asia and South Pacific, unless the forage production is doubled by the year 2000 and this was a grave concern to all animal production specialists dealing with the problem in the region. Similarly, the question of seasonality in the availability of feed resources as well as the poor quality of roughages is a problem which also besets all livestock-producing countries, whether in the *cerrados* of South America, in the savannas of Africa or even in some areas of the wet tropics.

The Director General of MARDI also emphasized the fact that, particularly in arid and semi-arid regions, trees and shrubs significantly contribute to the daily diet of animals. As they are less affected by the adverse environmental conditions such as dry seasons, compared to grasses, trees and shrubs can become important sources of feed during these adverse periods. Furthermore, leguminous tree crops can serve as protein banks to improve the quality of feed

resources and recycle nitrogen into the soil.

He also stressed the fact that, amongst the 300 species of trees and shrubs documented as being useful as animal fodder, only a few species have been studied and really utilized. The over-dependence on *Leucaena* is a remarkable example of this and the corresponding danger which has been brought to light by the severe psyllid attacks on *Leucaena*. However, given the time spent and the continual efforts made in the past, MARDI hopes to contribute towards the development of an acid-tolerant as well as possibly a psyllid-tolerant *Leucaena*. Given the diversity of fodder trees and fodder shrubs, the Director General of MARDI urged the need to recommend promising species, both in terms of plant productivity and nutritive value, for specific agro-ecological environments and animal production systems. Improved agronomic practices, harvesting and processing aspects should also be given greater consideration. The Director General of MARDI also urged that a network, including research institutions, be set up to screen and evaluate the potential of trees and shrubs in the major agro-ecological environments. In this way, the benefits can be reaped by other countries with similar climatic characteristics, taking into account socio-economic parameters in each country. In this respect, the small size of landholdings in a number of countries in Asia, the nomadic pastoralism methods of animal production in Africa and the ranching operations in countries with bigger landholdings should be considered.

To conclude, the Director General reiterated that he was very pleased to personally welcome the participants and to see MARDI hosting such a strategic meeting. He ended his address by declaring the meeting open and wishing the participants a very successful deliberation.

Prior to the first session, Mr. P.L. Pugliese, technical secretary of the Expert Consultation, reminded the participants of the exact subject matter of the Consultation and drew their attention on the fact that it so happened the selected theme for FAO World Food Day 1991, to

be celebrated right in the middle of the Consultation, was “Trees for Life” and that, clearly, one linked with the other.

He also pointed out that the subject of the Consultation would only cover a small part of the huge role trees have in everyday life for millions of people around the world who depend on trees to help meet their basic requirements for food, shelter or fuel. They also have universal roles as sources of income and employment, as a means to reverse environmental degradation, to sustain intensification of agriculture and grazing systems, to maintain biodiversity and to avoid catastrophic changes in climate. However, from the animal production point of view, the speaker emphasized the fact that trees play an essential role for some 30 to 40 million pastoralists in the world, who herd some 4000 million cattle, goats and sheep. Trees and shrubs, in fact, provide them with valuable fodder and, in some cases, allow grazing in areas where animals might not otherwise survive. Where land is intensively cultivated and space for grazing is very scarce, fodder trees and shrubs enable livestock to be kept on reduced areas of land. For both the pastoralist and the farmer, tree-planting programmes can meet the growing problem of providing a secure supply of nutritious fodder for livestock, distribute the workload - and income - more evenly throughout the year and help to sustain the intensification of grazing systems.

The conclusions and recommendations from this meeting would help to elaborate the continuation of FAO's policy on this subject and to set up development projects related to the integrated utilization of fodder trees all over the world.

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Trees as browse and to support animal production
by M. Baumer

INTRODUCTION

Ligneous plants, which may be trees, small trees , shrubs or undershrubs, are an important component of the fodder resources for livestock and wildlife. The fodder value of their leaves and fruits is often superior to herbaceous plants, particularly in the case of legumes. In arid and semi arid zones, they provide the largest part of the protein supply during the driest months; for example, it is estimated that, in the Sahel, up to 80% of the protein ration is provided by plants of the *Capparaceae* family during the three driest months of the year.

HISTORY

In the past, trees were commonly used as browse and the cutting of leaves or branches for animal feed is recorded as long ago as Roman times. Sometimes ligneous plants were used for different purposes but their importance as browse plants was only recognised late. For example, *Gliricidia maculata* and *G. sepium* were introduced at the end of the 18th century in Africa as shade trees for coffee, tea and cocoa plantations but it was recognised only a few decades ago that they provide a valuable feed, with 20 to 30% N in the leaves, 14% CF, and digestibility ranging from 50 to 75% according to the type of animal. Their main role now is to serve as a supplement to the natural flora (mixed with 50% grass) for feeding livestock, especially during the driest part of the year.

Erythrina burana was used by Central Ethiopian farmers to shade the coffee plantations. It is very common in this part of the world but its properties became known only recently to scientists. The buranas give a much appreciated fodder for the dry season and the leaves, pods and even bark are palatable to animals. The tree is easy to multiply from seeds or cuttings (large cuttings of 2m long and 10 cm diameter are usually used). It is therefore a very much appreciated multi-purpose tree in agroforestry.

SYSTEMS OF PRODUCTION

Trees are used both under natural conditions in range areas and under cultivation in farming systems.

Trees on ranges are subject to negative natural selection: animals browse the best first. But they also browse mixtures of browse and herbage, which constitute a more balanced diet with fewer risks of poisoning or intoxication. Animals also play an important role in the dissemination of the seeds through the faeces. The key problems are often the increasing rarity of the valuable species, reduced performance of livestock and poisoning due to increased consumption of "useless" browse.

The concept of usefulness is relative. It varies according to conditions but in the natural environment livestock usually select what is good for them.

In artificial agricultural systems, one of the key problems is the optimum density of tree plantations in relation to the system - direct browsing or cut-and-carry - and the timing and periodicity of their use, with the associated crops (if any) and the types of animals, etc.

NUTRITIVE VALUE

A large percentage of, but not all, fodder trees are legumes. Most of the legumes are rich in crude protein but they are not the only plant family which is rich in protein and a high protein content is not the only factor which makes a good fodder plant; the digestibility, which varies with the type of animal, is of great importance.

Leaves and fruits of ligneous species have a much higher level of digestible protein (DCP) than other fodder sources; in Senegal, it is 180 to 200 g DCP/kg DM in browse compared to 100 to

130 for groundnut leaves and 50 to 70 for leaves and fruits of various herbaceous species (Guérin *et al*., 1986). Cattle spend a lot of time browsing: 50% in May and June and more than 30% during the rest of the dry season. The regime is properly balanced when there is a sufficient diversity of ligneous species.

THE ARID ZONE

Acacia tortilis

One of the major difficulties with *Acacia tortilis* (Forssk.) Hayne is that the distribution of the species is very extensive and therefore its provenances are quite different. The nomenclature is still somewhat confused and hybridisation exists in the large species. For most modern authors, several species are distinguished:*A. tortilis, A. raddiana, A. heterophylla, A. spirocarpa*. The most elementary precaution in using seeds or material from any tree of the "tortilis" group will therefore be to enquire about the provenance. In addition, some authors have written that the palatability and the digestibility of *Acacia tortilis* (Forssk.) Hayne subsp. *tortilis* Brenan varied considerably accorded to the provenance. Its tannin content may be high and cause toxicity problems.

THE SEMI-ARID ZONE

Faidherbia albida

The great value of this tree as browse is due to its production of highly mutritive pods which can easily be kept for the dry season but it may have been considered too much as a miracle tree. At least two sub-species (A and B) are recognized. The production of pods is quite irregular but a tree may give up to 350 kg in a good year. Gassama (1989) has developed a technique of micropropagation from nodes collected on suckers.

Halophytes

In dry areas, whether warm or cold, halophytes are common on salty soils. They have a greater biomass than non-halophytic plants. In Algeria, *Atriplex halimus* produced 3.7t DM/ha compared to 0.8 to 1t DM/ha with *Artemisia herba alba* or *Arthrophytum scoparium*. In 1988, Iran had already planted more than 43 000 ha of rangelands with *Atriplex canescens, A. lentiformis* and *Haloxylon persicum*, so doubling the fodder productivity of its arid and semi-arid territory.

Climatic effects

In Northern Senegal, Poupon (1979) found that climatic variation may have an important effect on ligneous plants. During the 1972 drought, foliation was delayed by 4 to 7 weeks and its intensity was reduced; leaves did not regrow after they were browsed and the majority of flowers did not take shape, resulting in a very low and negligible fruit production.

In the semi-arid zone, there are relatively few species, but a large percentage of them is used as fodder and especially as browse by the animals. Wildlife is relatively more important, at least potentially, then domestic livestock. *Acacia* and related genera are the most important browse species, with most of the Capparaceae in the arid zones themselves, together with other genera such as *Balanites* and *Albizzia*. Le Houérou (1977) has established that in *grosso modo* in the Mediterranean basin each millimetre of rainfall was producing 4 kg of aerial biomass or 2 kg of palatable DM or 0.66 feed units (FU) and that in the Sahelian zone the production of one millimetre of rainfall is roughly equivalent to 2.5 kg of aerial biomass or 1 kg of palatable DM or 0,40 FU.

THE SUB-HUMID ZONE

Leucaena leucocephala

Although this small tree has been used with success in semi-arid zone, it is in the humid and semi-humid zone that it gives the best results. Like the two other species already briefly considered, the problem of lineage is very important. Many varieties have already been isolated and are being used. The big danger with the species is its extremely broad distribution through agroforestry and other development projects, which makes it a particularly sensitive species to diseases and parasites such as psyllids. The presence of mimosine in several cultivars has created problems with some animals, now better controlled by "vaccination" with rumen fluid from resistant livestock. The odour and taste given to milk of animals fed with *L. leucocephala* may be avoided easily by preventing the animals from eating *Leucaena* for two hours before milking. Inversely, the quality of the meat may be influenced by the nature of the feed: *pré-salé* mutton, produced for example in the Bay of the Mount Saint Michel in France is an example.

The toxicity of mimosine in *Leucaena* is comparable to many other similar phenomenons caused by the consumption of legumes and other browse. *Gliricidia sepium*, for example, is reported in some parts of the world as having an anti-nutritional effect: livestock are fond of it but do not grow when eating it even in large quantities. Perhaps inoculation of rumen fluid from resistant animals could help to cure this. These antinutritive substances seem to appear in some geographical regions or with some specific races or lineages of animals. It is embarrassing when some provenances of *Gliricidia sepium* were recognised as giving as much as 12 to 20 kg DM/tree/year in Maseno (Kenya).

These production figures are surpassed by the production of *Calliandra calothyrsus* which, in Yaoundé (Cameroon), reached 4.69t DM/ha at one year of age with 10,000 trees/ha when *Leucaena leucocephala* was giving 3.78t DM/ha, *Gliricidia sepium* 2.3t DM/ha and *Racosperma auriculiforme* 1.56t DM/ha.

Cutting ligneous vegetation may sometimes increase the total available biomass; this is why the American and Australian ranchers have, for decades, suppressed ligneous vegetation as much as possible from their ranches. but other research has shown the positive action of ligneous vegetation on the total biomass productivity and on its qualitative amelioration.

THE HUMID ZONE

Guilelma gasipaes

The peach palm *Guilelma gasipaes*, is a real multi-purpose tree species. In addition to providing the Indians of Amazonia with a fruit which gives oil and starch, it is also important source of browse for the animals. The fruits, given mainly to pigs and poultry, are too small for human consumption, damaged or have some malformation. They are left on the tree until they become overripe, otherwise it has to be cooked as it contains a diastasis which inhibits an other proteolytic ezyme which is necessary for the proper utilisation of protein by animals.

Jessenia battaua

The management of the bataua plam,*Jessenia battaua*, from South America, which exists only for the time being in wild state, seems to be theoretically comparable. But the value of its oil, which costs ten times mote than the oil of the oil plam tree, could modify its potential for management.

THE ROLE OF BROWSE TREES

A publication by the Commonwealth Agricultural Bureau in 1947 (Whyte, 1947) states: “Specialists of herbaceous pastures should be modest when they realise that there are more many animals feeding on trees and shrubs or on plant associations where these play an

important role than on pastures based on herbaceous legumes or grasses". Goats and camels feed essntially on ligneous plants: camels in Northern kenya spend 50% of their grazing time in browsing plants at a height of over 1.6m.

There are ligneous plants which provide important quantities of fodder although their main importance lies in other products. In the Salmé area in the medium range elevations of Nepal, forest and wild trees provide the most important part of available fodder. Each tree traditional rules for the period and the frequency the tree is to be lopped for browse. Sometimes the products of a cutting are for sheep, sometimes for goats, sometimes for cattle, In addition, there are trees and shrubs elsewher which are specially protected, or even planted and cultivated, for honeybees, silkworms or other small animals; the economic returns from these small animals are usually greater than those from larger one.

In the Chinampas of Mexico, trees and vegetables are grown on strips of land. Many of the trees are multi-purpose species, but most of them produce fodder. A similar system is in use int he eastern marshy lands of China; here, on the strips of land, livestock (usually goats) are partly bred and fed on the foliage of the trees and shrubs, mainly *Populus* and *Salix* species. The reson for breeding livestock in such this environment is to provide the soil with manure, which is necessary for the production of vegetables and mushrooms. In the Ban Tré Province of Vitnam, a comparable system has been studied where th leaves trees are used to feed fish.

The oldest agrosilipastoral system recorded in the world, the combination of olive tree, cereal and sheep breeding, is common all around the Mediterrance. From the browse and fodder point of view, the olive tree not only provide browse whtn it is cut (twigs and leaves) but it favours the growth of finer and tender grass in its shade.

OTHER ROLES TREES

In addition to their role in priduction of browse, trees have other production and service role. They produce wood for fuel and building purposes. They give food, fibre, drugs, fruits, pollen, nectar, dyes, gums, waxes, resins, etc. They play a very important role as wind breaks, in providing shade and protection against heat and cold and in reducing erosion.

FUTURE RESEARCH

A lot of work remains to be done in the area of trees and shrubs as browse species. One of the first requirements is a comprehensive list of browse species and theri foliar physiology should receive more attention. It could be useful also to select lines of trees which keep their leaves longer than usual on the stem.

more should be known on the management of browse species. This would make it possible to avoid the disappearance of some species by over-utilisation, as occurs with *Terminalia avicennioides* in the region of Maradi (Niger).

Combining research on meat, browse and wood production may yield interesting prospects. in the Mediterranean Zone, consideration should be given to:

- chestnut plantaions for fruits
- research on controlled fire and clearance of land by grazing with llamas of goats
- study of the effect of animals on trees in orderto better quantify the tree/animal interaction
- quantiitative studies of browsing and grazing, like in New Zealand
- identification of the best fodder trees for a specific zone

The response of the ligneous and herbaceous biomass to the density of grazing animals is also an important area. Animal preferences for certain species should be better investigated, The preference may very with external or internal conditions and may not correspond to the most productive choice from the point of view of plant growth. Allelopathic phenomena also deserve systematic investigation.

CONCLUSION

As a conclusion, one can imagine the ideotypeof the perfect tree as follows:

- **Adptability: the species should be easily estabilished and maintained in good condition in the selected environment.**

- **Palatability: it should readily accepted by animals; different animal species have different taste and the taste of a species varies with age and with pbysilogical condition. The ideotype should remain palatable in all circumstances and for every type of animal.**

- **High nutritive value: sometimes the palatability is high but not the butritive value. These two characters have to be evaluated separately.**

- **Growth and productivity: it is economically and practically important that the maximum quantity of feed is produced on every hectare of land.**

- **Hardiness and resistance: the plant should be capable of resistance to intense utilisation and to varied use (browsing, lopping, leafing, etc.). It should be able to recover quickly after intense utilisation and to form leaves again after these have been browsed of lopped.**

- **Shaade tolerance: the ideotype should be able to grow in the shade of other ligneous**

plants in order to maximise the total production.

- **rooting in order not to cause any inconvenience to other crops, it should be deep rooting, which allows it to absorb essential nutrients form a greater depth.**
- **Non-toxicity: the ideotype should not be toxic or noxious to animals. It should not have spines, hooks or spurs, nor have allelopathic properties, if it to be associated with crops.**

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Fodder trees and fodder shrubs in range and farming systems of the Asian and Pacific region

by C.P. Chen, R.A. Halim and F.Y. Chin

INTRODUCTION

The Asia and Pacific region encompasses a wide range of climatic conditions and a diversity of socio-cultural entities. This diversity has given rise to various farming systems, each of which aims at optimizing the utilization of the natural resources they are endowed with. The multitude of agro-climatic zones confers upon the region a vast assemblage of tree and shrub species which could potentially benefit livestock production. Despite the variability in farming systems there are some features which are common across the region. Farms sizes are generally small (1–2 ha) and some farmers may not own any land but have access to communal lands. Where soils and climate are amenable to cropping, food and commercial crop production takes precedence over livestock, especially in heavily populated areas. This paper discusses the various farming systems and the extent to which tree and shrub fodders have been incorporated into the system as feed resources for livestock. The list of species, the plant characteristics and the agronomic features will be discussed.

TREE FODDERS WITHIN CLIMATIC ZONES

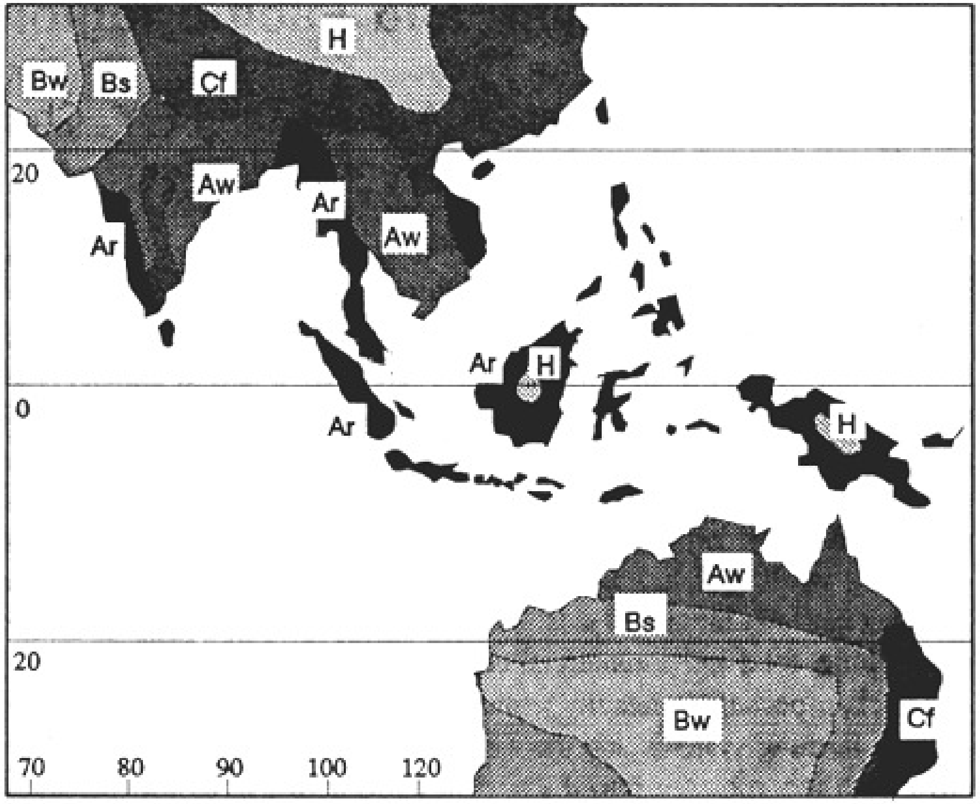
According to the classification of Trewartha (1954), there are five climatic groups in the Asia-

Pacific environment (Figure 1). These include:

a. **Tropical wet (rainforest)**
b. **Tropical wet and dry (savannah)**
c. **Semi-arid or steppe,**
d. **Arid or desert**
e. **Subtropical humid**

FIGURE 1. Classification of climatic environments in the Asia and Pacific region (Trewartha, 1954).

Pacific region (Trewartha, 1954).



Ar - Tropical humid (rainforest)

Aw - Tropical wet and dry (savannah)

Bs - Semi-arid or steppe

Bw - Arid or desert

Cf - Subtropical humid

H - Undifferentiated highlands

TROPICAL WET (RAINFOREST)

Most of the arable land has been utilized for high-value food and industrial crop production. Ruminant livestock production in these areas plays a complementary role in utilizing by-products of crops and bringing in some income from land unsuited to crop production. Where population pressure is relatively light, as in Malaysia and New Guinea, traditional farming systems have not exploited the ample feed resources made available by evergreen shrubs and trees (Wong, 1990). Some feeding of leaves of fruit trees such as *Atrocarpus*, bananas and cassava leaves to goats is commonly practised but this has been based on the observation that goats have a natural preference for a mixed diet. The use of fodder shrubs such as *Leucaena* has been a recent phenomenon and much needs to be done to encourage small farmers to exploit this valuable feed resource. Many potentially useful fodder shrub species such as *Gliricidia, Flemingia, Tephrosia* and *Albizia* are grown in cocoa plantations as shade trees. Despite the fact that pruning of the shade trees is routinely practised, they have seldom been exploited for their feed value.

The use of fodder shrubs and trees has been more widely practised in Java where population pressure on land makes it imperative that every available feed resource is fully utilized. It has been a traditional practice in many parts of West Java to use fodder shrubs and trees as protein supplements fed with a basal feed of rice straw (Rangkuti *et al*., 1990). *Leucaena* and *Sesbania grandiflora* are fed to Bali cattle at a rate as high as 15–20 kg/head daily.

In the Philippines, species such as *Leucaena* have been traditionally used in ruminant livestock production although the use of other species is rather new (Trung, 1990). *Leucaena* is not regarded solely as a ruminant feed and its use includes that as a source of fuel, reforestation and erosion control, shade and as fertilizer in agroforestry. Feed mills in the Philippines have established buying stations for dried *Leucaena* leaves in the villages, but this industry has

been hard hit by psyllid infestation in the late 1980's.

TROPICAL WET AND DRY (SAVANNAH)

For regions experiencing a monsoonal climate such as central Thailand and a major part of the Indian sub-continent, fodder shrubs and trees may be the only available living feed resource during the dry season when shallow-rooted grasses and herbs die off. Thus in Thailand, which experiences 3 months of dry season, drought-resistant fodder shrub species such as *Leucaena* provide valuable energy and protein sources for ruminants (Wanapat, 1990). In addition, leaves of fodder shrubs which grow well in the wet season, such as cassava, pigeon pea and pseudostems of bananas, are harvested and dried for storage to be fed later with rice straw during the dry season. Bangladesh, which has a similar monsoonal climate, has the added population pressure on limited land for fodder production. Arable land is used fully for food and cash crops. In this situation shrubs and tree fodders are planted on bunds, riversides, waysides and homesteads (Saadullah, 1990). The major ruminant feed is straw and the use of leguminous fodder shrubs supplements the protein needs of the animal.

SEMI-ARID

The semi-arid climate in many parts of India and the pressure on land use have made tree and shrub fodders a more important component of feeds for ruminants compared to grasses or grass-legume pastures. Dry, deciduous vegetation is mostly found in semi-arid regions and is confined to the north-west area of the subcontinent. Many of the fodder trees are not cultivated and the landless population which owns small herds of sheep and goats depends on shrubs and tree feed resources growing near the villages, roadsides and community lands (Raghavan, 1990). When the sources in the vicinity of villages are depleted the rural women frequently reserve forest areas in the hills to obtain the daily requirements of their livestock. It

is also a common practice throughout India to lop and dry tree leaves when they are abundant and store them for feeding during periods when feed is scarce. Although most of the trees and shrubs used for animal feed are not cultivated, there are traditional farming systems in India where they are deliberately planted by farmers in an agrosilvicultural system. Trees are planted with crops to provide sources of fuel and feed. In Pakistan, which has a semi-arid climate, trees play a dominant role in livestock feeding and in providing fuel. A system of alternate husbandry has become established in some areas of Sind, where *Acacia* is the main cultivated genus (Akram *et al.*, 1990). *Acacia* is mainly used for fuel but its leaves and pods are used for fodder when other types of fodder are in short supply. *Acacia* is cultivated in rows 10–12m apart and the land in between is used for cropping until the trees mature.

MONTANE REGIONS

The mountainous terrain in parts of Asia, such as in the northern Indian sub-continent, provides a different set of constraints to ruminant livestock production. In Nepal, most of the fodder trees and shrubs are found in the hill regions (800–2000m), where over 98 species are found to grow naturally. When farmers migrated to the *Terai* (plains) region many brought with them some propagatory materials which they planted around their farms and on marginal lands, terraced banks and forests (Joshi and Singh, 1990). Shrubs and tree fodders are used as fresh green feed to livestock as well as a source of fuelwood.

SUBTROPICAL HUMID

In the sub-tropical humid climate that is found in southern China, there is a great diversity of tree and shrub fodders that are traditionally utilized by ruminant livestock farmers. More than 400 species of trees and shrubs are cultivated, widely distributed and used by farm animals (Xu, 1990). The tree fodders are divided into three classes: needle leaves (pine), broad leaves

and shrubs. Pine needles are used in the industrial production of animal feed for pigs and poultry. Similarly, broad-leaf fodders such as poplar (*Populus*), willow (*Salix*), elm (*Ulmus*), and locust (*Robinia*) are made into leaf meal for monogastric feeding. Shrubs are mainly used by grazing animals especially goats. They are an important component of feed for the grassland areas in northern and western China, covering over 220 million ha with 100 million goats and sheep. In southern China, grazing districts are in the mountainous areas with 46 million ha of tropical and subtropical grasslands. The warm and wet climate favours tree and shrub growth where they provide a substantial portion of the feed for the 26 million goats and 10 million sheep.

There are more than 200 of such known multipurpose tree species which are fixing nitrogen and useful as fodder. Nearly all of these species are tropical or subtropical. Details of some of the 25 species on their origin, distribution, uses, description and forage value are summarised by Brewbaker (1986). Lately, a compendium list of more diversified tree and shrub species which includes 74 genera comprising 269 species, was complied by Blair (1990). Details of some *Tamarindus, Prosopis, Acacia* and *Pterocarpus* species used for fruit, forage and timber are described by NAS (1979).

There are 13 shrub and tree fodders being widely used and incorporated into ruminant feeding systems by the Asian farmers (Devendra, 1990). Those species are *Acacia* (*A. catechu, A. nilotica, A. sieberiana*), *Manihot esculenta, Calliandra calothyrus, Erythrina variegata, Ficus (F. exasperata, F. bengalnensis, F. religiosa*), *Gliricidia, Artocarpus heterophyllus, Albizia lebbeck, Leucaena, Prosopis* (*P. juliflora, P. glandulosa), Cajanus cajan, Sesbania* (*S. grandiflora, S. sesban*) and *Tamarindus indica. Cajanus cajan* is the species receiving intensive research as a grain crop (Nene, 1981). In the arid and semi-arid environment, such as in northern parts of Pakistan, India and China, species seem to have great potential for fodder and wood production but with slow establishment and growth. Whilst in the wet climate,

vigorous growing species, such as *Leucaena, Gliricidia, Sesbania, Erythrina* and *Cassava* are most popular leaf materials. However, *Gliricidia* tends to shed its leaves during the dry season, whereas the *Leucaena* receives severe attack from psyllids.

SPECIES CHARACTERISTICS AND AGRONOMY

The ideal multipurpose tree species, should be able to fulfil the six-"F"s basic objectives of fodder, fuel, fruit/food, fibre, forest and fertilizer (green manure) (Raghavan, 1990). The desirable agronomic characteristics of fodder trees are:

1. **ease of establishment,**
2. **good competitive ability,**
3. **high productivity and persistence under repeated cutting or grazing,**
4. **ability to adapt to Asian and Pacific climatic edaphic conditions,**
5. **require no fertilizer (low input system),**
6. **resistant to local pests and diseases,**
7. **ability to produce seed or be reliable for vegetative propagation, and**
8. **have good nutritive value and reasonable palatability to animals (Ivory, 1990).**

Generally, adverse soil conditions are prevalent in Asia and Pacific areas. For instance, of the soils in Southeast Asia and in South Pacific Islands, 51% of the total area are utisols and 44.6% combisols (ochrepts/tropepts) respectively (Blair *et al.*, 1986). Soils in the tropical and subtropical climatic zones are always associated with low mineral content such as N, P, S, K, Ca, Mg, Cu, Mo and B (Kerridge *et al.*, 1986) and high aluminium saturation which are restrictive to root growth.

In assessing species, it is essential to consider the plant agronomic features in relation to the

desirable objectives and the soil and climatic factors. For instance, Hill (1971) reported that *Leucaena* grows best in alkaline, calcareous, clayey soil and obtains poor growth on acid soils which are saturated with aluminium and manganese. Similar responses were observed in a solution culture that all *Leucaena* cultivars reacted to level of pH ranging from 3.5 to 6.0 and that the cultivars were severely affected by aluminium concentration at 8 ppm (Wong and Devendra, 1983).

Tree and shrub fodders usually sustain a long life-cycle, except for a few fast growing ones. This presents difficulties in multiplication through seed which faces severe competition from other weeds due to the slow plant establishment. Raising seedlings in the nursery may be beneficial especially for the small farmer, in trying to rapidly establish home plot fodder. For range farming, direct seeding in strips or rows is advisable. Sometimes it may be a problem to get sufficient seed from species like *Gliricidia* so that vegetative propagation may have to be employed.

One agronomic practice which affects fodder yield is tree plant density. Generally, the higher the tree density, the higher the total plant yield but individual tree yield decreases. Also, higher tree densities reduce weed competition. There is great variation in optimum plant density ranging from 1–15 trees/m^2 for optimum yield. Ivory (1990) reported that, under a cut and carry system, highest leaf and wood yield of *Leucaena, Gliricidia, Sesbania* and *Calliandra* were recorded at 4 trees/m^2, but this was dependent upon good rainfall. In less humid environments, a lower yield is expected. Other influential agronomic factors that affect tree and shrub fodder yields are the cutting intensity and frequency. Longer cutting intervals and less intensive cutting generally increase plant biomass. In the case of *Leucaena*, high forage yields are obtainable at a cutting height of between 1–3m and at a frequency between 60–90 days (Table 1). However, the edible material of tree fodders may vary greatly when leaf and wood fractions

are taken into account. A range of *Leucaena* leaf fraction of between 31% cut at 120 days to 71% cut at 30 days was reported (Ferraris, 1979; Topark-Ngarm, 1983).

It has been generally recommended that the supplement of fodder tree leaves should be less than 30% of the diet and for some species it should not exceed 15% of the total feed intake. Such a limitation is usually due to the plant toxins or secondary compounds which inhibit the digestibility and reduce the acceptability to animals. Phenolics are the most widespread secondary compounds in almost all the woody species. It occurs at 10–20% of leaf dry weight in the tropical shrubs. A wide range of *in vitro* dry matter digestibility (IVDMD) from 16.9 to 66.9 was reported (Vercoe, 1987). The mean IVDMD of 12 tree fodders ranged 36%–63% for leaf and 34.5–58.2% for edible stem, whereas the crude protein was 11.3–30.6% leaf and 9.4–18.1% edible stem.

TABLE 1. **Cutting height and cutting frequency effects upon yield of *Leucaena***

Cutting Height (cm)	Cutting interval (days)	Yield (t/ha/year)	Reference
100	(40)	113.0 FW total	**Siregar (1983)**
150	(60)	28.7 FW total	**Castillo *et al.* (1979)**
90	90	12.5 DW total	**Ozman (1981 a,b)**
50*	30	14.6 DW total	**Perez & Melendez (1980)**
150*	70*	39.4 FW total	**Krishnamurthy & Munu Gowda (1982a,b)**
150*	70*	28.0 FW total	
5*	(120)	50.6 FW total	**Takahashi & Rippeton (1949)**
(5)	110*	13.6 DW leaf	**Guevarra *et al.* (1978)**

30*	40	5.4 DW leaf	**Pathak *et al.* (1983)**
120*	(30)	4.0 DW leaf	**Isarasanee *et al.* (1985)**
(100)	85	-	**Samali *et al.* (1983)**
(30)	30/60/90n.s.	8.2 DW leaf	**Savory & Been (1979)**
(10)	120*	9.0 DW leaf	**Ferraris (1979)**
30–90n.s.	42–84n.s.	15.2 DW leaf	**Evensen (1984)**
75	70	14.2 DW leaf	**Topark-Ngarm (1983)**

() only height/frequency used

*** maximum height or longest frequency used**

n.s. no significant differences

Source: Adopted from Horne *et al.* (1986)

Blair (1990) reported that the nitrogen value of 8 tree legumes at or above 1.8% level, would be sufficient for the growth of 300–500 kg cattle. More detail information on forage quality and chemical composition of fodder trees was presented by Brewbaker (1986). However, information from Vercoe (1987) on 23 tree species indicated that the level of phosphorus (0.05–0.18%) was the most deficient, as well as the low concentration or marginal level of Na, Cu, Zn and potential deficient mineral of Co, Se and Mo.

INCORPORATION OF FODDER SHRUBS AND TREES INTO FARMING SYSTEMS

The competitive land use between crops and livestock exerts considerable pressure against utilization of arable land for planting fodders and pastures. In this situation, a number of

approaches have been suggested in order to incorporate fodder shrubs and trees without competing with crops. This has been discussed previously (Topark-Ngarm, 1990) and a summary of these approaches is presented. Four ways in which fodder shrubs and trees can be incorporated are:

1. Planting a living fence around the household

   Fodder shrubs such as *Leucaena leucocephala, Pithecellobium dulca, Gliricidia sepium, Sesbania grandiflora* and *Artocarpus heterophylus* can be grown as living fences which provide not only human food and fuelwood but also animal feed. Experience in Thailand shows that the fence can be established by direct seeding or transplanted seedings at close spacing and be ready for use in 6–8 months. *Gliricidia sepium* has been extensively used in Indonesia and the Philippines and is easily established by sticking the stem or branch cuttings into the ground.

2. Vegetation on uncropped lands

   In many of even the most intensively cropped areas of the region there are pockets of land which cannot be used for cropping. These may be in the form of farm boundaries, paddy bunds or forest margins which could be used to grow some shrubs and trees. These areas could be planted with fodder shrubs and trees to augment protein needs of livestock and integrated with plantation agriculture.

3. Hedgerows in alley cropping

   A specific concept in incorporating fodder shrubs and trees into farming systems producing annual crops has been developed by the International Institute of Tropical Agriculture (IITA). Shrubs and fodder trees are grown as hedgerows in cropped land.

These serve as windbreaks or heatbreaks and provide green manure fertilizer for the crops. During the productive period, the cut material from the hedgerow species often provides fodder in excess of the amount needed from green manure for animals. Shade trees such as *Gliricidia*, used in cocoa plantations, can be treated the same way when they are routinely pruned to prevent overshading.

4. Component species in inter-cropping

   In this system, shrubs or fodder trees are grown in alternate rows or rows adjacent to food crops. Trees are pruned once or twice for fodder or to reduce competition and shading during the growing period of the crops. Species used in this system are limited to fast growing ones and those tolerant to frequent cuttings. Examples of these include small shrub legumes like *Stylosanthes scabra, Stylosanthes viscosa, Cajanus cajan* and *Desmanthus virgatus*.

CONCLUSION

It is evident that the Asian and Pacific region is richly endowed with a diversity of fodder shrubs and tree species that can serve as useful feed resources. At present, most of the trees and shrubs used in farming systems comprise those that grow naturally in the forest and in uncropped marginal lands. Sufficient evidence from research has shown that improved animal production can be obtained by incorporating shrub and tree fodders as protein supplements. The fact that the planting of fodder shrubs and trees has not been more widely adopted by farmers in the region may have been caused by a lack of information on the economics of production and the long term benefits to the overall farming systems. While substantial work has been conducted on yield and nutritive value of fodder trees, very little work has been reported using a “systems approach” to study the interacting factors that impinge on a

farming system which incorporate fodder shrubs and trees. Package technologies that incorporate fodder shrubs and trees without imposing competition on crops must be formulated in order for it to be more widely adopted.

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Fodder trees and shrubs in range and farming systems in dry tropical Africa

by M.S. Dicko and L.K. Sikena

INTRODUCTION

Dry tropical Africa refers to about 38% of the continent and is characterized by an average annual rainfall of less than 600 mm. About 45% of the area is desert while the remainder constitutes the arid and semiarid zones which are actually the portions capable of supporting plant, animal and human life. The regional distribution of this climatic zone is 9% in Central Africa, 34% in East Africa and 20% in Southern Africa (Le Houérou and Popov, 1981).

Fodder trees and shrubs constitute a vital component in livestock productivity in the arid and semi-arid zones where about 52% of the cattle, 57% of the sheep, 65% of the goats and 100% of the camels in tropical Africa are found (Von Kaufmann, 1986). They supply goats and camels with the bulk of their nutritive requirements and complement the diet of cattle and sheep with protein, vitamins and minerals in which bush straw is deficient during the dry season. Nutrition of game animals also greatly depends on them. To people, they serve useful purposes such as the provision of food, drugs, firewood and building materials.

Despite this importance, research and development efforts with regard to trees and shrubs have been minimal until the occurrence, in recent years, of prolonged droughts which adversely affected the fragile ecosystem of the area. Consequently, increased interest has been shown by policy makers and researchers in the maintenance, and even expansion of, tree populations and the evaluation of the role and potential of fodder trees and shrubs in grazing systems.

FODDER TREES AND SHRUBS IN RANGE AREAS

A tree or shrub is classified as fodder if it is browsed by animals. Palatability depends upon a

number of interacting factors linked to animals as well as environment. The animal factors include species, physiological status and previous experience with specific vegetation, while the environmental variables comprise botanical composition, plant structure, forage quality and grazing pressure. Trees and shrubs recognized as fodder vary from region to region and an exhaustive inventory of them is difficult to make.

Main fodder trees and shrubs

Table 1 lists 124 fodder trees and shrubs found in dry tropical Africa. The inventory was based on the extensive reviews and reports made by Edwards (1948), Baumer (1983), Dicko (1980), Dicko and Sayers (1988), Keya *et al.* (1991), Lamprey *et al.* (1980), Le Houérou (1980), McKay and Frandsen (1969) and Walker (1980).

TABLE 1. **List of main fodder trees and shrubs**

Mimosaceae:	*Albizia anthelmintica, Acacia albida (Faidherbia albide), A. benthamii, A. brevispica, A. erioloba, A. ehrenbergiana, A. karoo, A. laeta, A. mellifera, A. nilotica, A. nubica, A. raddiana, A. senegal, A. seyal, A. tortilis, Prosopis africana, Parkia biglobosa*.
Combretaceae:	*Anogeissus leiocarpus, A. schimperi, Combretum aculeatum, C. apiculatum, C, denhardtiorum, C. eleagnoides, C. exaltatum, C. fragans, C. ghazalense, C. glutinosum, C. micranthum, C. mossambicense, Guiera senegalensis, Terminalia holstii, T. ruspolii.*
Caesalpiniaceae:	*Afzelia africana, Bauhinia petersiana, B. reticulata, B. rufescens, Cassia sieberiana, C. tora, Colophospermum mopane, Cordeauxia edulis, Piliostigma reticulatum, P. thonningii, Tamarindus indica.*
Capparidaceae:	*Boscia albitrunca, B. angustifolia, B. salicifolia, B. senegalensis, Cadaba farinosa, C. glandulosa, Capparis decidua, C. tomentosa, Crateva adansonii,*

	Maerua angolensis, M. crassifolia, M. parvifolia, M. tricophylla.
Papilionaceae:	*Baphia massaiensis ssp obovata, Dalbergia melanoxylon, Indigofera garckeana, I. spinosa, Lonchocarpus capassa, Pterocarpus lucens, P. erinaceus, Rhychosia flavissima.*
Tiliaceae:	*Grewia bicolor, G. flava, G. flavescens, G. kakothamnos, G. tenax, G. villosa.*
Acanthaceae:	*Barleria eranthmoides. B. proxima, Disperma Kilimandscharica, Justicia Caendeir. Justicia Caeruleir. J.* pinguor.
Convolvulaceae:	*Ipomea hardwickii, I. eriocarpa, I. acanthocarpa. I. coccinasperma.*
Rubiaceae:	*Feretia apodanthera, Gardenia amencana, G. spatulifolia, Mitragyna incenus*
Anacardiaceac:	*Lannea stuhlmannii, Sclerocarya birrea, S. caffra*
Labiatae:	*Leucas neufliziana, Hoslundia opposita, Plectranthus iginansus.*
Verbenaceae:	*Avicennia africana, Clerodendron myricoides, Premna vibumoides.*
Burseraceae:	*Commiphora africana, C. boiviniana.*
Euphorbiaceae:	*Acalypha fructicosa, Securinega virosa.*
Rhamnaceae:	*Ziziphus mauritiana, Z. mucronata.*
Simaroubaceae:	*Balanites aegyptiaca, B. maughamii.*
Amaranthaceae:	*Sericocomopsis hilderbrandtii.*
Annonaceae:	*Annona aremaria.*
Asclepiadaceae:	*Oxystelma bourmouense.*
Bombaceae:	*Adansonia digitata.*
Boraginaceae:	*Heliotropium albohispidum.*
Cyperaceae:	*Croton dichogamus.*
Ebenaceae:	*Dispiros mespiliformis.*
Erythroxylaceae:	*Erythroxylum zambesiacum.*

Hypocratheaceae:	*Hypocrathea africana.*
Liliaceae:	*Asparagus spp.*
Loganiaceae:	*Strychnos innocua.*
Lythraceae:	*Hypocratea africana*
Lythraceae:	*Lawsonia inernis.*
Malvaceae:	*Hibiscus micranthus.*
Moraceae:	*Ficus gnaphalocarpa.*
Moringaceae:	*Moringa oleifera.*
Ochnaceae:	*Ochna stuhlmannii.*
Oleaceae:	*Ximenia americana.*
Plumbaginaceae:	*Plumbago zeylanica.*
Salvadoraceae:	*Salvadora persica.*
Sterculiaceae:	*Cola laurifolia.*
Ulmaceae:	*Celtis integrifolia.*
Umbellifera:	*Steganotaenia araliacea.*

This list should certainly be longer, particularly if one considers the fact that severe forage scarcity in dry tropical Africa can make herbivores eat anything including pieces of paper and plastic material. Whyte's (1947) assertion that 75% of trees and shrubs in Africa are browsed to a greater or lesser extent by game and domestic animals is surely applicable to dry tropical Africa.

BROWSE PRODUCTION

Browse production is influenced by many environmental factors such as climatic, edaphic and topographic conditions and management background involving exploitation by animals, lopping

and burning forested areas.

The foliage and fruit production of some fodder trees and shrubs in the Sahel is given in Table 2. Noticeable is the wide variation in the browse production of the different species, particularly in the proportion of fruit which represents 3 to 55% of the deciduous biomass.

Browse productivity (production per unit area) has been found to be linked to habitat and soil texture. For instance, in a study carried out by Cisse and Wilson (1984) at Niono in Mali, the number of *Pterocarpus lucens* trees found on clay, loamy-clay and sandy soils was 845, 100 and 94 per hectare, respectively. The corresponding foliage production was 3.5, 0.9 and 0.4 tons DM/ha. In the same zone, and open woodland with *Sclerocarya birrea* and *Guiera senegalensis* produced only 0.02 ton DM/ha.

Regarding the effect of management, pruning is found to ensure better browse production than lopping and for both, the operation should preferably be carried out during the cold dry season rather than during the hot period (Le Houérou, 1980). Excessive lopping in dry areas often results in the death of trees. Fires have adverse effects on trees and shrubs in arid and semi-arid zones where low soil moisture balance prevails. In sandy soils, however, plants with deep root systems are less affected than those on shallow and heavy soils. Also, fires at the end of the dry season can be detrimental to trees and shrubs which have already flushed (Walker, 1980).

TABLE 2. **Foliage and fruit production per individual per year.**

Species	**Country**	**Rainfall (mm)**	**Diameter (cm)**	**Leaves (g DM)**	**Fruit (g DM)**
Acacia senegal	**Senegal**	250	15.9	3840	1340
Adansonia digitata	**Senegal**	250	140.0	22000	2400

Balanites aegyptiacum	**Senegal**	250	16.8	1850	1030
Commiphora africana	**Senegal**	250	16.5	290	80
Guiera senegalensis	**Senegal**	250	10.2	2850	-
Acacia laeta	**Burkina Faso**	440	15.0	2500	-
Acacia seyal	**Burkina Faso**	440	15.0	1700	-
Acacia tortilis	**Burkina Faso**	440	15.0	700	-
Balanites aegypticum	**Burkina Faso**	440	15.0	2500	-
Acacia albida	**Mali**	600	14.3	3100	-
Pterocarpus lucens	**Mali**	600	14.3	3980	-
Ziziphus mauritiana	**Mali**	600	14.3	3600	-

Adapted from Bille, 1980

NUTRITIVE VALUE

The main features of browse plants are their high crude protein (CP) and mineral contents. The concentration of CP in the leaves and fruit of the majority of fodder trees and shrubs is above 10% even in the dry season when it tends to decrease. Generally, calcium and potassium contents are higher than those of other minerals. The role of trees and shrubs in the supply of vitamins is indirectly demonstrated in dry tropical Africa by the fact that browsers such as goats and camels seldom contract photophobia or eye inflammation which many cattle are prone to during the dry season.

The dry matter digestibility, which is related to nutrient composition, varies widely among tree and shrub species. A range from 38 to 78% was given by Skarpe and Bergstrom (1986) working in Botswana with Kalahari woody species. Similar findings were reported by McKay and

Frandsen (1969) and Walker (1980). However, digestibility alone gives a poor assessment of the nutritive value of fodder trees and shrubs. This is because there is often no relationship between digestibility and intake.

Low intake and digestibility of browse may have some connection with the deleterious substances that it may contain. For instance, some browse species reported in Table 1, such as *Acacia albida, A. tortilis, A. erioloba* and *Ximenia americana*, contain substances such as cyanogenic glucosides, fluoroacetate or tannins which may considerably reduce their nutritive value or even be toxic to animal. However, toxicity depends upon the concentration of the deleterious compound in the fodder and the rate at which the forage is eaten. “An amount of the plant eaten quickly, say in one hour, could be fatal, whereas the same amount of plant material eaten slowly over, for example, a five hour period, would be harmless” (Storrs, 1982). On the range, the chances of animals getting poisoned are remote because they actually eat a combination of species and browse slowly, particularly when the plant is armed with defensive structures such as hairs and thorns.

For most of the fodder trees and shrubs identified in dry tropical Africa, knowledge of browse production and chemical composition is still lacking. Overcoming this constraint would ensure maximization of the use of this fodder by livestock.

FODDER TREES AND SHRUBS IN FARMING SYSTEMS

Exploitation of fodder trees and shrubs on rangelands

In addition to the exploitation *in situ* by domestic ruminants, rangeland fodder trees and shrubs are used for marketing purposes. They are also invaluable as consumable goods, drugs. Additionally, they are considered as embodiments of supernatural power.

In the Sahelian zone of West Africa, selling fodder is quite lucrative, as shown by the study of Dicko and Sangare (1981) (Table 3).

Table 3 indicates the predominance of browse in terms of types of fodder presented (4 out of 7) as well as quantity (522 out of 674 tons DM). The highest weight (458 tons) was recorded for *Pterocarpus lucens*. If one assumes a leaf off-take of 0.2 tons DM per hectare from woodlands of *Pterocarpus lucens* whose productivity ranges from 0.4–3.5t DM/ha, one arrives at exploited areas totalling about 23 Km^2.

TABLE 3. **Estimated quantities (in tons DM) and values (in US dollars)[*] of browse and crop residues presented for sale at Niono market, Mali, 1981.**

Fodder from	Quantity		Value	
	tons	%	US dollars	%
Pterocarpus lucens[a]	458	67.9	10734	36.7
Pterocarpus erinaceus[a]	4.5	0.7	292	1.0
Mixture of *Ipomea* spp.[ab]	51.6	7.6	3033	10.4
Hypocrathea + Oxystelma[ac]	8.1	1.2	238	0.8
Ischaemum rugosum	94.2	14.0	3157	10.8
Arachis hypogea	17.2	2.6	3936	13.4
Vigna unguiculata	40.0	6.0	7883	26.9

[*] **1 US dollar = 500 Mali franc in 1981**

[a] **leaves of shrubs and trees**

[b] mixture of *Ipomoea eriocarpa, I. acanthocarpa* and *I. coccinosperma*

[c] mixture of *Hypocrathea africana* and *Oxystelma bourbouense*

Source: Dicko and Sangare, 1981

The results also demonstrate that to farmers, browse leaves are not as valuable as the hay from cropped legumes. The browses were 8 to 10 times cheaper than the hays of groundnut (*Arachis hypogea*) and cowpea (*Vigna unguiculata*). However, despite this low cost, the leaves of shrubs and trees had an estimated value of 14,297 US dollars (Table 3).

Assuming that about 20 farmers were involved in the transactions[1] and that three quarters of the browse presented was sold, the average cash income per fodder trader would be about 45 US dollars per month. This is 50% more than the monthly salary of a casual worker in the zone. In dry West Africa, selling fodders is a specialized activity in its own right. The trade flourishes mainly during the 2 to 3 months preceeding the Muslim celebration of “Tabaski”.

INTRODUCTION OF TREES AND SHRUBS IN FARMING SYSTEMS

Traditional agroforestry system

Agroforestry is a long-standing practice among certain groups in Africa (Boudet and Toutain, 1980). Trees and shrubs are protected or grown on-farm primarily because they provide shade and edible leaves, fruit and seeds. They are also used for marking farm boundaries, controlling erosion, improving and stabilizing soils. Farmers therefore have policies regarding bush clearing. Their strategy considers the needs of both crop and livestock production, as testified by the words of an old couple from Zimbabwe talking about clearing Acacia woodlands: “It is a good idea to cut tall muvunga (*Acacia sp)*, because the ground will be shaded and there will be no grass and the tree will be too tall for the goats to eat. We should cut some old ones and leave the young ones. It is also best to cut those trees that do not produce pods" (Scoones, 1988). In West Africa, bush clearing policies advocate keeping reasonable tree densities in order to reduce crop damage which may be caused by birds using trees for perching.

A traditional agroforestry system based on *Acacia albida.* is found throughout the semi-arid zones. *Acacia albida* is a leguminous tree which enriches the soil, particularly with nitrogen and calcium. It also has the advantage of providing shade and valuable browse during the dry season. Jung (quoted by Charreau and Nicou, 1971) reported annual production of 97 and 125 kg of leaves and pods respectively from a tree which had a crown surface of 230m[2].

[1] The actual number is lower than that. There are a limited number of people specializing in the marketing of fodders.

In the semi-arid highlands of Ethiopia, *Acacia albida* was integrated on farmers' fields at a rate of 20 trees per hectare. Economic analysis of this intervention arrived at an additional income of 230 US dollars per hectare from cereal grain, stover, fodder and fuel wood (CTA, 1991).

Another traditional agroforestry system, especially in Niger and Sudan, is the one incorporating *Acacia senegal* in crop rotation (Boudet and Toutain, 1980). In addition to browse, this species also produces gum which brings important income.

Modern agroforestry systems

The expression "modern" is used here to qualify the agroforestry recently introduced in farming systems by government services, alone or in conjunction with non governmental or

international organizations. The actual development of the discipline occurred after the prolonged droughts of the early 70's which resulted in manifest desertification particularly in the Sahel.

In the projects[2] that were created in agricultural zones, erosion control and wood production were the primary objectives (Kerkhof, 1990). Pastoral zones were given little consideration as regards woodland management, probably because of the transhumant and nomadic style of life of pastoralists.

[2] Agroforestry projects in operation.

Projects in agricultural zones:

- **Burkina 1 = village woodlands project in Burkina (rainfall 400–1000 mm).**
- **Burkina 2 = Burkina Faso agroforestry project (rainfall 400–600 mm).**
- **Kenya 2 = East Pokot agricultural project (rainfall 600 mm).**
- **Mali 1 = Village woodlot project in Mali (rainfall 600 mm).**
- **Mali 2 = Koro village agroforestry project (rainfall 300–600 mm).**
- **Niger 1 = Majjia valley wind break project (rainfall 400–600mm).**
- **Niger 2 = Guesselbodi forest land use project (rainfall 500 mm).**

Projects in pastoral zones:

- **Kenya 1 = Turkana rural development project (rainfall 180–400 mm).**
- **Senegal 1 = project on reforestation round wells in N. Senegal (rainfall 300–400 mm).**

To realize the set objectives, the projects used indigenous and exotic trees which mostly have

potential for fodder production as well. These trees are:

- ***Acacia albida*: Mali 2, Senegal 1**
- ***Acacia nilotica*: Kenya 1, Niger 1**
- ***Acacia raddiana*: Mali 2**
- ***Acacia Senegal*: Senegal 1**
- ***Acacia tortilis*: Kenya 1**
- ***Azadirachta indica**: Burkina 2, Kenya 1, Kenya 2, Mali 1, Mali 2, Niger 1.**
- ***Atriplex nummilaria**: Kenya 2**
- ***Balanites aegyptiaca*: Kenya 1, Kenya 2, Niger 2.**
- **Dobera glabra: Kenya 1**
- **Salvadora persica: Kenya 1**
- ***Tamarindus indica*: Kenya 1**
- **Various *Acacia, Combretum* and *Bauhinia* species: Niger 2**
- **Various *Prosopis**: Kenya 1, Kenya 2, Mali 2.**
- ***Ziziphus mauritiana*: Kenya 1, Kenya 2.**

(* introduced species)

The technical packages involved the use of seedlings and also direct seeding, the latter having limited success mainly with indigenous species. *Acacia* were often planted in rows with spacing varying from 5 × 5m to 10 × 20 m (Senegal 1), but a dispersed intercropping which is preferred by farmers was also tried out. The design for windbreaks in Niger 1 and Mali 2 consisted of double rows of trees (4 × 4 m spacing) over 2 km. The trees were planted perpendicularly to the prevaling wind direction. Microcatchments were used with success in Burkina 2, Kenya 1 and 2, Mali 2 and Niger 2. However the high cost of their establishment is a drawback to their extension. Mulching consisting of leaving branches and other organic materials improved

natural regeneration in Niger 2 (Kerkhof, 1990).

After 8 to 15 years of operation, modern agroforestry has had little impact on farming systems. One of the major reasons is the top-down approach at the initial stage of most of the projects, with objectives which often do not match farmers' needs. For instance, woodland projects for producing building poles and fuel-wood rarely succeed in zones where people live in clay-brick houses and believe that firewood has to come from rangelands. Another reason is the difficulty of growing trees in harsh conditions of arid and semi-arid zones. The slow growth rate, poor survival rate and high labour input for protecting seedlings do not foster enthusiasm for adopting tree planting on a medium or large scale. Poor adoption is also due to the communal land tenure system and acquisition of land on a loan basis. In neither of the systems, do users consider themselves as owners and hence they are not willing to spend money on the land, particularly when the trees have a life span of about 30 years. Another important reason is that tree crops come into economic production after 6 to 7 years, while poor-resource farmers (who are in the majority) are interested in interventions which give profit within a year.

Fortunately, many projects have drawn lessons from past experience and now match intervention packages to farmers' needs and circumstances.

In addition to the indigenous fodder trees and shrubs used in modern agroforestry, the following species are interesting for further introduction: *Boscia senegalensis, Bauhinia rufescens, Cadaba glandulosa, Combretum aculeatum, Grewia bicolor* and *Pterocarpus lucens.*

At research level, tests of some Australian *Acacia's* have also been carried out in many countries of dry tropical Africa (including Burkina Faso, Mali, Mauritania, Niger and Senegal) (Cossalter, 1986). *Acacia holosericea, A. trachycarpa* and *A. tumida* were found to have high fodder potential and to be adapted to a variety of soils. Their main drawback is sensitivity to

prolonged droughts. According to Cossalter (*loc. cit.*) other interesting fodder species for further investigations are: *Acacia stenophylla, A. ampliceps, A. maconochiena* and *A. pachycarpa*.

CONCLUSION AND RECOMMENDATIONS

Dry tropical Africa is endowed with indigenous fodder tree and shrubs species which are an important feed source for livestock in the area. Unfortunately, details of browse production and nutritive value are still lacking for most of the species identified.

Over the years, woody plants have increasingly become subjected to intense exploitation pressure aggravated by prolonged droughts, thus posing a serious threat to the ecosystem of the area. This resulted in the initiation of Agroforestry projects involving indigenous and exotic species. However, the impact of these projects on farming systems has been limited by ecological, social and cultural factors.

Tests have shown that there is potential for introducing into the area fodder tree species from other regions of the world such as Australia.

For optimum utilisation of fodder trees and shrubs, it is essential that details of browse production, palatability and nutritive value of the prominent species are measured. Knowledge of deleterious substances in the various fodders is equally important.

To safeguard sustainability and protect the fragile ecosystem of dry tropical Africa, there is a need to develop appropriate range management packages for the region.

Due to the potential of fodder trees and shrubs from other regions of the world, it is recommended that deliberate efforts be made to expand the adapted species, while continue to

test new ones. However, this expansion should considers farmers' needs and circumstances.

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Fodder trees and shrubs in range and farming systems in tropical humid Africa
by O.B. Smith

INTRODUCTION

In many developing countries, sustained and high population growth rates, combined with limited and rapidly diminishing land for food and forage production, have created a need to intensify agricultural production in order to bridge the gap between requirement and supply of food and ensure proper human nutrition. Intensification, in the context of ruminant production systems, means a broadening of the feed resource base to compensate not only for the shrinking of rangeland and natural grasslands but also for the low quality and seasonal nature of this major feed resource.

Some of the alternate feed resources that could complement natural forages include cultivated leguminous and non-leguminous pastures, crop residues, fodder trees and shrubs. The choice of alternate feed resource should not be restrictive but must fit within the existing farming systems, and be adapted to the economic realities of the farmer.

Fodder trees and shrubs have been used for generations as multipurpose resources (food, fibre, fodder, timber, wood and live fences) across all of the agro-ecological zones of Africa.

FARMING SYSTEMS IN TROPICAL HUMID AFRICA

Tropical Africa, which lies between 23.5°N and 23.5°S of the Equator, can be divided into 5 major agro-ecological zones whose main characteristics are shown in Table 1. Tropical humid

Africa in this context is taken to include all areas receiving over 900mm of rainfall annually, i.e. both the humid and sub-humid zones.

TABLE 1. **Main characteristics of agro-ecological zones in tropical Africa**

Characteristics	Zone*			
	Humid	Sub-humid	Semi-arid	Arid
Rainfall (mm/yr)	>1500	900–1500	600–1000	<600
Growing season (days)	270	180–270	180	
Vegetation	Moist ever-green with trees dominant	Guinea-savannah with trees and shrubs	Sudan Savannah with scattered bushes/low trees	Steppe with scattered grasses
Farming/land use systems	Arable cropping Cash cropping Mixed crop-small ruminant farming	Arable cropping Agro-pastoralism Ranching	Nomadic, Pastoralism, Perennial arable cropping	Nomadic Pastoralism

* **The fifth zone - Highlands - varies according to altitude and latitude**

In the humid zone, the predominant farming activity or land use system is that of tree crop cultivation (cocoa, oil palm, kola nut, etc.), in conjunction with a shifting cultivation-bush fallow system of growing food crops (cassava, yams, maize, cowpea, etc.). Dwarf sheep and goats, which are not well integrated into the cropping system, are the predominant livestock species raised on a free roaming, low input, subsistence system.

In the sub-humid zone, on the other hand, livestock (predominantly cattle but with a large small ruminant population) are more important and better integrated into the shifting cultivation-bush fallow system by settled agro-pastoralists who cultivate mainly cereals and grain legumes. In both zones, trees and shrubs play an important role in the maintenance and regeneration of soil fertility, thus enhancing crop production (Atta-Krah *et al.*, 1986). Fodder from these trees and browse from fallow lands provide high quality feed for livestock production.

These feed resources have hitherto not been systematically exploited for strategic year-round feeding of livestock. However, efforts have been intensified recently to characterise the agronomic features, management requirements and feed value of some promising species, particularly introduced, exotic ones, so that they could be used in appropriate feeding systems for improved livestock productivity.

INVENTORY OF FODDER TREES AND SHRUBS

Trees are the dominant natural vegetation in the humid zone, while short trees and shrubs predominate in the drier sub-humid area. A large number of trees and shrubs, both leguminous and non-leguminous are listed in the literature as being suitable for feeding livestock (Le Houérou, 1980); Brewbaker, 1986; Atta-Krah, 1989). Amongst the several hundreds listed in the literature, only a small number apparently have a real feed value. According to Brewbaker (1986), the 5000 known nitrogen fixing woody species could be selectively reduced to 80 of acknowledged fodder value, out of which only 5 could be described as good.

This reflects a lack of knowledge of the value of many of the trees and shrubs indigenous to tropical Africa, rather than an intrinsic poor fodder value, and highlights the need to evaluate some of these materials. The list of fodder trees and shrubs in humid tropical Africa shown in Table 2 has therefore been limited to species whose fodder value is more universally

acknowledged.

AGRONOMIC FEATURES OF SOME OUTSTANDING SPECIES

Some of the desirable characteristics of trees and shrubs cultivated for fodder production have been summarised by several authors (Wilden, 1986; Atta-Krah *et al.*, 1986; Ivory, 1989). These include:

- **easy establishment and rapid early growth in order to compete effectively against weeds,**
- **thornlessness and perenniality,**
- **high productivity under repeated cutting, grazing or browsing,**
- **resistance to local pests and diseases,**
- **high seed production ability or reliable vegetative propagation,**
- **little or no fertiliser requirement,**
- **high production of good quality forage in terms of protein and mineral contents, palatability and digestibility.**

TABLE 2. **Trees and shrubs of known fodder value in tropical humid Africa**

Botanical name	**Common name**	**Fodder value***
*Acacia sieberiana***	-	High
Acioa barterii	-	Medium
*Afzelia africana***	Haemorrhage plant	High
*Albizia ferrunginea***	-	Medium
*Albizia lebbeck***	Woman's tongue	Medium
Alchornea cordifolia	Xmas bush	Low
Anacardium occidentale	Cashew	Low

Anthonata macrophylla	-	Low
Baphia nitida	Camwood	Medium
Baphia pubescens	-	Medium
Bridelia spp.	-	Low
Butyrospermum paradoxum	Sheabutter	Medium
*Cajanus cajan***	Pigeon pea	High
*Calliandra spp.***	Kaliadra	Low
Canarium schwenfurti	-	Medium
Ceiba pentandra	Cotton tree	Medium
Chlophora excelsa	Iroko	Low
Citrus spp.	Orange	Low
Creistis ferruginea	-	Low
Cussonia barterii	-	
Cyclicodiscus gabunensis	-	Medium
Dacryodes edulis	Pear	Low
*Daniella oliveri***	-	High
*Desmodium spp.***	-	Medium
Dialium guineense	Velvet Tamarind	Low
*Dichrostachys cinerea***	Kakada	Low
Elaies guineensis	Oil palm	Medium
Ficus elasticoides	-	High
Ficus exasperata	-	Medium

Ficus thonningii	-	High
Gardenia erubescens	-	Low
Glifforia simplicifolia	-	Low
Gliricidia sepium	Madre de cacao	High
Gossypium barbadense	Cotton plant	Medium
Grewia mollis	-	Low
Glyphaea brevis	-	Medium
Harungana madagascariensis	-	Medium
Hymenodictyon pachyantha	-	Medium
Leucaena leucocephala	Ipil-ipil	High
Mangifera indica	Mango	Low
Manihot utilissima	Cassava leaves	High
Musa sapientum	Plantain/banana	Medium
Newbouldia laevis	-	Low
*Pentachethra macrophylla***	Oil bean	Medium
*Piliostigma thonningii***	-	Low
Psidium guajava	Guava	Low
*Prosopis africana***	-	Medium
*Pterocarpus erinaceus***	African Rose Wood	Medium
Rauwolfia vomitoria	-	Low
Ricinodendron heudelotii	African wood oil tree	Low
Sesbania sesban	Sesban	High
Spondias mombin	-	High
	-	Medium

Sterculia tragacantha *Strychnos spinosa*	-	High
Treculia africana	African breadfruit	Medium
Waltheria indica	-	Low

*** Fodder value based on published information on palatability, intake and digestibility**

**** Leguminous fodder**

Some efforts are currently being made in Africa to select and evaluate trees and shrubs that meet these requirements, but with little success to date because of the long growth cycle of these fodder plants. Atta-Krah *et al.* (1986) reported that efforts to screen 22 native browse species in Nigeria were abandoned after two years of observations, redirected and limited to *Gliricidia* and *Leucaena* because none of the former species could match the productivity of the introduced species. It is not surprising therefore that information available in the literature on agronomic features such as establishment, yield, and management are limited to such species as *Leucaena leucocephala, Gliricidia sepium, Sesbania sesban* and *Cajanus cajan*.

ESTABLISHMENT

Trees and shrubs can be propagated either from seeds or stem cuttings, although certain species like *Leucaena* have traditionally been cultivated from seeds. *Gliricidia*, on the other hand, is easily established from cuttings or seeds. Conditions for high striking (i.e., germination) percentages of stem-cutting established *Gliricidia* have been extensively investigated.

Willis (1980), Chadhokar (1982) and Falvey (1982) suggested using mature stakes (six-month-

old or more), 1 to 1.5m long and 3 to 5cm in diameter, planted about 15cm deep. Stem sections should be planted fresh within 3 days after cutting and the exposed ends should be waxed or covered with vaseline, mud or polythene to minimise evaporation. There is no consensus as to the angle at which the planted end should be cut. Chadhokar (*loc. cit.*) recommended an oblique angle in order to increase the terminal bark area from which the roots emerge, while Willis (*loc. cit.*) preferred a straight or right angled cut to minimise the area exposed to rot.

Stake establishment of *Gliricidia* has two disadvantages. The plant develops a shallow root system that does not go deep enough to tap deep water sources during the dry season when it could suffer water stress and could easily be knocked down by animals browsing it. Secondly, a large amount of material may be required. According to Reynolds and AttaKrah (1986), about 25 tons of stakes were needed to establish 1 ha of alley farm with tree rows 4m apart.

The latter problem prompted the ILCA team to investigate seed collection and drying techniques as well as optimum spacing for seed established *Gliricidia*. The results summarised by Atta-Krah *et al.* (1986) showed that seeds of *Gliricidia*, which would otherwise be dispersed from the pods on drying, could be collected from fresh green pods and sun-dried without affecting seed viability. An 8 cm spacing of seeded trees, which gave 25,000 trees/ha, appeared most suitable for high yield. In other words, seed-established shrubs and trees are more suitable for fodder production.

Certain precautions need to be taken, however, to maximise this advantage. Many leguminous species such as *Leucaena* have hard seed coats that need to be treated prior to planting to enhance water imbibition and germination. *Leucaena* seeds are usually treated with hot water, acid or mechanical scarification. Vegetative domination of slow growing seedlings by weeds may result in high plant mortality. Transplanting nursery raised plants may therefore be preferable to direct drilling.

YIELD

Regardless of the production systems of fodder trees and shrubs (hedgerow planting or intensive production), foliage yield is affected by such factors as plant density and harvesting management, i.e., age at first harvest, height and frequency of cutting and season of harvest (Ivory, 1989). Biomass production figures available in the literature vary from 2 to 20 tons of dry matter/ha for *Leucaena* (NAS, 1984) 2–10 tons/ha for *Gliricidia* and *Sesbania* and 4–10 tons for *Cajanus cajan.* According to Hedge (1983) and ILCA (1988), higher yields of 30–50 tons/ha are possible for *Leucaena* under intensive monocultural production systems with tree populations of over 200,000 plants/ha.

The effect of planting densities on leaf yield has been investigated by several workers (Kang and Reynolds, 1986; Ella, 1988) who reported that, for *Leucaena, Gliricidia, Calliandra* and *Sesbania*, leaf yield per unit area increased with increasing planting density. In other words, when high leaf yield is targeted for fodder production, high planting densities are recommended. Although various planting densities ranging from 1 to 13 trees/m^2 have been assayed, optimum planting densities have rarely been recommended because of the confounding effects of such factors as season, rainfall and plant spacing. Ivory (1989) concluded that it may be difficult to define optimum planting densities for intensive production systems based on existing information. Nevertheless, an optimum planting density of 10–15 trees/m^2 was recommended for *Leucaena* by Hedge (1983) and 25 trees/m^2 for *Gliricidia* by Atta-Krah *et al.* (1986).

HARVESTING MANAGEMENT

Management factors that affect not only fodder yield per unit area but also total long-term productivity include age at first harvest, harvesting frequency and height and season of

harvest. Chadhokar (1982) indicated that frequent fodder harvest in the early years of *Gliricidia* establishment may reduce biomass yield in later years and recommended that, during the first to three years of establishment, foliage be harvested only once or twice a year. According to Ivory (1989), the older the tree at first cutting, the higher the rates of regrowth and biomass yield, since older trees would have thicker stems, more carbohydrate reserves and a deeper more extensive root system.

On the basis of experiments carried out on five-year old *Gliricidia* plants, harvested for two years at varying intervals of 2, 3, 4, 5 and 6 months, Chadhokar (1982) suggested that *Gliricidia* be harvested once every 3 months to maximise foliage yield.

Less categorical recommendations were made by Ivory (1989), following a review of studies on pruning frequency and biomass yield. The variable results reported were attributed to the modifying effects of factors such as intra-row spacings, fodder species, climate (wet or dry), production system (wood or leaf), etc. Thus ILCA (1988) reported a fall in *Leucaena* yield from 30.4 tons/ha, when cut at 12 weeks interval, to 10.3 tons per ha when harvested at intervals of 6 weeks, with an accompanying higher plant mortality. The same workers demonstrated the effect of intra-row spacings on *Leucaena* yield which fell from 41 tons/ha at 0.5m to 30 tons/ha at 1 to 2m intra-row spacing. In general, it could be concluded that, in humid climates where emphasis is on fodder production, short cutting intervals of 8–10 weeks appear suitable, while the longer interval of 12–14 weeks is recommended for the drier environment.

Although *Gliricidia* and *Leucaena* remain green all year round, particularly when pruned regularly, foliage growth and retention appear lower during the dry season, demonstrating a seasonal effect. Oakes and Skov (1962) obtained monthly dry matter yields of 0.99 tons of *Gliricidia* dry matter/ha during the dry season with an average rainfall of 55 mm/month, compared to 1.48 t/ha during the wet season (114 mm/month rainfall).

This demonstrable seasonal effect on regrowth and total biomass yield, calls for some management strategy that will ensure adequate all-year round supply of fodder for livestock feeding. In general, a pruning interval of 8 weeks during the wet and 12 weeks during the dry season may achieve this. Where the shorter pruning interval produces foliage in excess of livestock requirements, harvesting may be delayed to carry larger amounts as protein stores into the dry season.

FEED VALUE

The feed value of a forage is a function of its nutrient content and digestibility, its palatability (which determines its consumption level) and the associative effects of other feeds. An interplay of these factors determine the effective utilisation or feed value of the material.

Sufficient data exist in the literature on the nutrient content of several fodder trees and shrubs, including the usually neglected local species. Some of the published data are summarised in Table 3 and suggest that, on average, fodder trees and shrubs are richer in protein and lower in fibre and ash than tropical grasses. The differences are even more striking when dry season values are compared. Crude protein content of dry, mature tropical grasses often falls below the minimum 6% required for maintenance, while most fodder trees remain green with high protein contents. In a review of the nutritive value of browse in West Africa, le Houérou (1980) concluded that browse contains double the amount of energy of dry grass owing to its lower content of fibre.

There is less data available in the literature on the mineral concentrations in fodder trees and shrubs, particularly the local species. Available data for the favoured species like *Gliricidia* (Table 4) and some local species suggest that, except for a disproportionately high Ca:P ratio in leguminous species, most browses contain adequate levels of macrominerals to cover

animal requirements and that this should be better exploited. More studies are, however, required to fully characterise trace mineral contents of these fodder resources.

TABLE 3. **Nutrient content of selected fodder trees and shrubs (compared to *Panicum maximum*)**

Fodder species	% OF DRY MATTER					
	Organic Matter	Crude Protein	Crude Fibre	Acid Detergent Fibre	Neutral Detergent Fibre	Total Ash
Albizia lebbeck	85.0	21.7	36.6	24.6	35.4	7.3
Afzelia africana	85.0	17.8	27.8	26.0	-	13.0
Cyclicodiscus gabunensis	95.0	15.8	21.0	23.0	-	5.0
Ficus exersperata	90.5	14.8	22.0	25.0	-	7.0
Gliricidia sepium	90.0	23.0	20.7	28.7	42.8	9.7
Leucaena leucocephala	89.0	22.4	13.0	28.9	42.0	9.4
Sesbania grandiflora	88.2	23.5	-	21.7	27.1	10.0
Panicum maximum	88.4	12.0	30.0	55.9	76.0	13.0

TABLE 4. **Mineral content of *Gliricidia sepium.***

Mineral	Range	Mean
Calcium (% DM)	0.6 – 2.5	1.3
Phosphorus (% DM)	0.1 – 0.3	0.2
Calcium-Phosphorus Ratio	3.7 – 9.3	6.2

Magnesium (% DM)	0.2 – 0.6	0.3
Sodium (% DM)	0.1 – 0.5	0.3
Potassium (% DM)	2.4 – 3.4	3.3
Zinc (mg/kg)	22.0 – 37.0	26.0
Iron (mg/kg)	259.0 – 362.0	207.0
Manganese (mg/kg)	40.0 – 90.0	69.7
Copper (mg/kg)	4.0 – 7.7	5.8

The high variability in the nutrient content of fodder trees and shrubs often encountered in the literature could be attributed to within species variability due to factors such as plant age, plant part, harvesting regimen, season and location. These factors should be considered when chemically evaluating fodder trees. Even so, laboratory analyses may be of limited value in assessing fodder nutritive value because they do not indicate the availability of cell wall constituents. The nutritive value of fodder trees can therefore not be accurately determined without an indication of their digestibility. Unfortunately, there is even a greater dearth of data on the digestibility of fodder trees and shrubs native to tropical humid Africa.

Some of the available data are summarised in Table 5. In general, fodder trees and shrubs not only degrade fairly well and rapidly in the rumen, supplying soluble carbohydrates and fermentable nitrogen to the rumen (Smith and Van Houtert, 1987) but also are well digested postruminally, often at a higher level than tropical grasses, and should therefore improve the intake and digestibility of the latter.

It is also well known that digestibility values may not be a good indicator of the feed value of fodder because of such factors as palatability, associative effects of other feeds and metabolic principles which may reduce intake or bind up nutrients. An evaluation of the feed value of

these materials should therefore be completed by feeding trials using practical feed combinations offered at realistic levels. It has been recommended that, when used as supplements, the optimum dietary level of fodder trees and shrubs should be about 30 to 50 % of the ration on dry matter basis, or 0.9–1.5kg per 100kg body weight (Devendra, 1988). Table 6 shows some available data on the potential feed value of fodder trees.

TABLE 5. **Digestibility of selected fodder trees and shrubs (compared to *Panicum maximum*)**

Fodder species	***In vivo* Organic Matter Digestibility (%)**	***In vivo* Organic Matter Digestibility (%)**
Albizia lebbeck	53.2	59.5
Afzelia africana	-	45.5
Ficus exasperata	-	45.5
Gliricidia sepium	53.9	-
Leucaena leucocephala	64.9	57.5
Sesbania grandiflora	61.8	66.7
Panicum maximum	53.2	37.0

TABLE 6. **Potential feed value of fodder trees and shrubs**

Basal feed	**Fodder supplement**	**Response**	**Livestock species**	**Reference**
Rice straw	***Leucaena* (50% of ration)**	**Significant increase in organic matter digestibility (9%), energy intake (86%), and nitrogen retained (256%)**	**Sheep**	**Devendra (1983)**
Gliricidia	***Leucaena* (50% of**	**Significant increase in digestible dry matter intake**	**Goats**	**Ademosun *et al.***

	ration)	(12%) and growth rate (55%)		(1985)
Guinea grass hay	*Gliricidia* (30g/kg $W^{0.75}$)	Doubling effect on digestible dry matter intake	Goats	Ademosun *et al.* (1985)
"	*Leucaena* (30g/kg $W^{0.75}$)	66% increase in digestible dry matter intake		

PRODUCTION SYSTEMS OF FODDER TREES AND SHRUBS

A number of fodder production systems designed to produce sufficient foliage for livestock feeding particularly during the dry season are currently being evaluated and refined.

Two examples of such cultivation systems are alley farming and intensive feed gardens (IFG). Both systems are varieties of the same theme - that of cultivating suitable trees and shrubs either as pure monoculture stands, or mixed with herbaceous forages (IFG) or arable crops (alley farming). Biomass yields from both systems are usually high. Atta-Krah and Reynolds (1989) reported a yield of over 20 tons of dry matter/ha in an IFG of *Gliricidia* and *Leucaena* mixed with *Panicum maximum*. The tree hedgerows were established 2.5m apart with two rows of grasses. In the *Leucaena-Gliricidia* plots only, 30 tons of foliage dry matter/ha was harvested. A more extensive treatment of both systems is given later in this publication.

TOXINS AND ANTI NUTRITIVE FACTORS

Fodder trees and shrubs may contain high levels of deleterious compounds that make them unpalatable or harmful to livestock when consumed in large amounts. Particularly well documented in the literature are the harmful effects of mimosine, or its metabolite 3-hydroxy-pyridone (DHP), on livestock consuming large quantities of *Leucaena*, which may contain concentrations of 0.3 to 7.1% of mimosine depending on the variety and plant part. Levels of 2 to 2.3% of tannins have also been reported in *Gliricidia* and *Albizia* spp.

A number of methods are used by farmers to overcome or reduce palatability or toxicity problems caused by these compounds. Wilting, drying and dilution of the problem feed with other, feeds are common. Wilted *Gliricidia* leaves are more readily consumed by cattle than the fresh leaves which have an offensive odour and the feeding of *Leucaena* at a level not exceeding 50% of ration to ruminants lacking the specific DHP detoxifying rumen bacteria is recommended. The less well studied indigenous fodder trees and shrubs that have high potential feed value should be characterised by their contents of potentially toxic compounds.

CONCLUSION

Trees and shrub fodder play important roles within the farming systems of tropical humid Africa, contributing significantly to soil maintenance and fertility, as well as livestock production, particularly as dry season feed resources. The full potential of several species native to this region has not been systematically and fully exploited because of the benign neglect they have hitherto suffered in terms of research efforts which have been concentrated on a few introduced species. While research efforts should continue on such species as *Leucaena, Gliricidia* and *Sesbania*, emphasis needs to be gradually shifted to the local species currently being exploited by farmers. Adoption of technologies based on these species may be more rapid and widespread.

Research efforts should be directed towards:

a. Agronomic evaluation including seed production and storage techniques for promising local species.
b. Nutritional characterisation of these species under practical feeding systems.
c. Year-round feed utilisation systems that will maximally exploit improved biomass yields resulting from a better understanding of agronomic features.

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Fodder trees and shrubs in range and farming systems in North Africa
by A. El Aich

INTRODUCTION

The shrublands of North Africa cover about 940,000 km^2, of which 65,000, 350,000 and 525,000 km^2 are located in semiarid, arid and desert regions, respectively (Le Houérou, 1989a). They provide both a valuable grazing resource, because of their nutritive value and palatability, and prevent soil erosion by increasing soil stability. According to Le Houérou (1989a), grazing represents 60 to 80% of the economic output of North African shrublands. Used as fodder, trees and shrubs supply a greater amount of protein to livestock on a year round basis. In addition, browse plants are comparatively high in phosphorus but relatively low in energy-supplying constituents.

CONTRIBUTION OF FODDER TREES AND SHRUBS TO LIVESTOCK DIETS

The contribution of browse to the livestock diet varies with the nature of the ecosystem. In less favorable environments, where the grazing season for vegetation is short, the contribution of

native fodder shrubs to the animals' diet is very high and may exceed 70% (high mountain, steppe and desert ecosystems). In more favorable areas, shrubs are generally used on a seasonal basis.

SHRUBLANDS OF THE SEMI-ARID TO HUMID ECOSYSTEMS

In the semi-arid to humid ecoclimatic zones of the N. African countries, the major natural shrubland ecosystems are dominated by *Quercus* spp. (3.47 million hectares), *Cedrus atlantica* (0.15 million hectares), *Pinus halepensis* (1.27 million hectares), *Tetraclinis articulata* (0.94 million hectares), *Olea europea, Ceratonia siliqua, Pistacia lentiscus* (0.72 million hectares), *Juniperus phoenicea* (2.3 million hectares), and 0.7 million hectare parkland of *Argania spinosa* (Le Houérou, 1989a).

The High Atlas study case

In the High Atlas, farming systems integrate both agricultural and pastoral components in which fodder trees play an important role. Crops are cultivated on farms with an average size of 0.5 ha. Small ruminant feeding systems are based on pastoral resources which provide 94% of small ruminant energy requirements (Bourbouze, 1982). Pasture grazing, especially for small ruminants, comes primarily from watersheds which are public lands.

The main fodder trees in the watersheds are *Fraxinus xanthophyloides, Quercus rotundifolia* and *Juniperus oxycedrus.* The shrubs used as fodder are *Cytisus* spp., *Globularia mainii, Ormenis scariosa, Genista* spp. and *Thymus* spp.

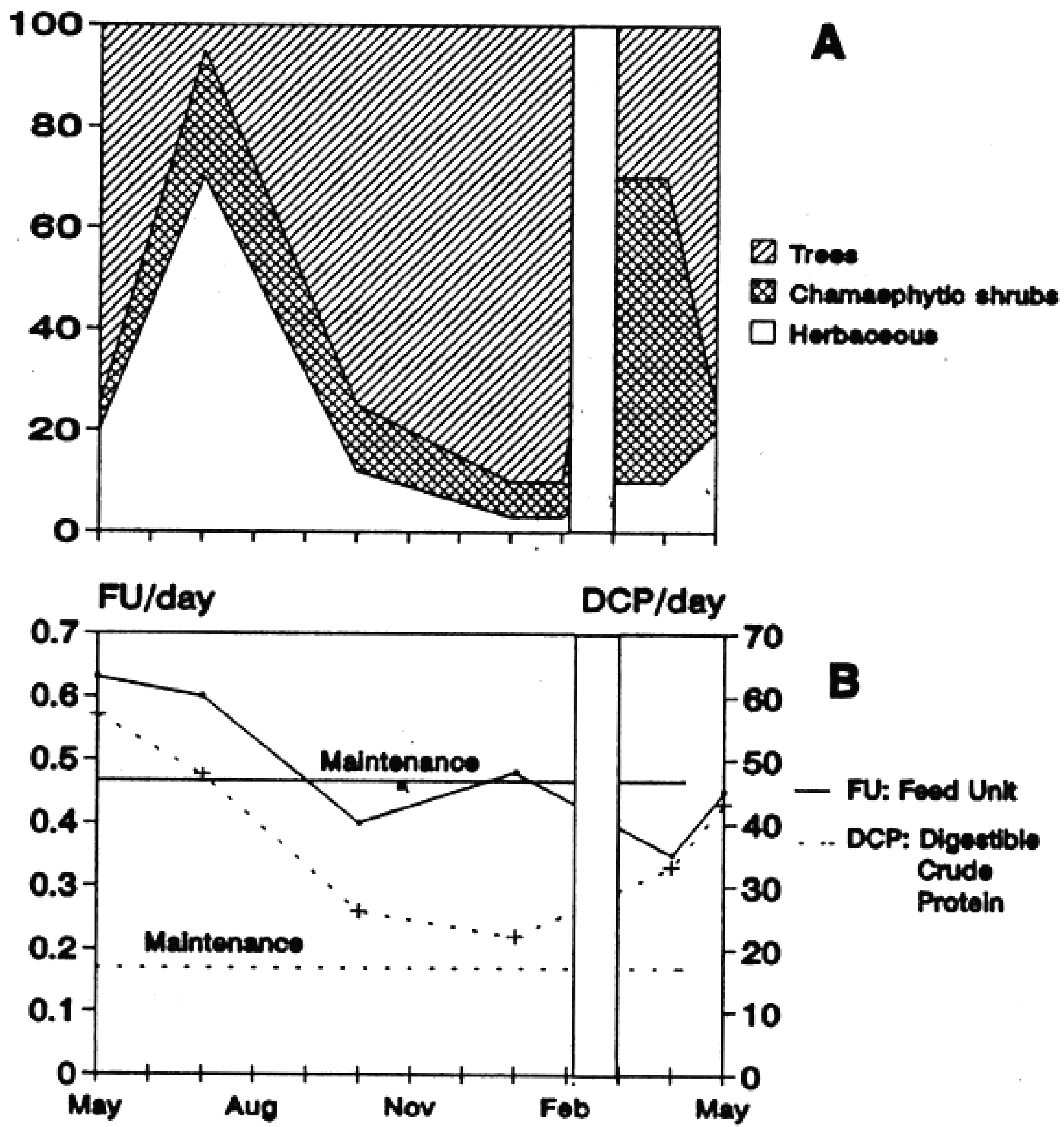
The nutritional quality of these fodder trees varies among species. *Fraxinus xanthophyloides* has a good nutritional quality (0.8 feed units (FU)/kg DM, and 15% crude protein in DM) and is an important source of both energy and protein. The nutritive values of *Quercus rotundifolia*

and *Juniperus oxycedrus* are low in comparison to *Fraxinus xanthophyloides. Quercus rotundifolia* and *Juniperus oxycedrus* average 8 and 5% crude protein and ash in DM, respectively. *Quercus* spp. is rich in phenolic compounds such as tannins which result in a decrease in digestive utilization. El Honsali (1982) compared the use of oak leaves, highly rich in tannins, by sheep and goats. He concluded that infusion of tannins slightly improved dry matter intake for goats whereas it had an adverse effect on sheep.

In the High Atlas, Bourbouze (1982) shows that the contribution of fodder trees and shrubs to goat diets remains high, except in July (Figure 1). Among fodder trees, *Quercus rotundifolia*, despite its low nutritive value, contributes the most, from both leaves and acorns, i.e, 86% in January. Indeed, during periods when food is short (winter), shoots or branches of *Quercus ilex* are cut by herders and provided to goats. The use of more *Juniperus oxycedrus* in goat diet is compromised by the presence of spines.

Trees and shrubs used as fodder provide a sufficient amount of protein to meet goat maintenance requirements year-round (Figure 1).

FIGURE 1. Diet botanical composition of goats (A) and contribution of range feed resources to cover goat maintenance requirements (B) in the High Atlas of Morocco (Bourbouze, 1982).



100
80
60
40
20
0
A
Trees
Chamaephytic shrubs
Herbaceous
FU/day
DCP/day
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
70
60
50
40
30
20
10
0
B
Maintenance
Maintenance
FU: Feed Unit
DCP: Digestible Crude Protein
May
Aug
Nov
Feb
May

STEPPE ECOSYSTEMS

Halophytic steppe and desert regions

Feeding systems in these regions, characterized by a pre-Saharan climate where the precipitation averages 70 mm/year at most, are based exclusively on open range feed resources since supplementary feeds are rare. The open ranges are used by herds of dromedaries in grazing patterns based on seasonal and yearly movements. Seasonal movements among regional grazing areas ensure forage balance and water availability. Yearly decisions concern environmental conditions (climatic crisis, droughts) and the political boundaries of the different countries.

The three major shrublands are: 1) crassulescent halophytic steppes, 2) nanophanerophytic steppes and 3)wormwood sub-desertic steppes. The crassulescent halophytic steppes with *Salsola* spp., *Suaeda* spp., *Arthrocnemum indicum* and *Salicornia* spp. cover 4 million hectares. The nanophanerophytic steppes with *Ziziphus, Atriplex, Calligonum* and *Tamarix* and wormwood sub-desertic steppes, dominated by *Haloxylon, Anabasis* and *Traganum*, occupy areas of 2 and 3 million hectares, respectively (Le Houérou, 1989a).

Trees and shrubs of these halophytic steppes survive a higher water stress and tolerate various amounts of salt in the soil. They supply the majority of protein to livestock, especially dromedaries and goats. The crude protein contents of these halophytic plants are high and remain stable throughout the seasons. The crude protein content in DM of *Acacia raddiana*, legume tree, and *Traganum nudatum* varies from 11% to 19% during the early and late season, respectively. *Calligonum comosum* and *Salsola* spp. have lower protein levels. Ash content in DM of the halophytic species is extremely high. It varies in autumn from 19% for *Haloxylon scoparium* to 45% for *Traganum nudatum*. Moreover, *in vitro* dry matter digestibility

coefficients are adequate (45 to 55% of DM on average). These levels should, however, be considered with caution because of the high ash content which might lead to a reduction in the metabolizable energy of these forages. These trees and shrubs are chiefly grazed by dromedaries.

TABLE 1. **Diet botanical composition, and nutritive value, and total consumption of the dromadery diet in the southern steppe of Morocco (Moumen 1991).**

	January	April	June	October
Botanical composition (in %)				
Species				
Nanophanerophytes				
Acacia raddiana		9.83	4.26	17.98
Calligonum comosun	4.47		8.51	
Salsola spp	43.72	11.15	5.58	9.45
Ziziphus lotus		0.98		
Haloxylon scoparium		7.17		17.02
Tamarix spp.				10.23
Traganum nudatum	36.52		13.97	16.08
TOTAL	84.71	29.12	32.31	70.77
Chamaephytes				
Gaillonia reboudiana		12.75		
Peganum harmala		6.17		
Launea arborescens				25.77
TOTAL		18.92		25.77

Herbaceous				
Diplotaxis harra	15.29		67.69	
Pennisetum dichotomum				3.46
Others		51.96		
TOTAL	15.29	51.96	67.69	3.46
Chemical composition				
Crude protein (% DM)	12.60	13.59	19.63	10.94
NDF (% DM)	33.11	38.24	42.34	33.82
ADF (% DM)	25.39	30.57	31.22	26.25
ADL (% DM)	11.82	10.88	7.30	8.19
In vitro dry matter digestibility (% DM)				
IVDMD	51.78	39.11	38.92	43.16
Intake (kg/An/Day)				
Intake (kg/An/Day)	10.58	13.56	12.10	10.90

A study carried out in the southern steppe of Morocco indicates that the diet of dromedaries is from fodder trees, fodder shrubs and herbaceous plants (Moumen, 1991). Contributions of the different species vary depending on the grazing season (Table 1). Early in the season, *Salsola* spp. and *Traganum nudatum* average 43.7 and 36.5%, respectively. In spring, dromedaries include more herbaceous plants in their diet whereas, in summer, they ingest mainly *Diplotaxis harra* (67.7%) and *Traganum nudatum* (14%). Late in the grazing season, fodder trees and shrubs become the only dietary component and average 71 and 25%, respectively.

The botanical composition of the diet is dominated by fodder trees and shrubs resulting in a

high crude protein content year-round (Table 1). The values for *in vitro* dry matter digestibility are adequate early in the season and become low thereafter. Digestibility coefficients, expressed on an organic matter basis, are much lower because of the high ash content of the available halophytic species.

Total dry matter consumption averages 10.6, 13.8, 12.00 and 10.9 kg/animal/day in January, April, June and October, respectively (Moumen, 1991). Total consumption is lower both early and late in the season because of the low availability of herbaceous plants. Dromedary production averages 198 kg of live meat and 580 kg of milk per animal unit per year.

Chamaephytic steppes

The climate in the chamaephytic steppes is arid with an average precipitation of 200 mm. It is characterized by a pulse of precipitation and a large number of years with precipitation below average. The major North African shrublands are *Artemisia herba alba* steppe (7 million hectares) on silty soils and *Artemisia campestris* (4 million hectares) on sandy soils (Le Houérou, 1989a).

In these steppes, sporadic cultivation makes the farming systems more and more agropastoral. Three different types of resources contribute to feed small ruminants, i.e., range forages, agricultural by-products (straw and stubble) and supplementary feed. El Aich (1987) found that 40% and 15% of the animal needs were provided by *Stipa tenacissima* and *Artemisia herba alba* in normal and dry years, respectively. *Artemisia herba alba* communities are used as spring pastures by sheep producers.

Aerial phytomass production of the *Artemisia* plant community averages 200 to 250 kg DM/ha (Merzak, 1990). *Artemisia herba alba* averages crude protein contents of 12 and 9% early and

late in the season, respectively. Ash levels remain high (> 19%) regardless of the period of the year (Merzak, 1990). Despite their mean digestibility coefficients (49%), *Artemisia* spp. have high content of essential oils which interferes with the energy assimilation. Cook *et al.* (1952) reported that the metabolizable energy in *Artemisia tridentata* is lower because of the essential oils; its metabolizability is of the magnitude of 0.30 as compared to alfalfa hay, 0.82.

A study conducted on the oriental steppe of Morocco indicates that sheep ingest a large proportion of *Artemisia herba alba* and the other shrubs, especially during periods of drought (Table 2). *Artemisia herba alba* contribution is 76.5 % on average.

However, sheep respond quickly to changes in range botanical composition resulting from concentrated rain. In the *Artemisia* spp. community, sheep ingest a diet rich in cell wall content, with an adequate level of protein (Table 2). The average ratio ADL/ADF of 45.6% indicates a depressed digestion of the fibre fraction. *In vitro* organic matter digestion coefficients of sheep diets are low whereas dry matter intake levels are acceptable (Table 2) and allow an average gain of 100 g/day during spring for yearling rams (Merzak, 1990).

Unregulated and selective grazing by livestock has shifted many *Artemisia* spp. communities to a situation where unpalatable forbs or aggressive shrubs of low palatability dominate. In addition, sporadic cultivation and uprooting make the extent of desertification serious. As results of shrubland depletion, feeding calendars for small ruminants experience a shortage of feed in summer and autumn, especially in dry years.

TABLE 2. Botanical composition of diet, nutritive value and intake of sheep in *Artemisia* plant community at Oriental Steppe of Morocco (Merzak, 1990).

	Early spring	Mid-spring	Early summer
Botanical composition (in %)			

Artemisia herba alba	78.05	68.55	82.95
Other shrubs	10.30	15.80	10.40
Herbaceous plants	5.63	12.31	3.15
Chemical composition			
Ash (% DM)	11.32	15.09	9.47
Crude protein (% DM)	7.55	7.90	7.98
NDF (% DM)	47.61	48.10	52.28
ADF (% DM)	36.41	34.79	36.25
ADL (% DM)	14.79	16.61	17.59
In vitro organic matter digestibility (% DM)			
IVDMD	48.78	47.43	31.42
Intake			
g DM/an/day	861	802	745
g DM/LW$^{0.75}$/day	76.77	76.29	72.16

SHRUBLAND IMPROVEMENTS

Grazing management

Strategies for improving shrubland productivity and use depend on the nature of the ecosystem. In more resilient ecosystems, i.e., semi arid to humid shrublands, there is a need to keep shrubs and find a way to increase the proportion of high quality preferred food available, relative to animal requirements. Indeed, small changes in forage composition of high quality protein plants are disproportionately important in improving animal status. For instance, a vegetation rest results in an increase in the abundance of preferred species and the standing crop of biomass.

Phosphorus fertilizers are expected to increase phytomass, improve botanical composition and enhance the establishment of legumes.

In a less favorable environment, stands containing high numbers of lesspreferred individuals must be managed to allow the establishment and persistence of preferred genotypes. Proper grazing pressure is the key factor in shrub management. Under higher stocking rates, the density of senescent *Artemisia herba helba* plants increased and the survival of seedlings decreased.

Plantations of introduced species

Seedling and planting provide an opportunity to include shrub species that will contribute to stability and diversity as well as useful productivity of the ecosystem. Many shrub species were introduced in the region, such as *Acacia* spp., *Atriplex* spp., and *Prosopis* spp. and *Opuntia* spp. They have been planted over more than half million hectares in Morocco, Algeria, Tunisia, Libya and Egypt. Among these fodder shrubs, *Atriplex* spp. are the most recommended and frequently planted species.

The ecological value of *Atriplex* spp.

Atriplex spp. can grow normally with only 150 to 200 mm rainfall and are not affected by heavy textured and high salinity soils and water. Their frost resistance is high. The choice of species is the determinant for establishment of a plantation. Baumann (1990) compared legume shrubs (*Acacia* spp.) to non-legume shrubs (*Atriplex* spp.) on the oriental steppe of Morocco. He concluded that the rates of establishment of legume shrubs were very low because *Acacia* spp.

need a mean precipitation of more than 150 mm and deep sandy soils. The rates of establishment of *Atriplex* varied among species in the range 70–75%. In the same study, *Artemisia herba helba* used as a control, had the highest survival rates.

The phytomass yield varies with the density of the seedlings. Palatable biomass of *Atriplex nummularia* (yearling twigs and leaves) averaged 462 kg DM/ha (Tazi *et al.*, 1991). Protection of *Atriplex* spp. during establishment increases the amount of herbaceous grown beneath and between bushes. There are regeneration problems with *Atriplex* spp. after 6 to 7 years of utilisation, especially on shallow soils. The average duration for *Atriplex nummularia* plantation is 8 to 10 years.

***Atriplex* spp. provide a good palatable fodder year-round, because they keep their foliage. However, animals avoid shrubs in spring when herbaceous plants are available. Palatability studies indicate that introduced shrubs (*Atriplex nummularia, Acacia cyanophylla* and *Medicago arborea*) are very low dietary components during the growing season when herbaceous plants are available but, as the season advances, animals ingest more shrubs (Saadani, 1987).**

***Atriplex nummularia* is relatively high in protein and ash. The crude protein and ash contents of *Atriplex nummularia* average 18.2±0.45 and 22.7±1.31 *per cent*. respectively. Crude protein content (ash) of *Acacia cyanophylla* average 13.5 (10.0), 10.4 (9.2), and 11.07 (11.9) for spring, summer and autumn, respectively. The mean ratios of ADL/ ADF (>50%) indicate a depressed digestion of the fibre fraction. The digestibility of *Atriplex* spp. averages 59% in spring and 49% in summer, whereas *Acacia cyanophylla* has lower digestibility, i.e., 26 and 20% in spring and summer, respectively (Saadani, 1987). The intake of *Atriplex* spp. varies in the interval of 50 to 55 g DM/kgLW$^{0.73}$. Increased consumption of *Atriplex* spp. is accompanied by higher water intakes because of the increased water required for urinary excretion of sodium. Sheep**

grazing *Atriplex vesicaria* consume 7 to 7.5 kg/day of water in comparison to 3.2 kg/day on grasslands (Wilson *et al*., 1969). As supplementary fodder, *Atriplex* spp. should not make more than 25 to 30% of the sheep's diet.

The economical feasibility of *Atriplex* spp.

The question of the economical feasibility is of central interest. The establishment costs for a plantation (nursery, soil preparation, transport, planting, watering and maintenance) averaged $350 US/ha (Tafrata Perimeter, Morocco) with *Atriplex nummularia* in 1987. A 30 to 35% supplementary cost should be accounted for as cost of protection. With an average production of 500 kg DM/ha (140 FU), and assuming that the duration of use of the plantations is 8 years, the cost per FU is about $0.45 US. Le Houérou (1989b) suggested that *Atriplex* plantations can be produced at a moderate cost as soon as yields are over 1000 FU/ha.

The economic viability of *Atriplex* spp. plantations appear uncertain under North African conditions. However, the value of browse plantations is undeniable if their multitude functions are taken into consideration. The comparison with other range improvements are aspects that answer both the technical validity and the economic feasibility of fodder shrub development.

The social feasibility of *Atriplex* spp.

Social acceptability must be assessed prior to any range rehabilitation programme. Questions such as: 1) why people prefer certain shrubs and 2) how people assess the value of a shrub, determine the success of the programme.

Feedbacks from shrub plantations are diverse. Shrub plantations are considered as government actions and are subject to lack of confidence from livestock producers. In the east of Morocco, sheep producers prefer rehabilitation with native shrub (*Artemisia herba alba*). For a technician, *Atriplex* spp. are planted to serve many purposes. But the message the livestock producer receives does not imply the same reasons. A survey on attitude regarding *Atriplex* in the Dhamar Montane Plains (DHV, 1989) showed nearly all villagers recognized “salt tree”(shajar al milh) could be grazed by sheep; but they did not mention that *Atriplex nummularia* can be used for firewood, as a windbreak or for erosion control.

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Practical technologies to optimise feed utilisation by ruminants
by R.A. Leng, B.S. Choo and C. Arreaza

INTRODUCTION

Rates of growth and milk production from ruminants in developing countries are generally low and often only 10% of the genetic potential of the animal. The reasons for low productivity are complex but in order of priority they appear to be:

- The imbalanced nature of the nutrients that arise from digestion of the available forage resources when these are fed without supplements
- The incidence of disease and parasitism
- The often harsh climatic conditions

The use of a high yielding genotype in these situatuions is often irrelevant because the primary constraint is poor nutrition. On the other hand, resistance of particular breeds to disease and high temperatures is an important overall consideration.

Nutritional research has shown that large increases in animal productivity and efficiency can be brought about by small changes in the balance of nutrients in the feed base (Leng, 1991). These increases are not restricted to laboratory studies and have been observed on a large scale at the small farm level (NDDB, 1989) and without alteration to the other management practices. This illustrates the large potential impact of feeding strategies in these environments.

Increased production of meat and milk is only one benefit. The improved body condition of animals also has an impact on reproductive rate. The age at puberty of heifers is lowered and the intercalving interval in mature cows is decreased.

Increased efficiency of forage utilisation by animals and improved reproductive rate together produce an increase in production of up to five fold without changing the basal feed resources. This is accomplished by identifying and providing critical catalytic nutrients that are deficient in the diet and therefore balancing nutrient availability with animal requirements.

In general, the supplements required are a source of fermentable N, minerals for the rumen organisms and a source of protein that is not readily degraded in the rumen but moves rapidly to the lower tract to improve the animal's amino acid supply.

In many countries, these feed supplements are available. In others, there is a need to identify alternative sources and provide them in the correct amounts and in an appropriate form.

In many pastoral areas of the world, the basic resource is pasture, which is generally low in total protein and fermentable N. Often a source of bypass protein is not available locally. Research and development is needed to produce supplements economically at the centres of high ruminant population densities. In the rangelands, particularly in the semi arid areas, tree forages, seeds and pods represent by far the greatest potential source of protein meals that can be used as supplements to provide soluble N, bypass protein and a source of minerals. When fed, they create a rumen environment more capable of fermentatively digesting poor quality forage. In addition, in the dry areas, these green supplements are a major source of Vitamin A.

FORAGE RESOURCES IN DEVELOPING COUNTRIES

Crop and livestock production in developing countries have more than doubled in the last 30 years; however, the demand for food has increased at an even greater rate, leading to an increase in food imports of approximately 10% per year. Increase in animal production in developing countries has been brought about through increases in animal numbers. Production rates per animal have remained low or have only increased to a minor extent (Jackson, 1981).

The demand for food for human consumption in Third World countries is likely to increase and, since cropping land is almost fully utilised at the present time, it appears that cultivated pasture is likely to become scarcer in these countries. The ruminant will therefore have to depend increasingly on forage biomass containing large amounts of complex carbohydrates which are not digested by intestinal enzymes and therefore require fermentative digestion. These include forage and crop residues which cannot be used by monogastric animals but can be used efficiently by ruminants. The ability of ruminants to convert otherwise waste materials into useful products or to accomplish work will ensure they remain important livestock species in the foreseeable future.

The increasing need for land for crop production indicates that ruminants will continue to use primarily crop residues, industrial byproducts and pastures from relatively infertile rangelands. The common characteristics of such feeds are low digestibility, low protein content and a low mineral components.

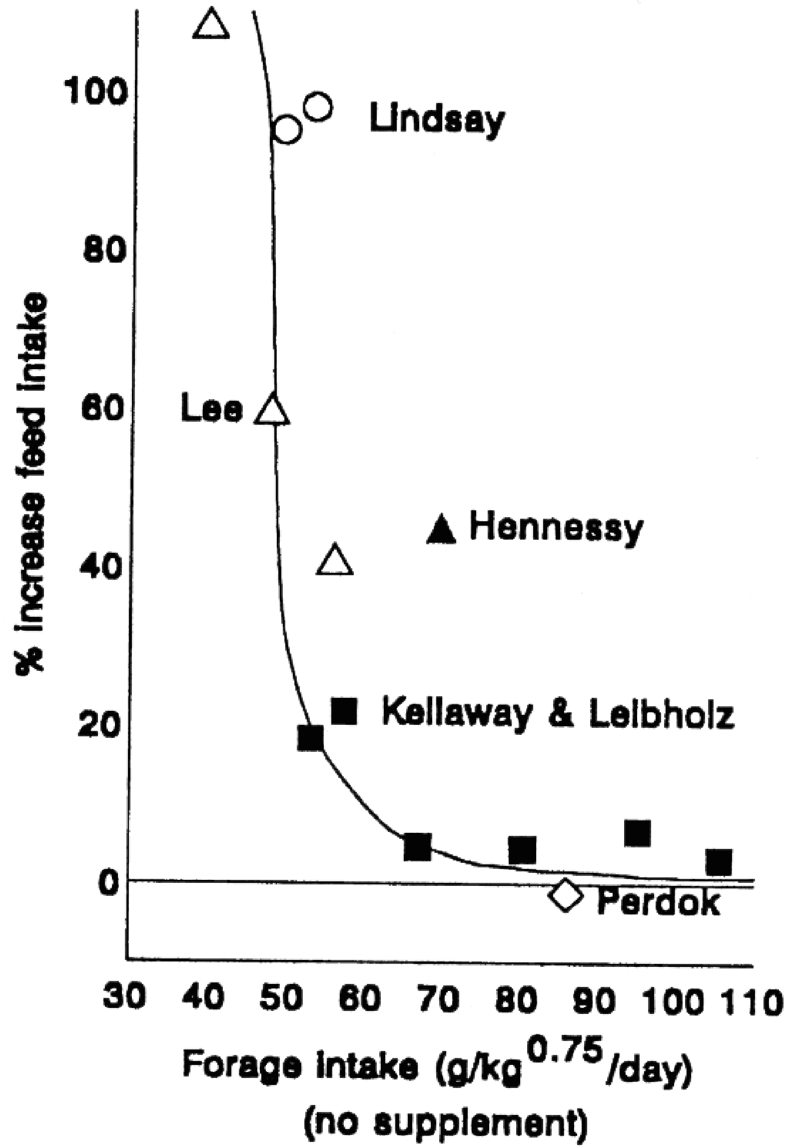
ANIMAL PRODUCTIVITY FROM AVAILABLE FEED RESOURCES

It has been a major misconception throughout the scientific literature that low productivity of

ruminants fed on forages is a result of the low energy density(i.e., low digestibility) of the feed. This is very misleading. There is abundant evidence that low productivity in ruminants on forages results from inefficient utilisation of the feed because of deficiencies of critical nutrients in the diet. The deficient nutrients may be those critical to growth of rumen microbes which ferment or digest the feed or those nutrients required to balance the products of digestion that are absorbed to meet requirements. The evidence for these statements has been considered in detail recently by Leng (1991). Inefficient utilisation of nutrients is accompanied by an increase in metabolic heat which has important implications for ruminant production in the tropics. The often low intakes of poor quality forage by ruminants in tropical countries may be imposed by a combination of metabolic heat stress and high environmental temperature and humidity (Leng, 1989). Correction of a nutrient imbalance by feeding a bypass protein often (but not always) increases the intake of poor quality forages to between 80-100 g/kg$^{0.75}$/d, particularly in hot climates (Figure 1).

Cattle in the tropics may require less feed for maintenance as they do not have to combat cold stress. If they can process these nutrients that would otherwise be oxidised for maintenance of body temperature, they can be more efficient than animals in a cold climate. The energy spared, however, must be supplemented with protein to ensure an appropriate protein to energy (P/E) ratio in the nutrients absorbed for optgimum efficiency of feed utilisation. For this reason the requirements for amino acids are higher in cattle in the tropics than in animals on the same feed in cool environments.

FIGURE 1. Intake of low digestibility forages by cattle either unsupplemented or supplemented with bypass protein or bypass protein and urea (Lindsay and Loxton, 1981; Lindsay *et al.*, 1982; Hennessy, 1984; Perdok, 1987; Kellaway and Leibholz, 1981).



IMPROVING RUMINANT PRODUCTION ON LOW DIGESTIBILITY FORAGES

The rationale and concepts on which the following discussions will be centred have been reviewed by Preston and Leng (1987) and Leng (1989, 1991). The basic concept is that

ruminants fed low quality forages require supplementation with critically deficient nutrients to optimise productivity. The required supplements must:

- correct nutrient deficiencies for the rumen microbes, and
- increase the ratio of protein (absorbed amino acids) to energy (VFA) available from digestion so that it more closely corresponds to the animal's requirements.

Rumen fermentative digestion

Anerobic fermentative digestion in the rumen provides microbial cells (which supply the protein (P) to the animal) and VFAs (E) (the major source of oxidizable substrate). The efficiency of microbial growth and therefore the P/E ratio will be low when nutrient deficiencies occur in the rumen. Thus a sub-optimal level of any nutrient required for microbial growth will result in low protein to energy (P/E) ratio in the nutrients absorbed. Ensuring a nutrient non-limited microbial digestion in the rumen by complete supplementation automatically improves the P/E ratio in the nutrients available to the animal.

Feeding a protein meal in which the protein has been made insoluble or otherwise not degraded by rumen microbes is a further major supplementation strategy to adjust the P/E ratio upwards. The P/E ratio appears to be the primary factor that controls the efficiency of feed utilisation and the partitioning of nutrients into various components of production (Leng, 1991).

The ratio of microbial protein to VFA produced and the effects of supplementation to provide an optimal environment for microbial growth efficiency is less important where dietary bypass protein is completely digested in the rumen (Table 1).

TABLE 1. The effects on P/E ratio in the nutrients absorbed of supplementation with a bypass protein to cattle with a poor or optimised (i.e., supplemented) microbial milieu in the rumen. The values are calculated for a steer digesting 4 kg DM in the rumen (Leng, 1982).

Rumen environment	Protein bypass (g prot/d)	Microbial cells produced (g/d)	Microbial protein (g/d)	VFA produced (MJ)	P/E* protein (g/MJ)
Deficient	0	830	500	41	12
Supplements	0	1630	1010	30	33
Deficient**	400	830	500	41	22
Supplements	400	1680	1010	30	47

* Ratio of microbial protein plus dietary protein to VFA energy

** Although the rumen environment is deemed not to change through the addition of protein meal,in fact it will have been improved but may not be optimized to the extent it would by feeding amolasses-urea block. P/E ration here is therefore underestimated.

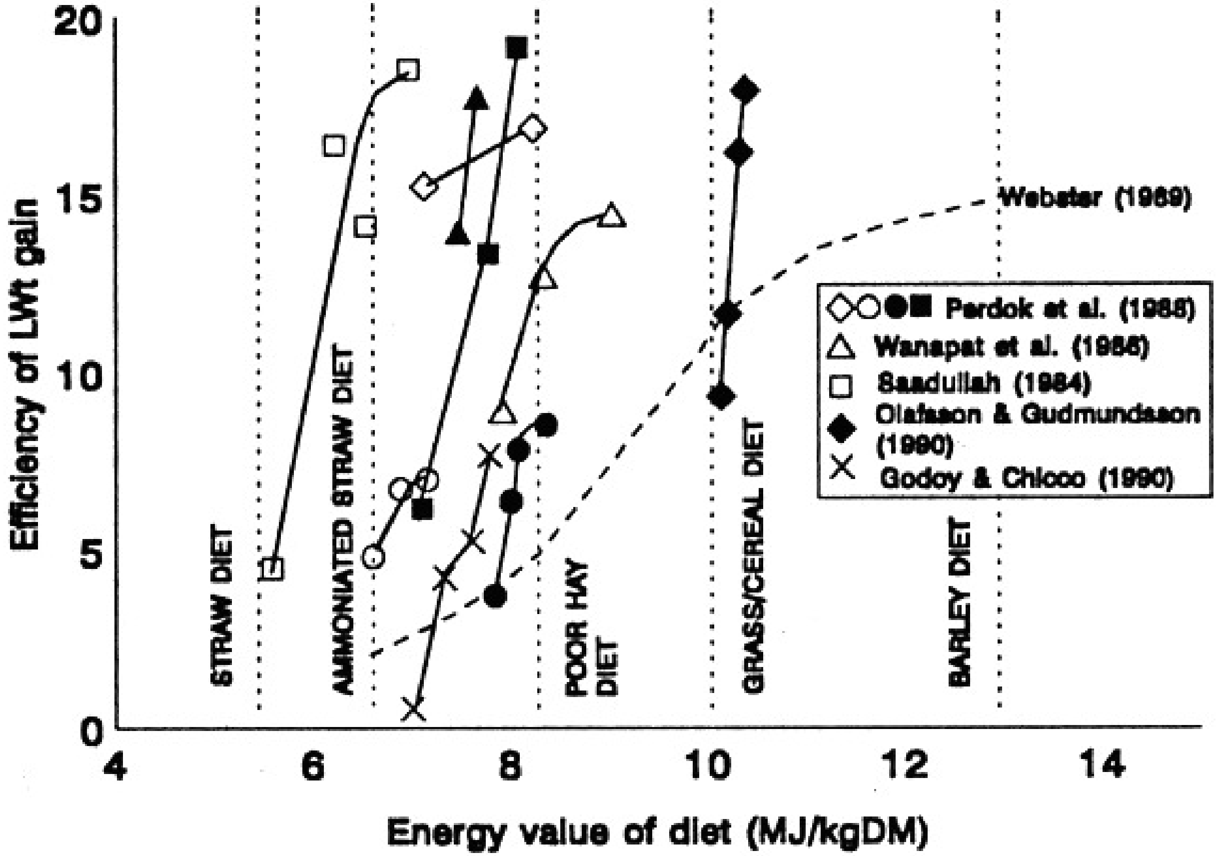
The reason for discussing these theoretical calculations at this point is to emphasise the large variations that can occur in P/E ratio (from 12 to 50) in the nutrients absorbed by ruminants fed unbalanced diets and diets balanced with supplements at the same level of feeding. A further point is that, on a diet supplemented with a high level of bypass protein, the rumen microbes need not grow highly efficiently as long as the digestibility is optimised.

Feeding standards: are they realistic?

The relationship of P/E of the efficiency of feed utilisation has a very large effect on growth, milk yield and reproductive performance. The levels of production achieved when P/E is

increased have been greatly superior to that predicted from present day feeding standards based on metabolisable energy of a feed (Figure 2). This illustrates the marked differences that result when supplements high in protein are given to cattle on diets of low ME/kg DM.

Figure 2: Schematic relationship between diet quality (metabolisable energy/kg dry matter) and food conversion efficiency (g live weight gain/MJ ME) (from Webster, 1989). The relationships found in practice with cattle fed on straw or ammoniated straw with increasing level of supplementation in Australia (Perdok *et al.*, 1988), Thailand (Wanapat *et al.*, 1986) and Bangladesh (Saadullah, 1984). Recent relationships developed for cattle fed silages supplemented with fish proteins (Olafsson and Gudmundsson, 1990) and tropical pastures supplemented with cottonseed meal (Godoy and Chicco, 1990) are also shown.



Except for temperate pasture, most forages consumed by livestock are relatively low in digestibility (55%). On most crop residues or tropical pasture, digestibility is 40-50%. The metabolisable energy in the dry matter (M/D) thus ranges from 4.8 to 7.5 MJ/kg DM. According to feeding standards, a metabolisable energy content in a feed of 7.5 will support a gain of approximately 2 g/MJ of ME intake in cattle. At 4.8MJ/kg DM cattle should be in negative energy balance (ARC, 1980; Webster, 1989). Contrast this with results of supplementary feeding trials based on balancing the nutrition of animals with urea/minerals and bypass protein, where cattle growth rates equivalent to 18 g/MJ of M/E intake have been achieved in cattle fed straw (Figure 2). Obviously the presently accepted feeding standards are misleading

and should not be used to predict animal performance on these feeds.

The application of the basic concept of balanced nutrition, as referred to here, can improve animal growth by 2-3 fold and the efficiency of animal growth by as much as 6 fold over previous estimates (a range of 2-10 fold). Also, although growth rates of cattle are below those on grain based diets, cattle on forage based diets in the tropics can be as efficient in converting feed to live weight gain.

The low productivity of ruminant livestock has been accepted in developing countries as an inevitable result of the poor feed base and a low feed conversion efficiency. This is no longer tenable and should give impetus to those developing animal production in Third World countries as the application of the new feeding technologies has carry-on effects of improved reproduction, increased percentage of a herd in production and an increased offtake from a herd. The benefit of improved reproduction may even outstrip the direct effects on live weight gain or milk yield *per se*. However, the remaining challenge is to develop the necessary supplements and to get these to the animals in the various production systems.

APPLICATION OF THE NEW FEEDING STRATEGIES

Even though the principles of feeding bypass protein to improve productivity have been known for many years, application has been slow and unspectacular. The application has been slowed by:

- **The desire by many scientists to stand by the feeding standards that have been promulgated for twenty years and which appear to be totally inappropriate for most feeding systems.**

- **The controversies surrounding the principal mechanisms of action of protein**

supplementation which has clouded the major issues.

- **The inability of research scientists to communicate with and be believed by applied technologists**
- **The unavailability of protein, minerals and non-protein nitrogen in the cattle producing areas**

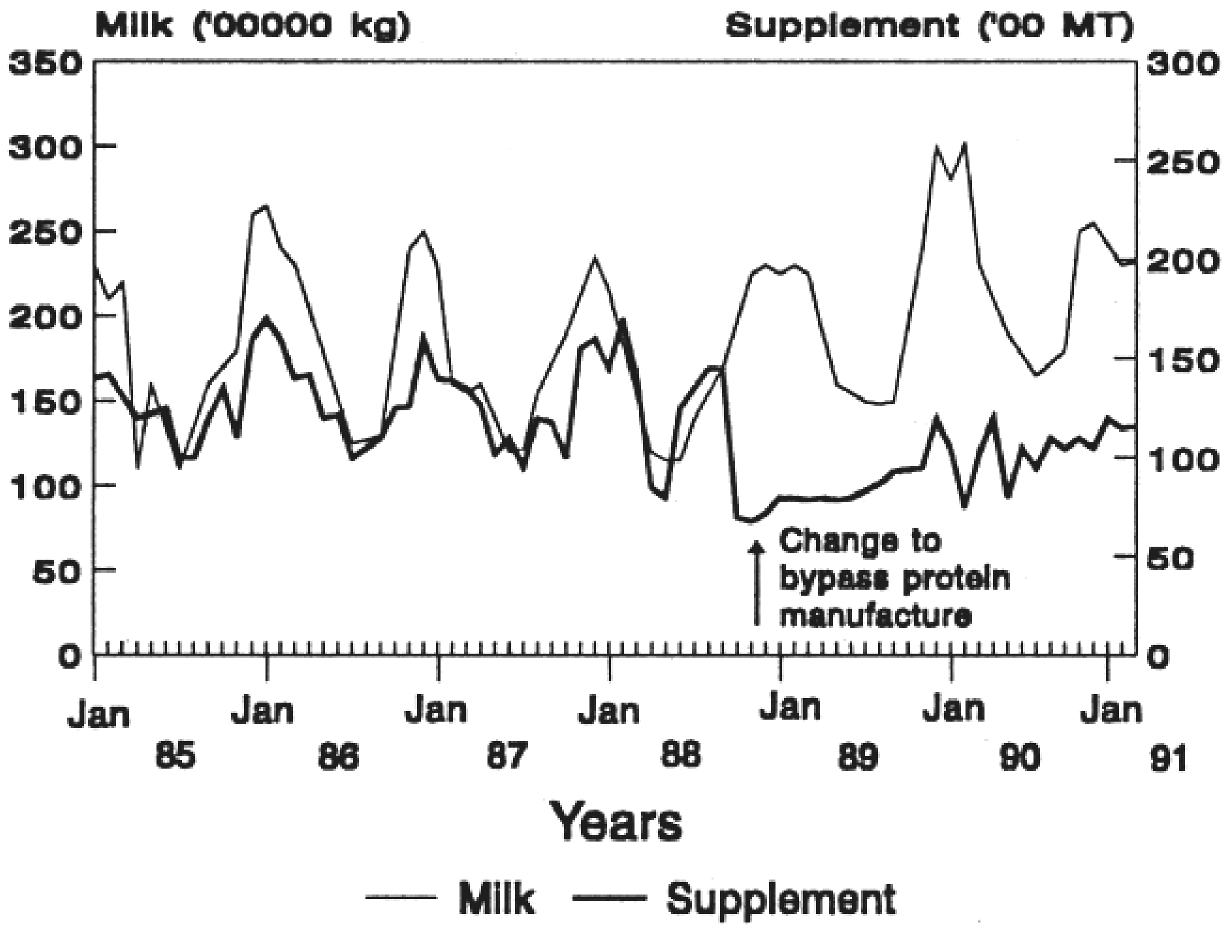
However, extensive application of the use of supplements high in bypass protein has occurred in India through the initiatives of The National Dairy Board of India (NDDB). For the same reasons as given above, progress was initially slow (the development started in 1980) but it is now accelerating at a pace which should see most feed mills in India dedicated to the production of bypass protein supplements within the next five years. At the present time, approximately 200 MT of bypass protein feed is being fed daily to dairy animals owned by village farmers in the central parts of India. In many situations, this is coupled with the use of molasses-urea blocks compounded to provide a spectrum of nutrients for the rumen microbes (NDDB, 1989).

Monthly milk collection is shown in Figure 3 for a dairy co-operative in the Kedah district of India that changed from feeding a traditional concentrate to a new supplement containing 30% protein with a high bypass capacity. The collection of milk is shown for the previous five years and for the twenty-six months since conversion to the new feeding system. Whilst a number of changes have occurred in the area which could contribute to the increased milk collected, local research confirms that the responses in milk production to the new supplements are in agreement with observed increases in milk collected (Leng and Kunju, 1988).

The effects of the changed feeding strategies appear to be a 30-50% increase in milk

production from 1 December 1988 to 1 December 1989. A further similar increase in production is apparent in 1989-1990 (unpublished observation). This increase probably represents a carry-on effect that would come from increased reproductive rate and the increased proportion of the herd in milk resulting from the improved feeding strategies.

FIGURE 3. Milk collection records and the sale of supplements for a milk cooperative in the Kedah district of India when supplements were compounded on traditional concepts (1985-1987) and following (1st December, 1988) their replacement with a 30% C.P. by-pass protein pellet (records provided by the NDDB of India).



THE APPROPRIATE STRATEGY

To ensure maximum utilisation of local forage resources in developing countries, the appropriate supplements are:

- **a combination of minerals and a source of nitrogen for rumen microbes.**
- **a supply of protein with a substantial proportion of bypass protein.**

Meeting the requirements for appropriate supplements

In most areas of the world, it is not practical to identify the deficient micro and macro minerals in a basal roughage diet as these will vary from site to site and year to year. The practical approach is one of 'rules of thumb', that is to provide a 'best bet' or 'shot-gun mixture' of minerals as economically as possible. A concentrated plant extract such as molasses provides such mixtures and can be fortified for specific areas where local knowledge points to specific deficiencies. In this respect, molasses (both sugar cane and beet) and concentrated palm oil sludge offer useful sources of these minerals. They are also quite palatable to livestock and are useful in hiding less palatable nutrient sources in supplements. Where forages are mature and dry, a tree forage or other green forages may also provide deficient minerals.

Mineral salt mixtures are commercially available in most countries. They usually have a high content of salt and only minor quantities of the trace elements. In practice, fortified materials, such as molasses, will be superior to these mixtures as they present a greater coverage of all the minerals required and are also a valuable source of other nutrients (e.g., B vitamins) and a small amount fermentable energy. It should also be pointed out that, where protein meals are supplemented, these often provide adequate amounts of essential minerals such as phosphorus.

Supplying the rumen microbes with ammonia/urea

The other requirement is a non-protein nitrogen source for the rumen microbes, usually urea. Urea is commonly administered together with minerals and its concentration in such mixtures is controlled by safety concerns and the difficulty of incorporation, and therefore rarely exceeds 10–15% of such mixtures. However, this is usually sufficient to allow an intake of between 50 and 100g of urea by cattle from a molasses-urea block, which is sufficient to

balance the rumen for ammonia on a low N roughage diet.

Results from India suggest that mineral-urea mixtures in, for example, molasses multi-nutrient blocks are best given free choice, allowing the animal some degree of selection. There are indications that the animal will learn to control the intake of urea to an optimal level. In Indonesia, the combined effects of NPN and minerals in molasses-urea blocks has a large effect on production of ruminants fed cut-and-carry green tropical pasture (Table 2) (Hendratno *et al.*, 1991).

TABLE 2. **Effects of UMMB supplements on growth rate of Friesian Holstein steers, Ongole steers, sheep and goats fed cut/carry pasture in Indonesia (Hendratno *et al.*, 1991).**

Animals	N	Growth rate		% Increase in production
	(g/day)	-UMMB	+ UMMB	
Friesian-Holstein steers	156.3	210	560	166
	171.3	400	810	102
Ongole steers	161.0	333	526	57
	204.0	478	465	-2.7
	291.0	388	822	111
	110.0	183	403	120
Sheep (local)	30.4	36	67	86
	31.5	140	316	126
Goats (does)	31.7	40	88	120
(kids)	51.7	91	105	15

Based on data collected by West Java and Central Java Livestock Services.

Bypass protein supplements

Providing bypass protein to cattle owned by small farmers is often difficult and at times too expensive. There is often little information on locally available protein sources, particularly the level of protection of these protein meals from degradation in the rumen. As a rule-of-thumb, solvent extracted oilseed cakes, fish meal that has been flame dried (but not sun-dried fish meal or fish silage) and protein sources that have been heat treated, have some considerable protection from rumen degradation. The degree of protection is enhanced by pelleting the protein meal in the presence of free glucose or fructose (as occurs in molasses), when a mild browning reaction occurs (unpublished observations).

Identification of protein sources

Some countries are fortunate in having large amounts of crop residues high in protein, most of which have a fair degree of protection brought about by processing methods. These materials are convenient for use directly by the farmer or may be processed through existing feed mills for the production of a supplement which can be fortified with minerals.

In many countries, particularly in extensive grasslands or savannas, where major constraints to production of cattle are essentially the same as those for cattle fed crop residues, protein sources may not be readily available or the sources not so obvious or easily obtainable. Most legume forages, legume seeds, edible tree leaves, seed pods and seeds that are available in these areas contain highly soluble protein which is easily fermented in the rumen. These, when used as supplements, provide a valuable source of ammonia and minerals (they have, for example, 0.5–1% phosphorus). This increases production of cattle on a basal diet of low protein roughage but, when fed as a small proportion of the diet, they provide little bypass protein as the protein degrades rapidly in the rumen.

Supplementation of cattle on green *Brachiaria decumbens* pasture with either urea/molasses or foliage of the fodder tree *Gliricidia* resulted in similar increases in production (Table 3). This indicates the value of a high protein tree forage as a rumen stimulator but illustrates that its effects are limited to the responses in the rumen.

TABLE 3. **The effects of feed supplementation on livestock gain of cattle (6 per group) grazing on green *Brachiaria decumbens* pastures in the wet season (with mineral supplements) with liquid molasses/urea 10% or *Gliricidia* foliage.**

Treatment	Rumen Ammonia (gN/l)	Initial Weight (kg)	Final Weight (kg)	Live Weight Gain (g/day)
No supplement	50	194	244	580
+ *Gliricidia*	170	204	266	717
+ Molasses/Urea	250	203	269	751

Source: ICA (1988)

CONCLUSIONS ON SUPPLEMENTATION

The above discussion defines and highlights the potential strategies to provide two types of supplements required for optimal efficiency of utilisation of low quality forage by cattle in areas with scarce resources of nitrogen or protein. The strategies must be to find forages, seeds or pods that are high in protein and minerals. These materials can then be used as catalytic supplements to provide for either the rumen soluble protein and minerals or (after treatment to protect the protein) as a bypass protein source. They can also be used in combination with a molassesurea block when the leaf protein is protected and/or as a source of locally available bypass protein when the leaf protein is unprotected. Tree forages have a major role, as they

are deep rooted and provide fresh forage particularly in the dry season.

Processing of local protein resources to provide bypass protein

There are a number of processing techniques that will effectively and adequately treat protein sources and render them non fermentable in the rumen but allow them to retain digestibility in the intestines. In general these include chemical treatments with agents which cross link with amino acids on the protein chain, including formaldehydes and aldehydes, tannins and simple sugars such as glucose and xylose. These reactions often require the protein source to be heated in processing. Heat alone will often denature the protein and effect protection. For instance, Goering and Waldo (1974) found significant effects of the temperature of drying lucerne on the subsequent animal production from that lucerne.

In general, the higher the temperature of drying the greater the retention of nitrogen by the animal. More recently Lewis *et al*. (1988) demonstrated that mild heat with a small amount of xylose is very effective in protecting soya bean meal protein (Table 4). Xylose can be readily produced by acid hydrolysis of many fibrous materials including bagasse and cottonseed hulls. The effects of protecting lucerne forage protein on productivity of sheep is shown in Table 5 (Arreaza *et al*., unpublished).

TABLE 4. **Effects on live weight gain of cattle supplementing a basal forage/concentrate based diet with soyabean meal or soyabean meal treated with sulphite liquor at 200�F for 2 hours (Lewis *et al*., 1988).**

	Live Weight Gain (g/day)
No supplement	591
+ 7% soyabean meal	673
+ 9% soyabean meal + 10% sulphite liquor	823

+ 8% soyabean meal + 5% sulphite liquor	841

There is a great need to research methods for protecting protein of forages, tree leaves, seeds and pods from local resources as these are potentially available in the pasture areas of the world but must be used in the most appropriate supplementation mode.

TREES AS A SOURCE OF PROTEIN AND SOLUBLE NITROGEN MINERALS IN THE RANGELANDS

A number of authors have pointed to the small percentage of pasture biomass that is actually consumed by grazing animals in the extensive arid and semi-arid rangelands (Ellis and Swift, 1988). Most tropical grasslands are highly leached and their pastures apparently have a low potential to provide ruminants with their required nutrients. The point to be stressed is that 10–30% of pasture biomass is often all that is used by grazing animals. Trees can produce considerable amounts of edible biomass. For example, the tree *Prosopis juliflora* produces up to 440kg of edible pods *per annum*. A more usual production is 200kg but, on average, it contains 16% crude protein (Riveros, F., personal communication). The protein in the pods is, in all probability, soluble. Compare this with the usable biomass of 250kg DM/ha from the poor native pastures of South America. The combination of trees and grassland would obviously be a desirable development and synergistic for cattle production.

TABLE 5. **Live weight gain and wool growth of sheep fed oaten chaff supplemented with either lucerne of xylose-treated lucerne.**

Treatment*	Oaten chaff intake (g/DM/day)	LWG** (g/day)	FCR** (g/day)	Wool growth (g/day)
LX0	690	44	22	9a
LX1	795	69	16	11b

LX2	693	50	20	9^{a}

* LX0 = 220g DM/day lucerne,

LX1 = 220g D>/day lucerne treated with 0.5% xylose

LX2 = 220g DM/day lucerne treated with 1% xylose.

**LWG = Live Weight Gain;

FCR = Feed Conversion Rate

a, b means with diferent superscripts are statistically different ($p>0.05$).

GENERAL CONCLUSION

The research needs are obvious. Local research in centres of cattle density must initially identify actual or potential protein sources. They must then establish mechanisms for harvesting and processing the protein to concentrate it, if necessary, and protect it from rumen degradation. Finally, appropriate means for using both the processed and unprocessed protein/minerals to optimise the efficiency of animal production must be established.

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Nutritional potential of fodder trees and shrubs as protein sources in ruminant nutrition by C. Devendra

INTRODUCTION

Fodder trees and shrubs represent an enormous potential source of protein for ruminants in the tropics. Until relatively recently, these feed resources have been generally ignored in feeding systems for ruminants, mainly because of inadequate knowledge on various aspects of their potential use, as well as initiatives associated with the development of more innovative systems of feeding.

Throughout the tropics, and especially in the humid regions, there exist a variety of feed resources. These include a variety of forages and abundant supplies of crop residues, agro-industrial by-products and also non-conventional feed resources. Among these, approximately 50 to 60% of the feeds produced are dry bulky roughages, mainly cereal straws and stovers. In Asia, the volume of production is increasing at about 3% annually. However, not all these feeds are put to maximum and efficient use. Inefficient utilisation is identified with low levels of animal production in which the contribution from ruminants (buffaloes, cattle, goats and sheep) compared to non-ruminants is especially low.

The use of fodder trees and shrubs has been secondary to these efforts, despite their potential value in prevailing small farm systems (Devendra, 1983). These alternative feeds merit increased research and development in the future (Devendra, 1990a). This paper highlights the potential value of fodder trees and shrubs as sources of feeds, draws attention to results of work where there are clear demonstrable benefits, practical technologies that are potentially important, and emphasises the need to accelerate their wider utilisation in feeding systems for ruminants.

NUTRITIONAL CONSIDERATIONS

It is appropriate to keep in view several fundamental aspects of nutrition which are associated with the use of tree fodders and shrubs. These are voluntary feed intake (VFI), which determines the amount of dry matter intake (DMI), and digestibility. These aspects are briefly reviewed.

Dry Matter Intake

Maximum DMI is very important factor in ensuring the release of adequate nutrients for maintenance and production. With temperate grasses, voluntary food intake (VFI) directly affects their digestibility, but the relationship is less definitive for tropical species (Milford, 1967) because of the different lengths of time required to digest tropical feeds. VFI has been shown to decrease with decreasing digestibility of dry matter within species for *Chloris guyana* (Milford and Minson, 1968), *Panicum* spp. (Minson, 1971a) and also for legumes (Minson, 1971b). Minson (1971b) also reported that tropical grasses decrease in dry matter digestibility at a daily rate of 0.1 to 0.2 digestibility units.

In terms of VFI, considerable variation exists between and within tropical grasses. Some of the variations are due to differences in digestibility but other unrelated factors such as those recorded for *Panicum* varieties may be involved (Minson, 1971a). Rate of decrease in digestibility of younger tropical herbages is as high as in temperate species (Minson, 1971a). The decline in digestibility with age of tropical grasses was more rapid than with tropical legumes which retained relatively high digestibilities at maturity (Milford and Minson, 1968). Differences in *in vitro* digestibility have been reported between genotypes of *Digitaria* (Strickland and Haydock, 1978). Selection for high *in vitro* digestibility was successful in producing a high *in vitro* digestibility of dry matter and superior VFI of *Cenchrus ciliaris* (Minson and Bray, 1985).

In the humid tropics, DMI is limited by the water content of, or the free water on, the ingested herbage. In the West Indies for instance, the dry matter content of herbage during the wet season was very low in Pangola grass (*Digitaria decumbens* Stent) with a dry matter content of 23.4%, compared to 39.3% in the dry season, such that the herbage contributes a high proportion of the total water consumed (Butterworth *et al.*, 1961). Similar observations have also been made in Thailand (Holm, 1973). Inadequate dietary energy arises from reduced DMI and is likely to occur when the DM content falls below 25%.

Digestibility

Associated with VFI of the forage is digestibility. Digestibility of a feedstuff is affected by stage of maturity of the crop, botanical composition, DMI and dietary supplements, processing, and chemical treatment. In general, the more digestible a feedstuff is, the more it is eaten by the ruminants (Blaxter, 1962). Such is the case that high digestibility increases DMI. Increasing digestibility means that high proportion of the food is absorbed and digestion is more complete, with the volatile fatty acids (VFA) showing a lower proportion of acetic acid, the energetically lowest and least useful VFA, and with the presence of higher proportions of the more useful acids such as propionic and butyric acids.

Level of Dietary Protein

VFI is influenced to a very large extent by the dietary crude protein content. The protein content of tropical forages is generally low (French, 1957; Bredon and Horrell, 1961; Butterworth, 1967). The protein content falls rapidly with growth and reaches a low level before flowering. During the dry season, the crude protein levels fall to very low critical levels, even below 7% in the dry matter. The level of protein in the diet affects voluntary intake of food (Campling *et al.*, 1962; Blaxter and Wilson, 1963; Elliott and Topps, 1963) and low protein diets are not readily eaten by ruminants. In sheep, a 7% crude protein begins to limit intake (Milford and Minson, 1968). Leibholz and Kellaway (1984) have estimated that the minimum required crude protein of a poor quality diet with a digestibility of organic matter of 50% would be between 6.1 to 7.4%.

Quantity of Net Energy Available

The quantity of net energy (NE) available for production is controlled by three related factors (Minson, 1985): the quantity of feed eaten (I), the proportion of each unit of feed that is digested (D), and the efficiency of utilization of the products of digestion (E). This is represented by the equation:

$$NE = I \times D \times E$$

The quantity of NE available and its utilization is dependent on the type of feed, nutrient balance, extent of VFI, animal species, and function.

IMPORTANT FODDER TREES AND SHRUBS

Diversity

There is considerable diversity in the forage supplements that are of value to ruminants. Table 1 brings together the more commonly used shrubs and tree fodders in different parts of the developing countries. The list is not exhaustive, but is meant to focus on those feeds that are emerging as important in feeding systems for various ruminants. Of the 12 more important feed sources listed, *Acacia* spp., *Ficus* spp., cassava (*Manihot esculenta* Crantz), *Erythrina* spp., *Gliricidia* spp., *Leucaena leucocephala, Prosopis cineraria* and *Sesbania* spp. are widely used in the tropics.

Nutritional advantages

The value of these forages is associated with a number of advantages. With *Leucaena* for example, it provides a valuable source of protein, energy and sulphur for the rumen bacteria. It is also valued in multipurpose use in fence lines and as a fuel. With specific reference to their value in animal feeding, the advantages include *inter alia* (Devendra, 1988): availability on the farm; accessibility; provision of variety in the diet; source of dietary nitrogen, energy, minerals and vitamins; laxative influence on the alimentary system; reduction in the requirements for purchased concentrates; and reduced cost of feeding.

TABLE 1. **Important tree fodders and shrubs for feeding ruminants.**

Common name	**Botanical name**
1. Acacia	*Acacia catechu* *Acacia nilotica* *Acacia siberiana*
2. Cassava	*Manihot esculenta Crantz*
3. Calliandra	*Calliandra calothyrsus*
4. Erythrina	*Erythrina variegata*
5. Ficus	*Ficus exasperata*
- Banyan	*Ficus bengalnensis*
- Peepul	*Ficus religiosa*
6. Gliricidia	*Gliricidia sepium* *Gliricidia maculata*
7. Jackfruit	*Artocarpus heterophyllus*
8. Leucaena	*Leucaena leucocephala*

9. Pigeon pea	*Cajanus cajan*
10. Prosopis	*Prosopis cineraria*
11. Sesbania	*Sesbania grandiflora* *Sesbania sesban*
12. Tamarind	*Tamarindus indica*

Nutritional characteristics

Table 2 presents some of the nutritional characteristics of principal tree fodders and shrubs. The data has been assembled from various sources, but in particular Devendra (1979), N.R.C. (1981), Kearl (1982) and Devendra (1990b). In the absence of data on cell wall contents, the average crude fibre level is indicated.

The table indicates that the crude protein (CP) contents of many of these feeds (cassava, *Calliandra, Erythrina, Leucaena* and pigeon pea) is high and in the range 22.2 - 25.8%. *Ficus, Acacia, Gliricidia*, jackfruit and *Prosopis* had crude protein contents in the range 14.0 -15.1%. The metabolisable energy (ME) content, with the exception of acacia was in the range 11.2 - 14.4 MJ/kg. It is of interest to note that the Ca content of many of these feeds is also relatively high. These include, in particular, cassava, *Calliandra, Prosopis*, tamarind and

***Gliricidia*, in which the range was 1.57 - 2.81%.**

TABLE 2. **Nutritional characteristics of principal tree fodders and shrubs.**

Feed source	DM (%)	% DM basis				ME (MJ/kg)	Ca (%)	P (%)
		CP*	CF*	EE*	Ash			
Acacia	29.0	15.1	22.6	8.9	8.2	8.4	1.21	0.06

Cassava	21.1	24.2	15.6	4.0	6.6	14.4	2.62	0.22
Calliandra	26.4	24.0	21.7	2.4	8.0	12.6	1.6	0.2
Erythrina	32.0	25.8	17.4	5.8	6.7	14.3	-	-
Ficus	17.0	14.0	22.4	4.5	5.8	12.0	1.31	0.17
Gliricidia	25.0	14.7	19.9	5.4	4.7	12.84	1.58	0.29
Jackfruit	36.6	14.0	22.1	3.8	11.5	14.2	1.46	0.15
Leucaena	30.0	22.2	19.6	6.9	4.4	12.1	0.27	0.12
Pigeon pea	25.2	22.8	20.1	5.6	5.8	13.4	0.37	0.17
Prosopis	23.4	14.0	17.8	1.9	6.8	11.2	2.73	0.15
Sesbania	18.0	22.6	18.4	2.1	9.3	13.6	1.48	0.34
Tamarind	28.0	14.0	21.0	4.6	8.6	14.4	2.81	0.20

* CP - crude protein, CF - crude fibre, and EE - ether extract

DEMONSTRATION OF BENEFICIAL EFFECTS

The potential value of these forages for ruminants has recently been reviewed (Devendra, 1990b). Tables 3 and 4 demonstrate the benefits in buffaloes and goats concerning feeding systems in which cereal straws were used. The review enabled the following main conclusions:

i. The use of forage supplements consistently increased live weight gain or milk production.
ii. Of the forage supplements that have been used, the leguminous types have been especially advantages.
iii. The beneficial responses (meat or milk production) was associated with a reduced cost of feeding.
iv. With large ruminants, research on the utilization of forage supplements for draught is very

sparse.

TABLE 3. **Results of economic benefits of forage supplements in diets for buffaloes**

Feeding regime	Forage supplement	Location	Significant response	Result	Reference
Wheat straw* + conc.	Lucerne + berseem	India	Milk	Reduced cost/kg SCM milk	Gupta *et al.* (1983)
Rice straw**	*Gliricidia* or *Leucaena*	Sri lanka	Milk	Increased margin over costs	Perdok *et al.* (1984)
Rice straw***	Berseem	India	Milk	Reduced cost/kg milk	Agarwal *et al.* (1989)
Rice straw**	*Gliricidia*	Sri Lanka	Milk	Increased milk production	van der Hock *et al.* (1988)

*** Wheat straw**

**** Urea-treated rice straw**

***** Urea-treated or untreated rice straw**

TABLE 4. **Results of the benefits of forage supplements to goats**

Breed	Major feed	Type of forage supplement*	Significant response**	Location	Reference
Native	Maize stover	LE	L.W.I.	Philippines	Linggodjiwo (1976)
					Abilay and Arinto

Native	Concentrate	LE	L.W.I.	Philippines	(1981)
Crossbreds	Napier grass	LE	L.W.I.	Malaysia	Devendra (1982)
Kachang	*P. purpureum*	CL	L.W.I.	Indonesia	Djajanegara *et al.* (1983)
Native	Browse	PR	L.W.I.	India	Parthasarathy (1983)
Native	Para grass	LE	L.W.I.	Philippines	Abayan and Boloran (1984)
Kachang	*P. purpureum*	CL	L.W.I.	Indonesia	Mathius *et al.* (1984)
Kachang	*P. purpureum*	GL	L.W.I.	Indonesia	Rangkuti *et al.* (1984)
Kachang	*P. purpureum*	GL	L.W.I.	Indonesia	Rangkuti *et al.* (1985)
Kachang	*P. purpureum*	CL	L.W.I.	Indonesia	Mathius *et al.* (1985)
Kachang	*Native*	*CL*	*L.W.I.*	Indonesia	Sitorus (1985)
Kachang	*P. purpureum*	LE, GL, S	L.W.I.	Indonesia	van Eys *et al.* (1986)
Native	Concentrate	PR	L.W.I.	India	Parthasarathy *et al.* (1986)
Kachang	*P. purpureum*	GL	L.W.I.	Indonesia	Haryanto (1988)

*** CL=*Manihot esculenta* Cranz.**

GL = *Gliricidia maculata*

S = *Sesbania grandiflora*

LE = *Leucaena leucocephala*

PR = *Prosopis cineraria*

**** L.W.I = Liveweight increase**

In Sri Lanka, a supplement of 1.5kg of rice bran with 3.0kg *Gliricidia maculata* per head to Surti buffaloes on urea treated rice straw in two systems of production (open system in which the straw from two systems of production was kept unsealed in stacks, and closed system in which the straw was kept in cement pits and sealed with polythene) showed that supplementation significantly increased (P>0.05) the difference in milk and butterfat production. There was no effect on live weight gain of cow and calf (van der Hock *et al*., 1988).

Earlier work, also in Sri Lanka, showed that feeding 1600g *Gliricidia sepium* forage (DM/cow/day) increased milk and milk fat yields. With coconut cake supplementation, both milk yield and milk fat yields were significantly increased (P>0.05), whereas *Gliricidia* and *Leucaena* leaves did not affect either component (Perdok *et al*., 1984).

Supplementation of *Chloris gayana* hay with 200 to 300g of dried *Leucaena* leaves given to goats in Tanzania significantly increased organic matter intake, crude protein intake and daily growth rate compared to the unsupplemented control group. In the digestibility study, *L. Leucocephala* supplementation increased total dry matter intake from 42.3 kg W^0 in the control

group to 77.9 kg $W^{0.75}$ in hay with leucaena fed *ad libitum*.

Current evidence of the value of supplementary forages and especially the leguminous ones suggests the following pointers for practical application (Devendra, 1988):

- **Optimum dietary level on DM basis: 30 to 50%**
- **As per cent of live weight: 0.9 to 1.5%**

POTENTIAL TECHNOLOGIES

The extension of the value of tree fodders and shrubs for ruminants needs to be identified with practical technologies that can ensure demonstration of the beneficial use and also relevance at the farm level. The following practical technologies are worthy of attention and are potentially important: (i) three-strata forage system; (ii) integrated tree cropping systems; (iii) agro-forestry systems; (iv) food-feed intercropping; (v) relay cropping; (vi) alley cropping; and (vii) grazing and stall feeding systems.

Three Strata Forage System

In dryland farming areas, a major constraint to higher productivity from ruminants is the unavailability of good quality feeds especially during the dry season and periods of drought. The development of feeding systems that can increase the supply of good quality forages and dietary nutrients for the animals is therefore especially important to improve the prevailing low level of animal performance.

This is exemplified by the situation in the island of Bali which has approximately three million people and three rainfall zones. Twenty five *per cent.* of the land area is semi-arid with a rainfall

of 900–1500 mm/year. Farmers constitute about 70% of the total population and most of them practice mixed crop-animal farming. Among ruminants, Bali cattle are particularly important and in the dry parts of the island, income from livestock accounts for about 39–43% of total farm income. Farmers generally own 2–3 head of cattle which are used for draught and beef production.

The need for increasing the feed resource base as well as develop sustainable systems of production led to the successful demonstration of the three strata forage system. The system involves grasses and ground legume (first stratum), shrub legumes (second stratum) and fodder trees (third stratum).

Considerable progress has been made in the implementation of this concept and research over the last 6 years has demonstrated considerable benefits. For example, the inclusion of *Stylosanthes, Centrosema, Acacia, Gliricidia* and *Leucaena* increased the supply of forages and enabled higher stocking rates and live weights to be achieved: 3.2 animal units (375 kg)/ha/year in the TSFS compared to 2.1 animal units (122 kg)/ha/year. Additionally, the system promoted increased firewood production as well as reduced soil erosion (Nitis *et al*., 1990; Lana *et al*., 1990).

Integrated tree cropping systems

Integrated tree cropping systems with coconuts, oil palm and rubber trees, involving ruminants, is a potentially important production system especially in the humid tropics. The benefits of the system include: increased fertility of the land via the return of dung and urine; control of waste herbage growth; reduced use of herbicides; presence of shade reduces heat stress; easier management of the crop; and distinct possibilities of increases in crop yields, consistent with greater economic including sale of animals and their products.

In these situations, tree crops have a very valuable role in terms of multi-purpose use: supply of feed, fenceline, fuel and soil fertility. Several of the tree fodders identified in Table 1 will fullfil these objectives.

Silvi-pastoral systems

Agro-forestry systems that combine the use of multi-purpose trees and integration of animals is an avenue that has not adequately investigated. The system has considerable importance, especially in upland areas and elsewhere where the role of fodder trees becomes especially important. The wider use of agro-forestry systems has complimentary advantages of forage production, supply of fuelwood, improvement of soil fertility and permanent soil cover and promotion of economic and sustainable land use.

Food-feed intercropping

The concept of food-feed intercropping in both lowland and upland small farm systems has two principle advantages: firstly, the system aims to provide sustainability, involving the complimentary role of crops and animals; secondly, and with respect to animals, the use of appropriate forage crops provides fodders and crop residues which are valuable for feeding both ruminants and non-ruminants, as has been demonstrated by work in the Philippines.

The criteria for the choice of the crops to be used in the system include *inter alia*: the type of animals reared, potential forage or crop residue biomass yield, promotion of soil fertility, drought tolerance and extent of the dry season, shade tolerance in upland areas, ease of eradication and resource requirements. The strategy is to integrate, within the rice cropping pattern (inter-cropping and relay cropping), other feed producing crops and also forage crops without, reducing the area of the land used.

Relay cropping

An important means to further increase the supply of feeds for farm animals is to plant a second crop into the first before harvest. Examples of relay cropping are the introduction of legumes (e.g., groundnut and pigeon pea) into the main crop (e.g., rice or wheat). The strategy extends the supply of feeds throughout the year.

Alley cropping

Alley cropping provides an alternative opportunity to integrate crops with animals as well as enhance sustainability. The development of the system has the following advantages: the maintenance and promotion of soil fertility; increasing the supply of animal feeds and fuelwood; and contributing to the development of all-year-round feeding systems.

Grazing and stall feeding systems

Increased and more intensive utilisation of tree forages and shrubs is largely dependent on the type of feeding systems to be practised. Where land is not limiting for intensive pasture production, either grazing and or stall feeding can be adopted. A comparative study of both systems to examine potential milk production in Sahiwal x Friesian cows on *Leucaena leucocephala-Brachiaria decumbens* mixed pasture indicated that rotational grazing was better than stall feeding with mean responses of 8577 and 9180 kg/ha/lactation. Supplementation of concentrates at 4 and 6 kg/cow/day further increased milk production to 13323 and 17070 kg/ha/lactation respectively. The net profit per cow with or without supplementation was lower for rotational grazing on account of higher labour cost for the stall feeding system. The choice of one or the other system is dependent to a very large extent on the cost of the inputs.

DELETERIOUS PRINCIPLES

An area which is emerging to be extremely important in the utilisation of shrubs and tree fodders is the problem of deleterious principles, since they constitute problem in the diet of animals. A variety of these principles are found.

Tannins exist in the condensed or hydrolysable forms at varying levels. The effects of tannins in ruminant feeding is not entirely clear, with possible harmful and beneficial effects, but evidence is increasing that they can have some benefits (Zelter *et al.*, 1970; Barry and Ducan, 1984). High concentrations of tannins can lower voluntary feed intake (Burns and Copè, 1974). More recently, Feng Yu and Leng (1991) have shown that low concentrations of condensed tannins from *Acacia floribunda* provided protection of proteins in lupins and stimulated growth and wool production.

There appears to be an inverse relationship between the proteinprecipitating capacity of tannins in tree leaves and their palatability, voluntary intake and digestibilities of crude protein and dry matter in grazing and also browsing animals. The authors have also reported that sulphur and iron become limiting to animals consuming tannin-rich leaves and prolonged consumption of these also induces toxicity. Several of these feeds have deleterious principles and depending on the levels fed, some have side effects on animals. In general, however, these do not present a major barrier to their utilisation by ruminants when used as supplements (about 30% on a dry matter basis).

Under these circumstances, the presence of tannins is an advantage as they protect the proteins from excessive microbial degradation and make these more available posterior to the rumen. Some experiments have shown that supplementation of a basal diet of tropical grass with dried or fresh *Leucaena* resulted in significant quantities of protein leaving the rumen of sheep.

Farmers currently overcome and reduce problems of effects on animals by feeding mixtures of the feeds with or without sun drying. This process not only extends choice of feeds available but also dilutes and reduces problems of palatability and side effects. More information is required on optimum dietary levels of forage supplements either fed alone or in mixtures appropriate to individual ruminants, methods to reduce the incidence and development of suitable mixtures of these in economic feeding systems for individual ruminants. It is possible that between species differences also exist in the response to tannin content in these leaves and these need to be determined.

CONCLUSIONS

Present knowledge on the potential value of fodder trees and shrubs indicates that together with their diversity, these feed resources are extremely useful for feeding domestic ruminants. The demonstrable benefits are improved performance of animals and reduced cost of feeding. These advantages justify more intensive and wider utilisation of fodder trees and shrubs in appropriate feeding systems and represent an important strategy for increasing the current level of contribution from ruminants.

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Nutritional potentialities of fodder trees and fodder shrubs as protein sources in monogastric nutrition
by J.P.F. D'Mello

INTRODUCTION

Over the past two or three decades, there has been a significant upsurge of interest in the use of fodder trees and shrubs as sources of protein and other nutrients for non-ruminant animals. Although considerable attention has been given to the use of leaf meals derived from these trees and shrubs, there is a growing realisation that the seeds of these species may serve as protein sources in their own right and limited work has been published in this area.

Much attention has been focused on leaf meals from *Leucaena leucocephala* and *Manihot esculenta* (cassava) but, more recently, interest has turned to leaf meals derived from other sources such as *Gliricidia sepium, Robinia pseudoacacia* (black locust or false acacia), *Cajanus cajan* (pigeon pea), *Sesbania sesban, Prosopis* spp. (mesquite) and *Albizia* spp. It is clear that the leguminous species predominate in this group due to their relatively high crude protein (CP) contents and to the ability of some species to thrive in adverse soil and climatic conditions. While the potential exists for the wider utilisation of the seeds of fodder trees in non-ruminant diets the limited data in the literature relate to the grain of just one legume: *Cajanus cajan*.

The purpose of this paper is to critically review current knowledge on the role of leaf meals and seeds derived from fodder trees and shrubs in monogastric nutrition, identify chemical constraints, formulate practical recommendations where appropriate and to identify research and development priorities where potential exists for exploitation of novel species with specific reference to developing countries. Chemical constraints to the use of browse species will also be considered.

FEEDING TRIALS WITH LEAF MEALS

The relatively high crude protein (CP) content of leaf meals in comparison with that of cereals is well recognised. However, the fibre component is also a major fraction of the dry matter (DM). In many instances the fibre content of leaf meals may equal or exceed CP concentrations. Consequently, digestibility of the CP fraction of many leaf meals is low which tends to depress overall CP digestibility when leaf meals constitute a significant proportion of the diet (Tangendjaja *et al.*, 1990).

Although lysine concentrations in leaf meals are considerably higher than those of cereal grains and certain by-products such as coconut oil meal, they are somewhat inferior to those of soyabean meal and fish meal. It follows that leaf meals cannot be expected to fully replace high quality ingredients in diets for monogastric animals. Deficiencies of the sulphur containing amino acids add a further dimension to the nutritional limitations of leaf meals. For example, biological values (BV) for cassava leaf meal range from 0.49 to 0.57 which may be enhanced to 0.80 on supplementation with methionine (Eggum, 1970). Although this leaf meal confers a superior dietary amino acid profile relative to by-products such as coconut oil meal, this difference is not reflected in BV determinations with pigs (Ravindran *et al.*, 1987).

Further insight into the nutritional value of leaf meals is provided by a consideration of

metabolisable energy (ME) content. The limited data point to extremely low ME values for *Leucaena* (D'Mello and Acamovic, 1989) and *Robinia* as determined with poultry, but the ME content of cassava leaf meal appears to be appreciably higher, not only for poultry but also for pigs.

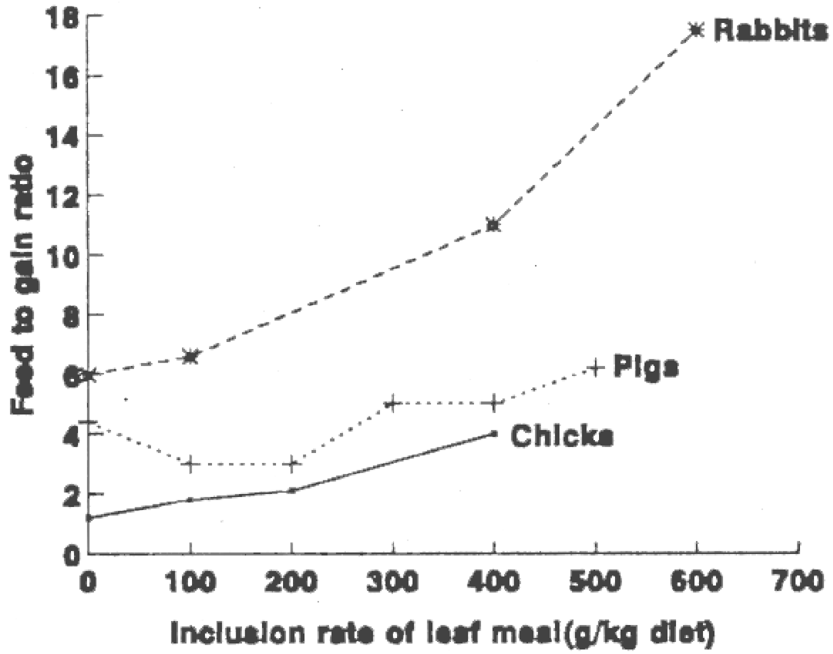
Leucaena

Consistent with the low digestibility of CP and the inadequate ME content, graded additions of *Leucaena* leaf meal induce dose-related depressions in growth of chicks even when maize oil is used to compensate for the low ME value of the leaf meal. The adverse effects of *Leucaena* on the growth of young chicks is now well established (see D'Mello and Acamovic, 1989). Moreover, with older broiler chicks, D'Mello *et al.* (1987) showed that diets containing 100g leaf meal/kg significantly reduced growth without affecting DM intakes. On the other hand pigs given diets containing *Leucaena* leaf meal at 100 g/kg grew significantly faster than control animals but live weight gain declined progressively with higher inclusions (Malynicz, 1974). It should be noted that in this study *Leucaena* was substituted for a commercial ration containing 180g CP/kg diet and, consequently, all *Leucaena* diets had higher CP concentrations than the control diet. Furthermore, all diets were supplemented with ferrous sulphate to counteract possible toxicity arising from the non-protein amino acid, mimosine, present in the leaf meal. The addition of ferrous sulphate to the mimosine-free control diet was unnecessary and may have depressed growth of pigs on this diet.

Despite the favourable digestibility of the CP fraction of *Leucaena* leaf meal for rabbits (Raharjo *et al.*, 1986), graded additions of this legume to a control diet precipitated progressive depressions in growth such that, at the 400g/kg inclusion, weight gain was less than 40% of control values (Tangendjaja *et al.*, 1990).

Concomitant with these growth responses is a consistent and striking increase in feed:gain ratios for the three classes of animals when dietary inclusion rates of *Leucaena* leaf meal exceed 200g/kg (Figure 1). The data for chicks relate to two separate studies by D'Mello and Acamovic (1982) and D'Mello *et al.* (1987) in which oil additions to diets were held at a constant level irrespective of inclusion rates of *Leucaena*. Although the studies of Malynicz (1974) show significant improvements in feed conversion ratios on inclusion of *Leucaena* at rates of up to 200 g/kg diet (Figure 1), more recent studies by Chen *et al.* (1981) indicate no differences in these ratios between the control diet and diets containing up to 160g leaf meal/kg. The decrease in feed efficiency of rabbits given high *Leucaena* diets (Figure 1; Tangendjaja *et al.*, 1990) is all the more remarkable given the herbivorous nature of this species. It is apparent that coprophagy confers no special advantage as regards the ability of rabbits to utilise *Leucaena*-based diets.

FIGURE 1. Effect of *Leucaena* leaf meal on feed to gain ratios of growing chicks, pigs and rabbits.



Egg production in hens is also adversely affected by dietary inclusion of *Leucaena* leaf meal. For example Vohra *et al.* (1972) showed that while inclusion rates of 50 and 100g/kg diet elicited satisfactory laying performance, the diet containing 200g/kg precipitated severe reductions in food intake and egg production. These deleterious effects occurred despite adjustments to the ME content of the diet by addition of oil. It should be noted that the duration of this study was only five weeks. Earlier studies over eight weeks (Mateo *et al.*, 1970) employing pair-feeding techniques indicated that the depression in egg production was specifically attributable to the intake of *Leucaena* leaf meal.

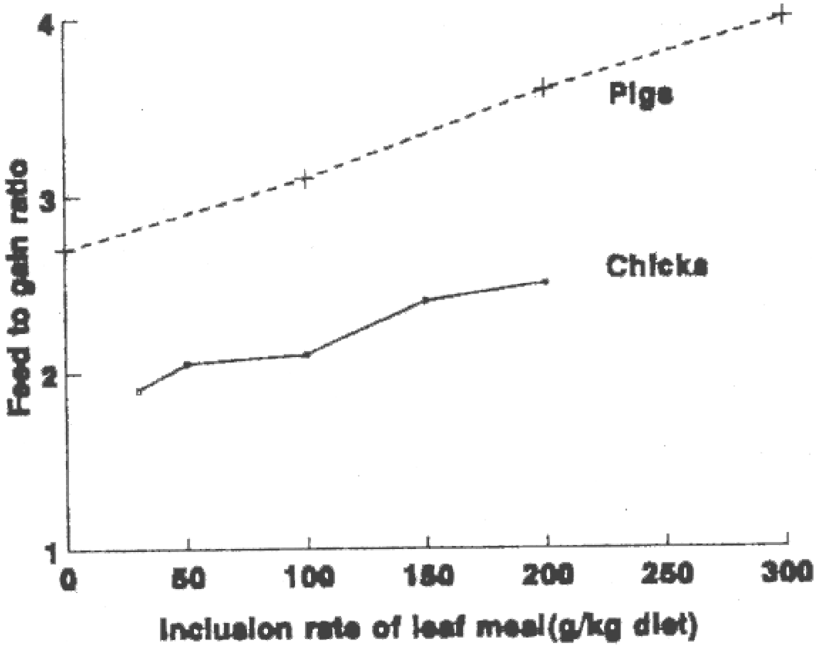
Cassava

Although cassava leaf meal has been accorded with a favourable ME value, graded inclusion of this leaf meal as a replacement for soyabean meal and maize in practical-type diets elicits

progressive depressions in growth rates of both growing chickens and pigs (Ross and Enriquez, 1969; Ravindran, 1990). In addition, cassava leaf meal induces greater reductions in growth rate of chickens than dehydrated alfalfa meal at all inclusion levels from 50 to 200 g/kg diet (Ross and Enriquez, 1969). However, if substitutions of cassava leaf meal are accomplished at the expense of poor quality ingredients such as coconut oil meal in a control diet, then dietary inclusion rates of cassava leaf meal of up to 150g/kg may be employed without reducing growth of broiler chicks (Ravindran *et al.*, 1986). Similarly, Ravindran *et al.*, (1987) showed that performance of growing pigs was unaffected by cassava leaf meal concentrations of up to 267g/kg diet when the leaf meal was substituted for coconut oil meal. At the 400g/kg dietary inclusion, cassava leaf meal significantly reduced average daily gains of pigs. A different picture emerges, however, if this leaf meal is used as a replacement for good quality protein sources. Thus, Ravindran (1990) substituted cassava leaf meal at rates of 100, 200 and 300g/kg diet for maize and soyabean meal and observed significant reductions in live weight gains of pigs with each level of the leaf meal.

The effects of cassava leaf meal as a replacement for soyabean meal and maize are most clearly seen in the feed: gain ratios depicted in Figure 2.

FIGURE 2. Effect of cassava leaf meal on feed to gain ratios of growing chicks and pigs.



Other Leaf Meals

Limited work with leaf meals from *Robinia, Sesbania* and *Gliricidia* suggests poor replacement values for conventional ingredients in diets for poultry. In the case of *Sesbania*, there are signs of acute toxicity with inclusion rates as low as 100g/kg diet, with 100% mortality in chickens fed *Sesbania* at 300g/kg diet (Brown *et al.*, 1987). Pigeon pea leaf meal may be more acceptable as a feed component for laying hens (Udedibie and Igwe, 1989). However, feed efficiency declines on inclusion of this leaf meal and body weight losses may also occur.

POTENTIAL OF GRAIN FROM FODDER TREES

On the basis of chemical composition, the grain of fodder trees should offer greater potential as protein and energy sources for non-ruminants than do their corresponding leaf meals. Thus CP concentrations have been reported to be over 30% higher in the seed than in the leaf of

***Leucaena leucocephala* and, although CP concentrations in pigeon pea are similar in the seed relative to the leaf, fibre content of the former is considerably lower (D'Mello, 1987) leading to favourable ME values for poultry.**

The feeding value of pigeon pea seed is reasonably well documented. In one investigation (Tangtaweewipat and Elliott, 1989), live weight gains of broilers were unaffected by dietary inclusion of raw pigeon pea seed even at levels of 500g/kg. Pigeon pea seed was substituted for maize and soyabean meal in the control diet. Feed conversion efficiency, however, deteriorated with diets containing 400 and 500g seed/kg. It should be noted that ME values for the seed were somewhat low at around 8 MJ/kg DM and consequently graded levels of oil were added with increasing levels of pigeon pea seed. On the other hand, the results of two trials with laying hens indicate that raw pigeon pea seed induces adverse effects on egg production and feed efficiency when inclusion rates of 300–400 g/kg diet are used (Tangtaweewipat and Elliott, 1989; Udedibie and Igwe, 1989). Body weight losses occurred consistently with diets containing 400g seed/kg, a response similar to that observed with lower dietary concentrations of the leaf meal of pigeon pea. Deleterious effects also occur in pigs fed raw pigeon pea seed at 300g/kg diet (Visitpanich *et al.*, 1985).

The nutritive value of seeds from other fodder trees and shrubs has not been examined on any systematic basis but potential exists for exploitation of a variety of seeds, particularly those from leguminous browse species.

UPGRADING OF LEAF MEALS AND GRAIN

It will be apparent from the foregoing account that the observed nutritive value of leaves and seeds of fodder trees frequently falls considerably short of that expected from their chemical composition. The constraints to enhanced utilisation of these commodities reside chiefly in

factors such as fibre content, the presence of anti-nutritive compounds and deficiencies of certain essential amino acids.

The lower fibre contents of seeds relative to leaf meals from fodder trees inevitably means superior quality of the former. Thus the seed of pigeon pea has an ME value for poultry and pigs, which is considerably in excess of the ME content of any of the leaf meals examined thus far.

The leaves and seeds of fodder trees and shrubs are known to contain a wide array of compounds which are capable of reducing performance of animals. A complex combination of different groups of compounds such as toxic amino acids, tannins, cyanogenic glycosides and proteins may occur in a single tree species. The presence of such a disparate range of deleterious compounds has provided the stimulus for much work on methods of detoxification and upgrading of both leaves and seeds. The production of leaf meals for non-ruminant feeding inevitably involves at least some measure of processing. Sun-drying is the method of choice in the tropics and this treatment alone can be an effective method for the removal of anti-nutritive substances in some leaf meals. Thus, sun-drying of cassava leaves may reduce HCN concentrations by as much as 90% (Ravindran *et al.*, 1987).

Thermal processing is an effective method of upgrading plant products through the inactivation of most of the heat labile anti-nutritive substances. In this respect, Visitpanich *et al.* (1985) were able to reduce trypsin inhibitor activity by heating the grain of pigeon pea to 124°C for 15 minutes. This treatment eliminated all adverse effects on performance of pigs fed 300g seed/kg diet. Heat treatment is a less effective procedure for the upgrading of leaf meals derived from *Leucaena, Robinia* and *Sesbania* and, in the case of cassava leaves, boiling may reduce the availability of amino acids (Eggum, 1970).

Another strategy for upgrading leaf meals involves the use of additives. Ferric sulphate and polyethylene glycol (PEG) have been used to complex with mimosine and tannins respectively, with marked improvements on the growth of chicks fed *Leucaena*-based diets (D'Mello and Acamovic, 1989). Methionine supplementation appears to offer the most viable procedure for upgrading cassava leaf meal for poultry and pigs, in combination with energy-rich additives such as coconut oil (Ravindran, 1990). The response to methionine is presumably a reflection not only of the low content and availability of methionine but also of the need for this amino acid in detoxification of residual HCN.

RECOMMENDATIONS

The scope for leaf meals as protein sources in monogastric nutrition is limited primarily by their low contents of digestible CP, ME and sulphur amino acids and by increased bulkiness of these products. Dietary inclusion rates will depend to a significant extent on the protein sources they are intended to replace. Thus the replacement value of leaf meals is relatively low in diets based on good quality protein sources such as soyabean meal and fish meal. On the other hand, in diets based on poor quality raw materials such as coconut meal or cottonseed cake, higher substitution rates for leaf meals have been recommended. It is salutary to note, however, that, even under these conditions and despite their superior lysine content, leaf meals are unlikely to completely replace poor quality feedstuffs without deleterious consequences.

As regards *Leucaena* leaf meal, it would not be prudent to exceed inclusion rates of 50g/kg diet for broiler chicks and 100g/kg diet for laying hens, growing pigs and rabbits. In the latter cases, provision of additional energy from coconut oil and of ferrous sulphate may be necessary adjuncts, which may, nevertheless, still not promote optimum feed conversion ratios.

Recommended rates for cassava leaf meal are somewhat better if methionine and oil supplements are used. Up to 150g/kg diet may be used for broiler chicks, and diets for growing pigs may contain up to 300 g/kg without compromising feed efficiency. The available evidence precludes any role in monogastric nutrition, for leaf meals derived from *Gliricidia, Robinia*, pigeon pea or *Sesbania* as these are associated with adverse effects and even acute toxicity in some cases.

Considerable potential exists for the grain of pigeon pea in that heat processing offers an effective method of detoxification of protease inhibitors with consequent enhancement of nutritional value for poultry and pigs. Inclusion rates of up to 300g/kg diet have been found to be satisfactory for growing pigs providing that the seed is first subjected to thermal processing procedures. It should be stressed that the use of supplements and heating procedures should not be undertaken without an economic assessment of efficacy.

CONCLUSIONS

The exploitation of under-utilised feedingstuffs is destined to continue in an effort to mitigate regional shortages of protein sources. In this context, leaf meals may have an important but limited role to play in the feeding of non-ruminant animals. Although the presence of anti-nutritive substances undoubtedly contributes to the poor nutritional value of some leaf meals, it is likely that their high fibre content represents the major constraint for monogastric animals. However, the removal of the fibrous components in the production of leaf protein concentrates (LPC) from fodder trees and shrubs is not consistently accompanied by enhanced nutritional value (Cheeke *et al.*, 1980). It appears unlikely that LPC production would be a commercially viable procedure for upgrading leaf meals even if nutritional value can be improved.

In the long-term, any expansion of the poultry and pig industries in the tropics cannot be

sustained with the extended use of leaf meals alone and alternative strategies should be considered. One attractive option may be the exploitation of grains not only from fodder trees but also from under utilised or novel legumes such as *Canavalia ensiformis* (jack bean); *Cyamopsis tetragonoloba* (guar); *Psophocarpus tetragonolobus* (winged bean); and *Vigna unguiculata* (cowpea). These seeds are not without major limitations emanating from their anti-nutritive components but in many instances a relatively simple detoxification procedure can yield a product nutritionally comparable to soyabean meal (D'Mello *et al.*, 1983; D'Mello and Walker, 1991). The extended utilisation of by-products such as coconut oil meal and rice bran should also be pursued with renewed impetus. These, together with the wider use by non-ruminants of protein sources from fodder trees and shrubs, merit high priority in the developing countries.

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Feeding behaviour, quantitative and qualitative intake of browse by domestic ruminants by M. S. Dicko and L. K. Sikena

INTRODUCTION

Nutrition of domestic ruminants in the tropics is mainly based on the exploitation of rangeland resources which are subject to high quantitative and qualitative variations over the year. Fodder trees and shrubs are an integral part of the diet of these animals and constitute the main source of proteins, minerals and vitamins during the dry season.

Selection and intake of diet depends not only on the available plant resources but also on the feeding behaviour of the animals. Better understanding of feeding behaviour allows the development of management strategies aimed at maximizing the use of ecosystems for increased animal production.

Among domestic ruminants, camels are classified as browsers, goats as intermediate selective feeders with preference for browse, sheep as nonselective intermediate feeders with preference for grasses and buffalos, cattle and donkeys as grazers (McDowell, 1988; Schwartz and Schafft, 1988). These dietary preferences are however influenced by the constantly changing enviornment and human intervention in livestock management.

This paper presents an account of the effects of environmental factors on the feeding behaviour of domestic ruminants and the contribution of browse to their productivity. Based on this review, recommendations have been formulated which are aimed at maximizing the use of fodder trees and shrubs to increase animal production in developing countries.

FEEDING BEHAVIOUR

Most behaviour studies have been carried out by visual observation of grazing activity but also by examination of faeces, rumen contents and intake samples collected through oesophageal fistulae and evaluation of the forage offered minus the quantity left over. These studies have shown that feeding behaviour is controlled by factors of animal and plant interaction. The animal factors including species, physiological status, previous experience with the vegetation and habitat exploration, while the plant variables relate, among other things, to availability and the physical and qualitative characteristics of plant biomass. In grazing situations, the relative importance of all these factors can be modified by environmental variables such as human interventions which determine strategies of land use and stock management.

Dietary preference of domestic ruminants and effects of management decisions on feeding behaviour.

Some results of the behaviour studies carried out with cattle, sheep and goats by one of the

authors in the arid and semi-arid programme of International Livestock Centre for Africa (Dicko *et al.*, 1983; Dicko and Sangare, 1984) will be used here to describe the complex interaction between animal, forage availability and management decisions.

The study site in the sahelian zone of Mali has an average annual rainfall of 580mm occurring during the July-September period. The notable features are: (i) an irrigated land of 45,000 ha devoted to rice cultivation where a few trees and shrubs are found along irrigation ditches as well as around villages; and (ii) a dryland with villages and millet fields. The behaviour studies concerned:

1. **A herd of cattle under a semi-sedentary management system which associates the exploitation of both the dry and irrigated lands. Over the year the animals stayed successively on the rangeland (July October), millet fields (November-December) and rice fields (January -June). The feeding behaviour of the cattle is illustrated in Figure 1.**
2. **A herd of cattle subjected to sedentary management on the dryland. The animals therefore had a fixed settlement all the year round and they exploited the rangeland from July to September, and the rangeland plus millet fields from October to June. The feeding behaviour of these animals is presented in Figure 2.**
3. **A herd composed of sheep and goats under a sedentary management system on the dryland. The feeding of these animals was based on range resources and millet residues as for the sedentary cattle above. The feeding behaviour of the sheep and goats is shown in Figure 3a and 3b respectively.**
4. **A herd of sheep and goats managed under sedentary system on the irrigated lands. During the rainy season, the feed resources were limited to grasses and shrubs along irrigation ditches and, in the dry season, they were extended to the rice straw and regrowths of grasses on harvested rice fields. The feeding behaviour of the sheep and goats is illustrated in Figures 4a and 4b respectively.**

The preference of the cattle for grass rather than for browse is obvious in Figures 1 and 2, particularly during the wet season when the cattle spent more than 95% of their grazing time on grass despite the simultaneous availability of abundant browse with the grass. Browsing started to increase at the beginning of the dry season (October) but this intake was not sustained by the cattle under semi-sedentary management (Figure 1) because of their shift to millet, then to rice fields where there were relatively few trees and shrubs. Conversely, with the cattle under the sedentary system (Figure 2), browsing in the dry season increased steadily, with a peak at the close of the season (June) because of the flush of a great number of trees.

The increase in the grazing time during the dry season in Figure 1 and the reverse trend in Figure 2 are due to the influence of herd management on grazing activity. In the semi-sedentary system, the herdsman always settled on an open pasture near a watering point convenient to both his family and cattle, while in the sedentary system the permanent kraal and watering point had an eccentric position relative to pastures. In consequence, the semi-sedentary cattle spent less time walking to and from pastures than did the sedentary animals. In addition, they were able to practise night grazing because of the closeness of the pasture lands while in the sedentary system, long walks and lack of night grazing had a depressive effect on grazing activity.

Figure 3a and 3b constitute good examples for classifying sheep as intermediate feeders with preference for grasses and goats as intermediate feeders with preference for browse (Schwartz and Schafft, 1988). While grazing together, these two animal species behaved according to their dietary preferences. The time spent by the sheep in browsing varied with the season from 2 to 76% of their grazing time while that spent by the goats ranged from 73 to 93%. The sheep, like the sedentary cattle, ate browse mainly during the dry season, with the time spent on browse increasing throughout the season.

Figures 4a and 4b demonstrate the influence that low availability of browse plants has on the feeding behaviour of the sheep and particularly the goats. Because of limited number of fodder trees and shrubs on the irrigated land, the time the goats spent on browse varied over the year from 4 to 93% of their grazing time. A browsing duration of only 4% of their daily grazing time is abnormal with goats. Such a great modification of feeding behaviour was brought about in this system by human intervention.

Among domestic ruminants, the most effective browsers are camels. In the arid zones of Kenya, Lusigi*et al*. (1984) have found that more than 50% of the tree species and 55% of the shrub species were utilized by camels, while only 14 to 19% of the perennial grasses were eaten. There is a great overlap between the diet of camels and goats but little competition in browse utilization occurred between the two species owing to the superior reach of the camels (Keya *et al*., 1991).

Preference for specific plant species and seasonal changes in palatability of trees and shrubs are also some features of the feeding behaviour of domestic animals. In addition, some intrinsic characteristics of trees and shrubs such as glabrousness, toughness, hairs, thorns and presence of deleterious substances may also influence palatability.

A better understanding of the feeding behaviour of domestic animals allows the development of management strategies aimed at maximizing the use of ecosystems for increased animal production.

Distribution of grazing time among various types of forages.

FIGURE 1. Semi-sedentary cattle.

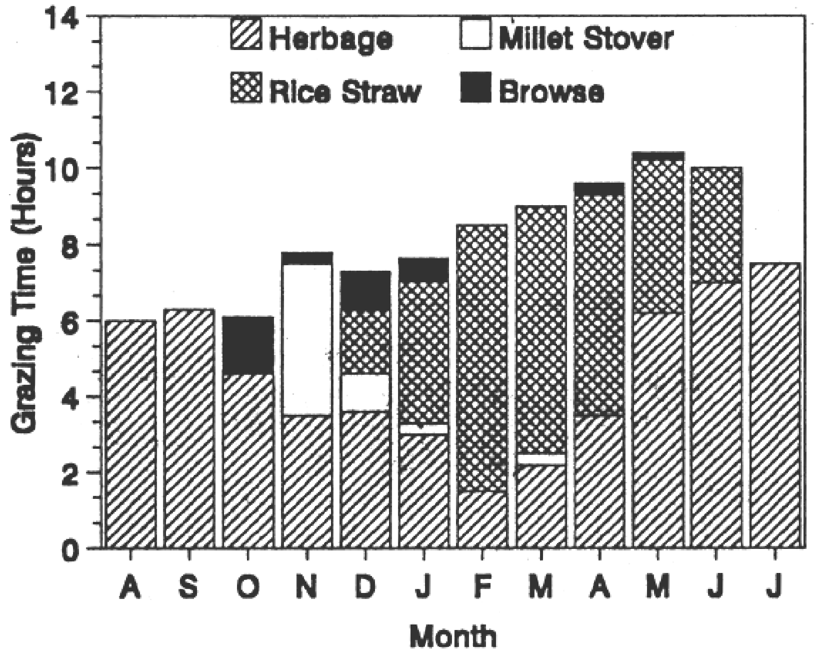
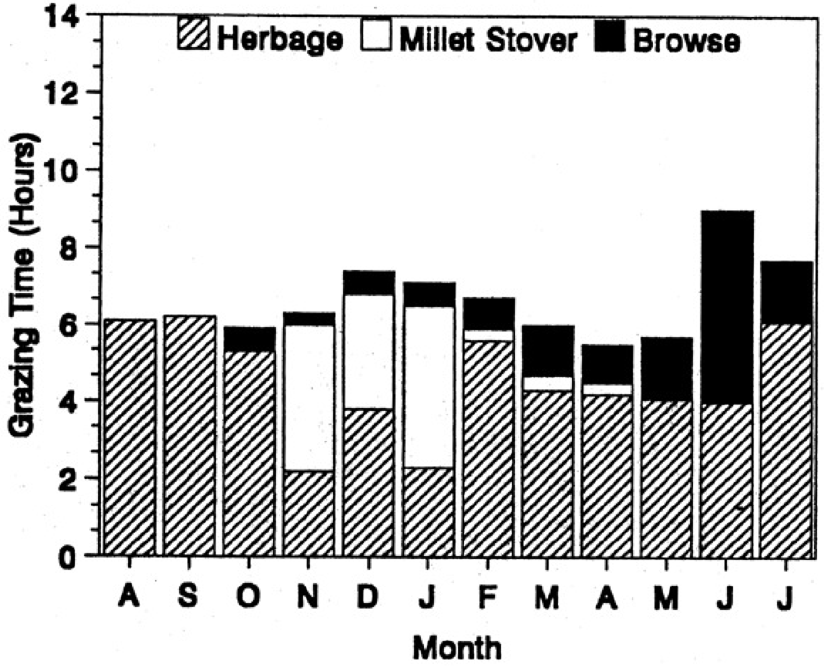


FIGURE 2. Sedentary cattle in dry areas.



Distribution of grazing time among various types of forages.

FIGURE 3a. Sedentary sheep in dry areas.

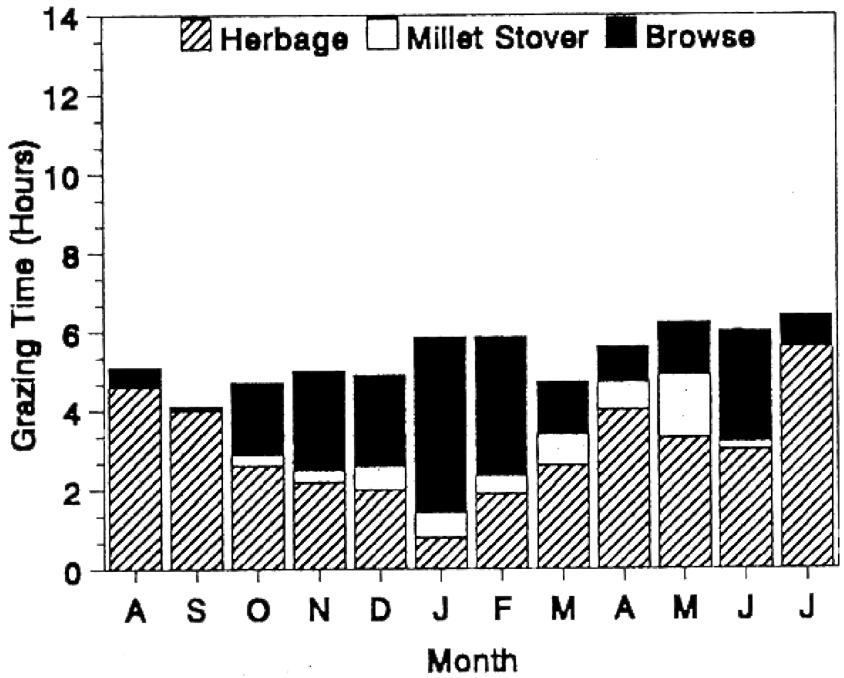
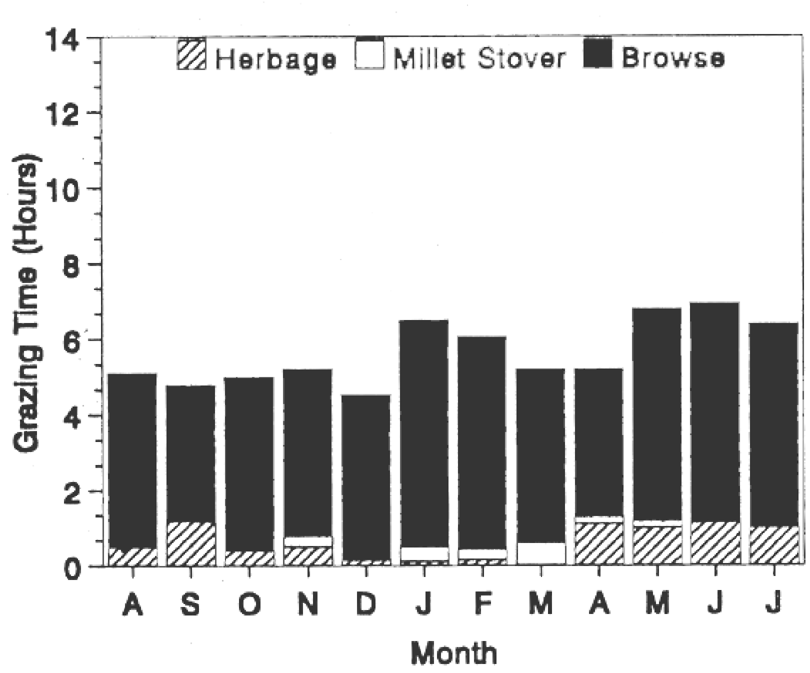


FIGURE 3b. Sedentary goats in dry areas.



Distribution of grazing time among various types of forages.

FIGURE 4a. Sedentary sheep in irrigated areas.

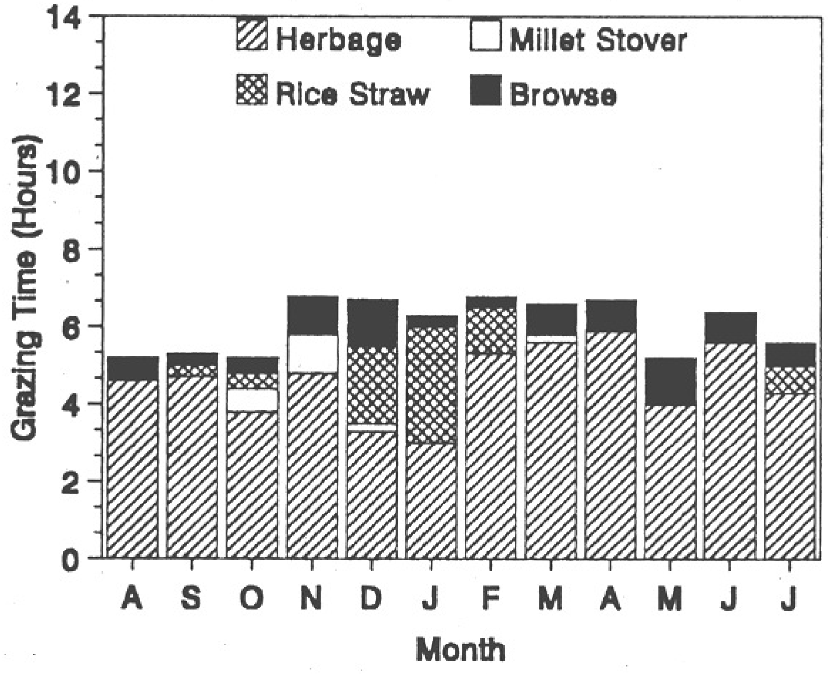
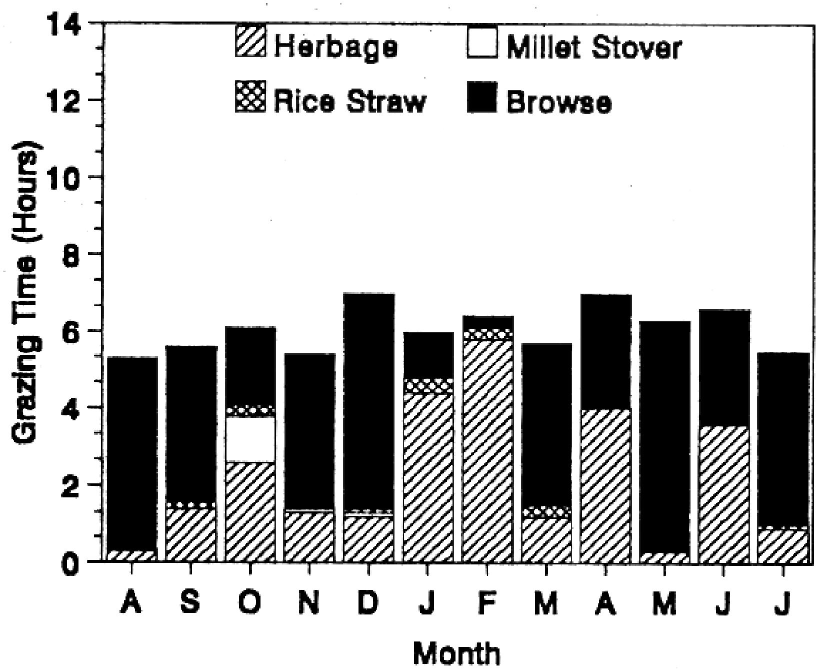


FIGURE 4b. Sedentary goats in irrigated areas.



NUTRITIVE VALUE

Compared to grasses, fodder trees and shrubs have relatively higher concentrations of crude protein, minerals and neutral detergent fibre plus acid detergent lignin, while their average concentration in acid detergent fibre, as well as their average dry matter digestibility, are both lower. These nutrient contents are subject to less variation than with grasses and this particularly enhances their value as dry season feeds for livestock (Wilson, 1977; Ibrahim, 1981).

Protein

A significant variation in crude protein (CP) content occurs between species of trees and shrubs and even between edible parts of the same plant. Guérin (1987) reported a variation of

CP content from 6 to 23% in dry matter (DM).

In general, leaves are higher in CP than twigs, almost twice as much in the case of southern African browse according to Walker (1980). They also contain more CP on average than pods but the latter were found with higher organic matter and digestibility (Göhl, 1981).

Leguminous species were found to contain 25 to 50% more crude protein than non-leguminous plants (Wilson, 1969; Nitis, 1989). Leaves of phyllodenous acacias tend to have higher crude fibre, lower crude protein, phosphorus, organic matter and digestibility than other acacias (Goodchild and McMeniman, 1987).

In Saudi Arabia, Mirreh and al Daraan (1991) found that perennial shrubs retained high CP content for a longer period than did annual shrubs. The CP in perennials varied from 14% in spring to 7% in winter while, in annual ones, a variation from 22% to 8% was recorded during the same spring season.

In addition to seasonal changes, environmental factors such as fire, substratum and amount of tree cover also influence nitrogen content. Barbero *et al*. (1991) reported a difference of 20% between the CP contents of an underwood calcicolous stand and an open silicicolous stand in a Mediterranean environment. Lay (1967) found that CP content in browse increased by 42.2% after burning. However, most of the benefits disappeared within a year or two.

Minerals and vitamins

The concentration of calcium and potassium is usually higher than that of other minerals; the average being around 1 to 1.5% for southern African browse (Walker, 1980). However, abnormally high concentrations of some minerals such as sodium chloride and selenium may be found in browse (Underwood, 1981; Olsson and Welin-Berger, 1989).

Vitamin A, B, C and PP are present in varying concentrations in leaves, fruits and seeds of some trees and shrubs (Bergeret, 1986). Carotene content is usually high during early growth and declines rapidly with maturity, except in evergreen shrubs which tend to retain it for long periods (Ibrahim, 1981).

Digestibility

Dry matter digestibility (DMD), which is related to nutrient composition, varied widely among tree and shrub species. Skarpe and Borgstrom (1986), working in Botswana with Kalahari woody species reported a range in digestibility from 38 to 78%. Similar findings were reported by Wilson (1977).

The digestibility of cellulose and cell walls decreased as the lignin to cellulose or lignin to acid detergent fibre ratio increased (Robbins and Moer, 1975). The digestibility of crude protein did not always match the high CP content which characterizes fodder trees and shrubs. For example Wilson (1977) found an apparent digestibility as low as 14% for *Heterodendrum oleifolium* containing 12.5% of CP while *Atriplex vesicaria*, also with 12.5% CP, had a nitrogen digestibility of 71.4%. Also there was not always a correlation between intake and digestibility; highly digestible stuff may be poorly consumed and *vice versa* (Wilson 1977).

Deleterious substances

Tannins, mimosine, cyanoglucosides, fluoroacetate, oxalate, selenium, saponin and sodium chloride are among substances which have the potential of decreasing feed intake, animal productivity and even causing toxicity at high levels ingestion.

Tannins relate to a large number of phenolic compounds whose deleterious effects are not uniform. Some compounds like condensed tannins (CT) even have positive effects on nitrogen

utilization by protecting protein from microbial degradation. According to Barry and Manley (1985), CT concentration of 20–40mg/kg in DM is ideal. Higher levels (76–90mg) were found to be detrimental to the health of animals.

Detannification techniques include heating, wilting, treatment with chemicals, storage of fresh leaves in polythene bags and bio-treatment using the fungus *Sprotrichum pulverulentum* (Makkar, 1991).

Mimosine is found in *Leucaena leucocephala.* Its concentration, which varies with sub-species, is also affected by environmental factors such as soil and climate. Studies have shown that *Leucaena* can be used without harm as asupplementary feed for ruminants at a rate of 20–50% of the ration (Gupta *et al.*, 1991; Atta-Krah and Reynolds, 1989). Differences in minosine concentration could explain such variation in results.

Domestic ruminants, however, were seen to be better adapted to the consumption of trees and shrubs with high content of deleterious substances, provided there was agradual ingestion of the browse. This phenomenon of adaptation, as well as the whole metabolism of antinutritional substances, still need further investigation (Schwartz and Schafft, 1988).

INTAKE

Domestic ruminants utilize trees and shrubs both as browse *in situ* and "cut and carried" branches in the stall. On rangelands, animals have the advantage of selecting from a wide choice of browse and obtaining high quality feed. Consumption of various types of forage reduces chances of poisoning. However, the effective contribution of trees to the nutrition of livestock is not always realised due to inability to reach the browsable canopy of tall trees.

The cut and carry system obviates the limitation of inaccessibility of the browse. The system

also facilitates rational usage of trees and shrubs. Its disadvantages include damage to trees due to injudicious lopping and the imposition of a limited variety of feed which may increase the risk of poisoning.

Use of fodder trees and shrubs in stall feeding.

The period of adaptation (i.e., up to intake stabilisation) to new feed may be quite long, as shown in the studies of Le Houérou (1991) in Libya. The intake of 9 species of native and exotic shrubs offered either alone or in a mixture to ewes increased with time and stabilized after 3 to 5 months at levels 3 to 5 times the initial intake (increasing from 25 65g/kg$^{0.75}$/day to 35–145 g/kg$^{0.75}$/day). The author also reported that consumption of mixed shrubs was higher than that of a single species. Wilting for 24 to 48 hours also increased the intake.

Many trials on the use of shrubs and leaves of trees to supplement either natural grasses or crop residues gained positive responses in livestock performance.

Nitis (1989) reported a case where sheep and goats fed on *Pennisetum purpureum* supplemented with 0.3 to 1.8 kg *Gliricidia* per day gained 17– 27% more weight than the unsupplemented animals. With Bali cattle fed on 80% of natural grasses plus 9% of *Leucaena* and *Musa*, and 11% of tree leaves, the increase in weight was 58% more than that of the control group.

ILCA studies in Nigeria established that the use of *Leucaena* and *Gliricidia* as supplementary feeds significantly increased the growth and survival rates of lamb. Statistical analyses of the data showed that each 100g of browse DM consumed per day raises the productivity index by 1.41 kg lamb weaned/dam/year (Atta-Krah and Reynolds, 1989).

Unfortunately, the interesting findings on supplementary feeding are not adopted by small-scale farmers, particularly in sub-Saharan Africa. Investigations of the limitations on the adoption of this practice is recommended as a way to alleviate inadequate nutrition in domestic ruminants.

Exploitation of fodder trees and shrubs on rangeland

Owing to their dietary preference and the influence of animal size on the vertical utilization of plants, there is little competition among domestic ruminants in the exploitation *in situ* of fodder trees and shrubs. According to Ibrahim (1981), the proportion of browse eaten by cattle and sheep varies from 2–30% of their intake. With goats, the intake ranges from 25–50% in the rainy season and up to 75% or more during dry periods. However, as the above feeding behaviour study demonstrates, these estimates may vary widely.

Studies on the contribution of fodder trees and shrubs to the productivity of grazing animals are still limited. Reasons for this include difficulties encountered when implementing trials with paired areas (i.e., plots with trees and those without) and the negative effects of lopping or deforestation on the environment.

A study by Rees (quoted by Bingham, 1983) on the evaluation of browse potential in cattle production is one of the few reports available. She used steers on 3 types of paddocks: natural, lopped (all trees lopped) and cleared (all trees removed).

Table 1 shows that lopped paddocks had the highest fodder potential for increased animal production, particularly when young steers (1–2 years) were used. Comparison of the performance of the 2–3 year old steers suggests that the efficiency of habitat exploitation and feed utilization increased with age.

TABLE 1. **Yearly live weight gain of 1–2 and 2–3 year old cattle on natural, lopped and cleared woodlands. 1969–71 Mbala Ranch.**

Age of cattle	Woodland	Lopped	Cleared
1–2	13.7	90.8	40.6
2–3	46.6	100.0	97.5

Source: Bingham (1983)

Further monitoring of the effect of lopping showed that, within 3 years, most of the trees managed for browse either die or grow beyond the reach of animals.

This study confirms that fodder trees and shrubs have potential for increased livestock production but has shown that the magnitude of the contribution to the productivity of grazing animals greatly depends upon accessibility of the browse. High accessibility is not often achieved in the grazing situation prevailing in the dry tropics which carry the majority of domestic ruminants. Increasing accessibility of browse entails human interventions which may be detrimental to woody plants. There is therefore a need to develop appropriate woodland management systems which will ensure optimum utilization concomitant with persistence of browse production in grazing systems.

RECOMMENDATIONS

In order to enhance the utilization of fodder trees and shrubs by domestic animals, there is a need to:

- **assess the suitability of animal species to their environment through better knowledge of their feeding behaviour. This will allow the development of management strategies aimed at**

maximizing the use of ecosystems;

- **carry out an exhaustive assessment of the nutritive values (including deleterious substances) of fodder trees and shrubs, particularly of those intended to be used in stall feeding;**
- **conduct socio-economic surveys on the limitations of on-farm supplementation in certain developing countries;**
- **work out appropriate woodland management systems which will ensure optimum utilization, concomitant with the persistence of fodder trees and shrubs in grazing systems.**

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Anti-nutritional factors, the potential risks of toxicity and methods to alleviate them
by R. Kumar

INTRODUCTION

The anti-nutritional factors (ANFs) may be defined as those substances generated in natural feed stuffs by the normal metabolism of species and by different mechanisms (e.g., inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed) which exert effects contrary to optimum nutrition. Being an ANF is not an intrinsic characteristic of a compound but depends upon the digestive process of the ingesting animal. Trypsin inhibitors, which are ANFs for monogastric animals, do not exert adverse effects in ruminants because they are degraded in the rumen (Cheeke and Shull, 1985).

The utility of the leaves, pods and edible twigs of shrubs and trees as animal feed is limited by the presence of ANFs. The *raison d'être* of ANFs in plants seems to be as a way of storing nutrient or as a means of defending their structure and reproductive elements (Harborne, 1989). In fact, plants contain thousand of compounds which, depending upon the situations, can have beneficial or deleterious effects on organisms consuming them. These compounds, with the exception of nutrients, are referred to as 'allelochemicals' (Rosenthal and Janzen, 1979). ANFs may be regarded as a class of these compounds, which are generally not lethal. They diminish animal productivity but may also cause toxicity during periods of scarcity or confinement when the feed rich in these substances is consumed by animals in large

quantities.

The ANFs which have been implicated in limiting the utilization of shrub and tree forages include non-protein amino acids, glycosides, phytohemagglutinins, polyphenolics, alkaloids, triterpenes and oxalic acid (Table 1).

TABLE 1. **Anti-nutritional factors in the leaves of tree and shrubs documented as being used in livestock feeding.**

Anti-nutritional substances		**Species**
1.	**Non-protein Amino acids**	
	Mimosine	***Leucaena leucocephala***
	Indospecine	***Indigofera spicta***
2.	**Glycosides**	
	(A) Cyanogens	***Acacia giraffae*** ***A. cunninghamii*** ***A. sieberiana*** ***Bambusa bambos*** ***Barteria fistulosa*** ***Manihot esculenta***
	(B) Saponins	***Albizia stipulata*** ***Bassia latifolia*** ***Sesbania sesban***
3.	**Phytohemagglutinins**	
		Bauhinia purpurea
	Ricin	***Ricinus communis***

	Robin	*Robinia pseudoacacia*
4.	Polyphenolic compounds	
	(A) Tannins	All vascular plants
	(B) Lignins	All vascular plants
5.	Alkaloids	
	N-methyl-B-phen	
	ethylamine	*Acacia berlandieri*
	Sesbanine	*Sesbania vesicaria*
		S. drummondii
		S. punicea
6.	Triterpenes	
	Azadirachtin	*Azadirachta indica*
	Limonin	*Azadirachta indica*
7.	Oxalate	*Acacia aneura*

MIMOSINE

Mimosine, a non-protein amino acid structurally similar to tyrosine, occurs in a few species of *Mimosa* and all species of closely allied genus *Leucaena*. Concern has arisen because of the importance of *L. leucocephala*, in which the level of mimosine in the leaf is about 2–6% and varies with seasons and maturity.

In non-ruminant animals, mimosine causes poor growth, alopecia, eye cataracts and reproductive problems. Levels of *Leucaena* meal above 5–10% of the diet for swine, poultry and rabbits generally result in poor animal performance. The mechanism of action of mimosine in

producing its effect is not clear but it may act as an amino acid antagonist or may complex with pyridoxal phosphate, leading to disruption of catalytical action of B6-containing enzymes such as trans-aminases, or may complex with metals such as zinc (Hegarty, 1978).

The main symptoms of toxicity in ruminants are poor growth, loss of hair and wool, swollen and raw coronets above the hooves, lameness, mouth and oesophageal lesions, depressed serum thyroxine level and goitre. Some of these symptoms may be due to mimosine and others to 3, 4 dihydroxypyridine, a metabolite of mimosine in the rumen (Jones and Hegarty, 1984). Toxic signs like skin lesions also resemble Zn deficiency. Reduction in calving percentage due to *Leucaena* feeding has also been noted (Jones *et al.*, 1989).

A solution to the mimosine problem could be the development of low mimosine cultivars. However, low mimosine types are found to be unuroductive and of low vigour. The other approach is to feed *Leucaena* mixed with other feeds. Hiremath (1981) suggested that use of *Leucaena* fodder may be restricted to 30% of the green forage in the case of cattle and buffalo, and 50% for goats. The effect of *Leucaena* and mimosine can be reduced by heat treatment (Tangendijaja *et al.*, 1990), by supplementation with amino acids (Rosenthal and Janzen, 1979) or with metal ions such as Fe^{2+}, Al^{3+} (D'Mello and Acamovic, 1989) and Zn^{+2} (Jones *et al.*, 1978).

CYANOGENS

Cyanogens are glycosides of a sugar, or sugars, and cyanide containing aglycone. Table 1 provides a few examples of fodder trees and shrubs containing cyanogens.

Cyanogens can be hydrolysed by enzymes to release HCN which is volatile gas. However, the glycosides occur in vacuoles in plant cell and enzymes are found in the cytosol. Damage to the

plant results in the enzymes and glycoside coming together and producing HCN. The hydrolytic reaction can take place in the rumen by microbial activity. Hence ruminants are more susceptible to CN toxicity than non-ruminants. The HCN is absorbed and is rapidly detoxified in the liver by the enzyme rhodanese which converts CN to thiocyanate (SCN). Excess cyanide ion inhibits the cytochrome oxidase. This stops ATP formation, tissues suffer energy deprivation and death follows rapidly.

The lethal dose of HCN for cattle and sheep is 2.0–4.0mg per kg body weight. The lethal dose for cyanogens would be 10–20 times greater because the HCN comprises 5–10% of their molecular weight (Conn, 1979). For poisoning, forage containing this amount of cyanogens would have to be consumed within a few minutes and simultaneous HCN production would have to be rapid. Recorded accounts of livestock poisoning by cyanogenic plants show that such situations do arise.

Cyanide can cause goitrogenic effects due to thiocyanate produced during detoxification. Poor animal performance due to *A. sieberiana* pod feeding has been attributed to cyanogens (Tanner *et al.*, 1990). Cyanogens have also been suspected to have teratogenic effects (Keeler, 1984).

Post-harvest wilting of cyanogenic leaves may reduce the risk of cyanide toxicity. Animals suffering from cyanide must be immediately treated by injecting a suitable dose of sodium nitrate and sodium thiosulphate.

SAPONINS

Saponins are glycosides containing a polycyclic aglycone moiety of either C_{27} steroid or C_{30} triterpenoid (collectively termed as sapogenins) attached to a carbohydrate. They are widely

distributed in the plant kingdom. Table 1 includes some of the fodder trees in which they may have nutritional significance.

Saponins are characterised by a bitter taste and foaming properties. Erythrocytes lyse in saponin solution and so these compounds are toxic when injected intravenously. The anti-nutritional effects of saponins have been mainly studied using alfalfa saponins. In non-ruminants (chicks and pigs), retardation of growth rate, due primarily to reduction in feed intake, is probably the major concern (Cheeke and Shull, 1985). Such effects have also been noted when *Sesbania sesban* leaf meal (saponin 0.71%) was incorporated in a chick diet (Shqueir *et al.*, 1989).

In ruminants, saponins were implicated in causing bloat. However, later studies indicate that they are not involved in the bloat syndrome. Furthermore, because saponins may also undergo bacterial degradation in the rumen, they may not retard the growth of ruminants. Nevertheless, recent studies indicate that they inhibit microbial fermentation and synthesis in the rumen (Lu and Jorgensen, 1987).

In ruminants, some reports of toxicity due to dietary saponins have also appeared. Sharma *et al.* (1969) observed that 4–7 weeks of *ad lib.* feeding of *Albizia stipulata* gave rise to toxic manifestations in sheep. The toxicity of broombreed (*Gutierrezia sarothrae*), a resinous shrub, is believed to be due to its saponin content. Symptoms include listlessness, anorexia, weight loss and gastroenteritis (Molyneux *et al.*, 1980). Joshi *et al.* (1989) observed that mowrin, a saponin in *Bassia latifolia* seed cake, was not toxic to calves when consumed orally at as high a level as 94g/day. These results indicate that saponins from different plant species have varied biological effects probably due to structural differences in their sapogenin fractions.

The adverse effects of saponins can be overcome by repeated washing with water which

makes the feed more palatable by reducing the bitterness associated with saponins (Joshi *et al.*, 1989).

PHYTOHEMAGGLUTININS

Phytohemagglutinins, otherwise referred to as lectins, are proteins which agglutinate red blood cells. They have been shown to occur in some important fodder trees (Table 1). The highest concentrations of lectins are found in seeds but, in the leaves, their concentration is low due to translocation. The biological effects of lectins probably result from their affinity for sugars. They may bind to the carbohydrate moieties of cells of the intestinal wall and cause a non-specific interference with nutrient absorption (Liener, 1985). In fodder trees, the lectins of interest are robin and ricin.

Robin, a lectin from *Robinia pseudoacacia*, has been reported to cause symptoms of anorexia, lassitude, weakness and posterior paralysis in cattle (Cheeke and shull, 1985).

Ricin occurs in castor beans (*Ricinus communis*) which have been reported to cause poisoning in all class of livestock. Due to ricin, deoiled castor seed cake (CP 35%) is seldom used as a livestock feed. However, the mature leaves of *R. communis* have been found suitable for feeding to sheep (Behl *et al.*, 1986); hence precautions against bean contamination are necessary. Castor bean meal can be detoxified by autoclaving at 20 psi for 60 minutes for incorporation in sheep diets (Rao *et al.*, 1988).

TANNINS

Tannins are water soluble phenolic compounds with a molecular weight greater than 500 and with the ability to precipitate proteins from aqueous solution. They occur almost in all vascular plants. Hydrolysable tannins and condensed tannins (proanthocyanidins) are two different

groups of these compounds. Generally tree and shrub leaves contain both types of tannins. The two types differ in their nutritional and toxic effects. The condensed tannins have a more profound digestibility-reducing effect than hydrolysable tannins, whereas the latter may cause varied toxic manifestations due to hydrolysis in rumen. Sheep ingesting 0.9g hydrolysable tannins kg/body weight showed signs of toxicity in 15 days. Animals like mule deer, rats and mice have been shown to secrete proline-rich proteins in saliva which constitute the first line of defence against ingested tannins. Nevertheless, deleterious effects and episodes of toxicity suggest the inadequacy of defence against high quantities of dietary tannins (Kumar and Vaithiyanathan, 1990).

The anti-nutritional effects of the tannins present in tree leaves are summarised in Table 2. The mechanism of dietary effects of tannins may be understood by their ability to form complex with proteins. Tannins may form a less digestible complex with dietary proteins and may bind and inhibit the endogenous protein, such as digestive enzymes (Kumar and Singh, 1984). Tannin-protein complexes involve both hydrogen-bonding and hydrophobic interactions; the precipitation of the protein-tannin complex depends upon pH, ionic strength and molecular size of tannins. Both the protein precipitation and incorporation of tannin phenolics into the precipitate increase with the increase in molecular size of tannins (Kumar and Horigome, 1986). However, when the molecular weight is very large (>5000), the tannins become insoluble and loose their protein precipitating capacity. Hence the measurement of the phenolic profile in terms of total phenols, condensed tannins, their protein precipitating capacity and degree of polymerization becomes imperative to asses the role of tannins in ruminant nutrition (Kumar, 1983; Lowry, 1990). In tree leaves tannins are present in NDF and ADF in significant amounts which are tightly bound to the cell wall and cell protein and seem to be involved in decreasing digestibility (Reed *et al.*, 1990). Hence, there is a need to account for these tannins in estimating the nutritive value of tree leaves.

In ruminants, dietary condensed tannins (2–3%) have been shown to impart beneficial effects because they reduce the wasteful protein degradation in the rumen by the formation of a protein-tannin complex (Barry, 1987). The complex appears to dissociate post-ruminally at a low pH where, presumably, the protein becomes available for digestion. However, free condensed tannins would probably be available to form a complex with digestive enzymes such as pepsin and also with the protein of gut wall. Condensed tannins of *Prosopis cineraria* precipitate pepsin at pH 2.0 and the net effect of the presence of condensed tannins may therefore be negligible.

TABLE 2. **Some examples of anti-nutritional effects of tannins in shrub and tree forages.**

Fodder Tree/Shrub	**Predom-inant Tannin***	**Animal**	**Nutritional Effect**	**Reference**
Acacia aneura[a]	CT	Sheep	Reduction in N digestibility decreased wool yield and growth, decreased S absorption	Pritchard *et al.* (1988)
A. cyanophylla	CT	Sheep	Reduced feed intake, negative N digestibility, loss in weight	Reed *et al.* (1990)
A. nilotica (pods)	CT	Sheep	Low growth rate, reduced N and NDF digestibility	Tanner *et al.* (1990)
A. sieberiana[b] (Pods)	HT	Sheep	Low growth rate, reduced N and NDF digestibility	-do-
Albizia chinensis[d]	CT	Goat	Reduced *in sacco* N digestibility	Ahn *et al.* (1989)
Leucaena leucocephala[c]	CT	Poultry	Poor N retention, low apparent metabolisable energy value	D'Mello and Acamovic (1989)

Manihot esculenta[b]	CT	*In vitro*	Inhibits digestibility	Rickard (1986)
Prosopis cineraria	CT	Sheep	Reduction in feed intake protein, digestibility, decreased wool yield & growth, decreased iron absorption	CSWRI (1989)
Robinia pseudoacacia[e]	CT	Rat	Reduced protein digestibility	Horigome *et al.* (1988)
		Rabbit	Reduced feed intake & growth, cecotrophy increased protein digestibility	Raharjo *et al.* (1990)
Terminalia oblongata	HT	Sheep	Reduction in feed intake, toxicity but no effect upon digestibility	McSweeney *et al.* (1988)
Ziziphus nummularia	CT	Sheep	Reduction in feed intake protein and DM digesti- bility; decreased wool yield and weight loss	Kumar and Vaithiya- nathan (1990)

*** CT- Condensed Tannins;**

HT- Hydrolysable Tannins

In addition to tannins, the other reported deleterious compounds in above top feed are marked withsuperscripts as:

a. oxalate

b. cyanogens

c. mimosine

d. saponins

e. lectins.

A number of methods have been tried to overcome the deleterious effects of tannins (Kumar and Singh, 1984). Alkali treatments include ferrous sulphate and polyethylene glycol-4000 (PEG-4000); the last was found to be effective for deactivation of tannins in tree leaves (CSWRI, 1987–89). However, using PEG-4000 in routine feeding may not be economic. Three months feeding of *P. cineraria* leaves and *Cenchrus* spp. (50:50) with 1% urea has been found to maintain adult sheep. In such a feeding system, urea not only provides extra nitrogen to the animals but also deactivates the leaf tannins (Russell and Lolley, 1989). Therefore, the use of urea to overcome the deleterious effects of tannin may be of practical value and should be studied.

OTHER ANTI-NUTRITIONAL FACTORS

Apart from the ANFs discussed in preceding sections, shrub and tree forage may contain alkaloids, terpenoids, oxalate, indospecine, lignins (Table 1) and certain other ANFs. Alkaloids such as N-methyl-a phenethylamine cause locomotor ataxia of the hindquarters in sheep. Sesbaine causes haemorrhagic diarrhoea. The terpenoids azadirachtin and limonin impart a bitter taste and the leaves of *Azadirachta indica* are therefore not relished by cattle. Oxalate in the leaves of *Acacia aneura* may limit the Ca availability and a negative correlation between digestibility and lignin content in tropical browse has been observed (Bamualin *et al.*, 1980).

STUDYING THE ANFs: A CHALLENGE

As previously noted, most of the ANFs belong to a group of related compounds with similar mode of actions. There are about 8,000 polyphenols, 270 non-protein amino acids, 32

cyanogens, 10,000 alkaloids and several saponins which have been reported to occur in various plant species. Studying such a vast number of compounds is bound to provide major challenges.

1. Detection: This can be approached either by evaluating animal performance or by chemical analysis. Certain ANFs can be detected through chemical analysis but it is not easy to look for all possible allelochemicals in a single plant. Furthermore, lesser known fodder trees and shrubs may contain unknown ANFs and their presence would only be revealed through feeding trials, not by chemical analysis directed at known compounds.

2. Quantification: There is wide variation in the reported concentration of ANFs in the same plant species. This may be either real, because of the changes occurring due to environmental conditions, or may arise because of lack of standardization of methods between laboratories, as well as their destruction in assays.

3. Assessment of biological effects: It is often observed that sensitivity to ANFs varies between species of animals, different ages and physiological stages. Furthermore, the leaves of a particular tree or shrub may contain different group of ANFs and it becomes difficult to separate their biological effects.

METHODS TO ALLEVIATE: AN OVERVIEW

The uncertainty of quantification and the imperfectly understood biological effects of ANFs impede the development of methods to alleviate their effects. The simplest approach of dilution, i.e., feeding allelochemical containing leaves in mixtures with other feeds, may certainly reduce the risk of toxicity but simultaneous nutritional benefits may not accrue. Moreover the required degree of dilution is difficult to recommend because of uncertain

quantification.

Several studies indicate that tannin-rich leaves, in combination with concentrate rations, could be fed to animals without any adverse effect (Raghavan, 1990). This happens because animals consume protein in excess of their requirement from the concentrate and therefore, the antinutritional effects of tannins were masked. Moreover, these studies do not show the utilization of tree leaf proteins for which they are mostly fed.

The utility of management practices involving lopping/harvesting of tree leaves at times when the concentration of ANFs are lowest, (Vaithiyanathan and Singh, 1989) is limited because pattern of changes in concentration of various allelochemicals may not be same. For a particular ANF, the effect of season also varies between plant species. It has also been noted that, as leaves mature, both the ANF and nutrient contents decrease (Singh, 1982).

Another approach of supplementation, e.g., polyethylene glycol-4000 with tannin-rich leaves, may be suitable during acute shortage to avoid livestock losses. These cannot be used routinely because of prohibitive costs. However, metal ions and urea supplementation could be recommended to farmers after thoroughly assessing their alleviating effects against highest possible reported concentrations of allelochemicals.

Many ANFs are heat labile. Hence simple heating or autoclaving has been found useful in removing the effects of allelochemicals. This practice can be used by the feed industry but not by farmers. Unfortunately, heating would substantially increase the cost due to the energy involved both in the treatment and transport. The efficacy of wilting in reducing the risk of cyanide toxicity needs to be tested before it is recommended to farmers. Simple washing with water removes the soluble allelochemicals but nutrients also leach out.

Since ANFs have a major role in plant defence, selecting for low ANFs lines may have undesirable effects on the plant.

Alleviation By Rumen Microbial Activity

Ruminant animals have a symbiotic relationship with rumen microorganisms. The rumen environment (slightly acidic pH:E° = -0.35V; 10^{10} microbes/ml) provides many reductive and hydrolytic reactions which, in the majority of cases, decrease the biological activity of the allelochemicals before their absorption from the tract.

Rumen bacteria and fungi capable of degrading lignin have been isolated. Anaerobic degradation of flavonoid and hydrolysable tannins by mixed rumen microbes has also been demonstrated. Such rumen microbes are present in small numbers and their growth rate is slow. Anaerobic microbial degradation of condensed tannins has also been demonstrated.

Dietary oxalate can be degraded by rumen microbes into CO_2 and formic acid. Ruminants adapted to diets with high oxalate content can tolerate oxalate levels that are lethal to non-adapted animals. Moreover, it has been shown that the transfer of rumen fluid from animals in Hawai to Australian ruminants resulted in complete elimination of the toxic effects of mimosine and the bacteria involved in such effects have been identified (Allison *et al.*, 1990). Evidence also exists that rumen microbes can be genetically manipulated (Russell and Wilson, 1988).

These findings imply that future research may be drawn towards identification of the various anaerobic and rumen microbes capable of dissimilating ANFs, testing the survivability of organisms in the rumen and investigating whether the dissimilation is plasmid encoded, so that genetic manipulation of rumen bacteria can be effected for the useful fermentation of ANFs.

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Lessons from main feeding experiments conducted at CATIE using fodder trees as part of the N-ration

by M. Kass, J. Benavides, F. Romero and D. Pezo

INTRODUCTION

In the tropics, the quantity and quality of forages (mainly grasses) traditionally used by the smallholders to feed ruminants vary with rain precipitation patterns, causing periods of nutritional stress and a consequent reduction in animal productivity. Supplementing animals in periods of feed shortage is a common practice among farmers but, most of the time, this extra feed is barely enough to fulfil the animals maintenance requirement. The high cost of supplements for ruminants, especially protein, and the competitiveness of their use by monogastrics are perennial problems to many farmers in developing countries, leading researchers to look more aggressively for non-conventional protein sources.

In recent years, there has been growing interest in many regions throughout the developing world in exploring the possibilities of including shrub and tree foliages in ruminants diets.

Laboratory methods traditionally used to estimate the nutritive value of forages (proximate analysis, neutral and acid detergent fibre, *in vitro* and *in vivo* digestibility) do not give very consistent results when assessing tree and shrub foliages (Shelton, 1991; Kass and Ruiz, unpublished data) because of the presence of secondary compounds (tannins, alkaloids, etc.). There is therefore little knowledge about the characteristics of these forages as feeds. However, the ultimate indicator of nutritive value is the measurement of the animal production response.

TABLE 1. Summary of the research carried out by CATIE on shrub and tree foliages as protein supplement to growing small ruminants.

Foliage species	Crude protein %	IVDMD[1] %	--Dry matter intake--			Energy Source	ADG[2] g/head	Animal Species	Reference
			Foliage % BW	kg/day	Total % BW				
Stemmadenia donell									
smitii	24.5	49.4	2.0					goat	Benavides (1991)
Sambucus mexicanus	24.3	75.8	1.9					goat	Benavides (1991)
Malvabiscus arborescens	21.0	68.3	1.8					goat	Benavides (1991)
Hibiscus rosa-sinensis	19.9	71.2	1.2					goat	Benavides (1991)
Guazuma ulmifolia	36.3	50.0	1.0					goat	Benavides (1991)

Eugenia jambos	**34.2**	**33.4**	**0.6**					**goat**	**Benavides (1991)**
Erythrina berteroana	**25.0**	**49.0**		**0.6**		**green bananas**	54	**lamb**	**Arguello *et al.* (1986)**
Morus sp.	**24.2**	**89.2**	**0.5**	**0.1**	**3.7**	**green bananas**	75	**lamb**	**Benavides (1986)**
Morus sp.	**24.2**	**89.2**	**1.0**	**0.2**	**4.0**	**green bananas**	85	**lamb**	**Benavides (1986)**
Morus sp.	**24.2**	**89.2**	**1.5**	**0.3**	**4.3**	**green bananas**	101	**lamb**	**Benavides (1986)**
Gliricidia sepium	**26.9**	**58.0**		**0.6**		**green bananas**	60	**lamb**	**Arguello *et al.* (1986)**
Gliricidia sepium [3]	**19.9**	**56.0**		**0.3**		**green bananas**		**goat**	**De la Fuente (1990)**
Gliricidia sepium [4]	**19.4**	**56.3**		**0.2**		**green bananas**		**goat**	**De la Fuente (1990)**
Erythrina poeppigiana	**29.0**	**52.0**		**0.5**		**green bananas**	35	**lamb**	**Arguello *et al.* (1986)**
Erythrina poeppigiana	**26.0**	**51.9**	**3.5**			**green bananas**	74	**lamb**	**Benavides and Pezo (1986)**
Erythrina poeppigiana	**26.0**	**51.9**	**3.2**			**molasses**	92	**lamb**	**Benavides and Pezo (1986)**

Erythrina poeppigiana	**26.0**	**51.9**	**3.3**			**green bananas**	112	**lamb**	**Benavides and Pezo (1986)**
Erythrina poeppigiana	**26.0**	**51.9**	**3.0**			**yam**	128	**lamb**	**Benavides and Pezo (1986)**
Erythrina poeppigiana	**25.6**	**53.7**	**3.3**			**yam**		**goat**	**Esnaola y Benavides (1987)**
Erythrina poeppigiana	**26.1**	**53.5**	**2.7**			**green bananas**		**goat**	**Rodriguez *et al.* (1987)**

[1] In vitro Dry Matter Digestibility

[2] Average Daily Gain

[3] G. sepium silage from Turrialba, Costa Rica

[4] G. sepium silage from Guapiles, Costa Rica

TABLE 2. **Summary of the research carried out by CATIE on shrub and tree foliages as protein supplement to milking goats fed on chopped *Pennisetum Purpureum*.**

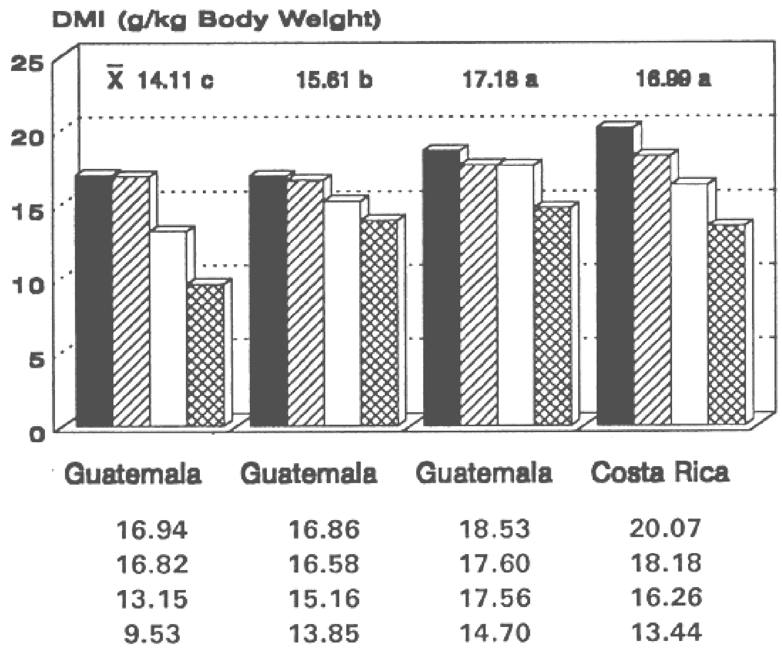
Foliage species	**Crude Protein %**	**IVDMD[1]**	**Dry matter intake**			**Energy source**	**Milk Yield kg/day**	**Reference**
			Foliage % BW	**kg/day**	**Total % BW**			
Gliricidia						green		Rodriguez *et al.*

sepium	25.4	57.3	0.9		3.6	bananas	1.1	(1987)
Erythrina poeppigiana	24.8	53.1	0.6			ripe bananas	1.1	Gutierrez (1983)
Erythrina poeppigiana	25.3	55.0	0.6			green bananas	1.3	Samur (1984)
Erythrina poeppigiana	25.3	55.0	0.6			ripe bananas	1.2	Samur (1984)
Erythrina poeppigiana	23.7	52.6	0.5	0.2	3.6	green bananas	0.7	Esnaola and Rios (1986)
Erythrina poeppigiana	23.7	52.6	1.0	0.4	4.0	green bananas	0.8	Esnaola and Rios (1986)
Erythrina poeppigiana	23.7	52.6	1.5	0.6	4.4	green bananas	1.0	Esnaola and Rios (1986)
Erythrina poeppigiana	27.8	54.0		0.5	3.9	green bananas	1.3	Castro (1989)
Erythrina poeppigiana	27.8	54.0		0.5	3.8	green bananas	1.1	Castro (1989)
Erythrina poeppigiana	27.8	54.0		0.3	4.0	green bananas	1.1	Castro (1989)
Erythrina poeppigiana	27.8	54.0		0.3	3.6	green bananas	1.1	Castro (1989)
Malvabiscus arborescens	21.0	68.3	1.3	0.6	5.2		1.8	Hernandez and Benavides
								(unpublished data)

Morus spp.	24.2	89.2	1.3	0.6	5.4		2.2	Benavides (unpublished data)

[1] **In vitro dry matter digestibility.**

FIGURE 1. Dry matter intake (DMI) of different families and individual plants within the same family of *Gliricidia sepium*.



SMALL RUMINANTS

In 1980, CATIE began to develop goat and sheep feeding systems utilizing tree foliages as protein supplements to grasses diets, together with several energy sources, especially green banana fruits. The results have been extensively described by Pezo *et al*. (1990) and Benavides

(1991), and are summarized in Tables 1 and 2. From these initial studies several conclusions can be drawn.

Dry matter intake (DMI) by goats of several Central American shrub and tree foliages was shown by Benavides (1991) to be very high. However, *Gliricidia sepium* foliage was found to produce an erratic DMI (De la Fuente, 1990; Rodriguez *et al.*, 1987). More recently, the nutritional diversity of this species has been studied by Kass and Ruiz (unpublished data), indicating important variation in DMI among provenances, families within provenances and individual plants within the same family (Figure 1). In spite of the negative relationships between foliage DMI and NDF, ADF and tannin content, these correlations were lower than those found with traditional forages (Table 3), indicating that other factor(s) is (are) responsible for DMI variation in *G. sepium* foliage.

The supplementation of *Pennisetum purpureum* and green banana fruits with increasing amounts of *E. poeppigiana, Morus* spp. and *Malvabiscus arborescens* foliages enhanced milk yields and daily gains in goats and lambs respectively. Although a partial substitution effect on king grass DMI was detected, the total DMI increased (Benavides, 1986; Esnaola and Rios, 1986).

The addition of an energy source to grass diets supplemented with *E. poeppigiana* improved the daily weight gain of lambs (Benavides and Pezo, 1986) and daily milk production in goats (Samur, 1984). However, starch sources such as green banana fruits and yams gave better results than soluble carbohydrate sources like molasses and ripe bananas, indicating either more microbial synthesis in the rumen when readily degradable energy sources are used and/or more bypass feed energy with starch supplements. Also, the crude protein:digestible energy ratio was shown by Castro (1989) to be more important than levels of foliage and energy for milk production by goats fed on grass (*P. purpureum*) and supplemented with

Erythrina poeppigiana **foliage and green banana fruits. Nevertheless, *Morus* spp. and *M. arborescens* foliages, used as the only feed to dairy goats, showed high DMI and milk production without energy supplementation (Benavides, unpublished data; Hernandez and Benavides, unpublished data). However, it is interesting to note that both foliages showed very high *in vivo* dry matter digestibility (64% and 81% for *M. arborescens* and *Morus* spp. foliages, respectively).**

Milk yield from goats supplemented with *E. poeppigiana* was lower than commercial concentrate supplements with the same level of crude protein, confirming that the protein quality of this tree foliage is less than that of traditional protein supplement. But the economic analyses favoured the use of *E. poeppigiana*.

TABLE 3. **Correlation coefficients between foliage dry matter intake and chemical composition of *Gliricidia sepium* families.**

	Correlation coefficient	P F
Dry matter %	0.31	0.24
IVDMD[1] %	0.06	0.81
Crude Protein %	-0.04	0.86
NDF[2] %	-0.50	0.05
ADF[3] %	-0.48	0.06
Soluble phenolics %	-0.62	0.03
Insoluble proanth.	-0.36	0.16

Source: Kass and Ruiz (unpublished data)

[1] *In vitro* dry matter digestibility

[2] Neutral detergent fibre

[3] Acid detergent fibre

[4] Insoluble proanthocyanidins.

CATTLE

It was only in 1986 that CATIE's began studies on the utilization of tree foliage as nitrogen supplement to cattle. Pineda (1986) evaluated different levels of substitution of a traditional protein source (soyabean meal) with *E. poeppigiana* foliage to dairy heifers (48 kg live weight) fed on king grass (*Pennisetum purpureum*). The replacement of soyabean meal with increased levels of *E. poeppigiana* resulted in a linear decrease in daily gains and grass dry matter intake (Figure 2).

However, these effects were more evident in another experiment carried out by Abarca (1989). When *E. poeppigiana* and sugar cane molasses were compared with commercial concentrates as protein supplements to milking cows grazing African star grass, the foliage supplementation consistently resulted in lower milk production and pasture DMI (Table 4).

FIGURE 2. Average daily gain and dry matter intake of *P. purpureum* as influenced by the level of *E. poeppigiana* intake.

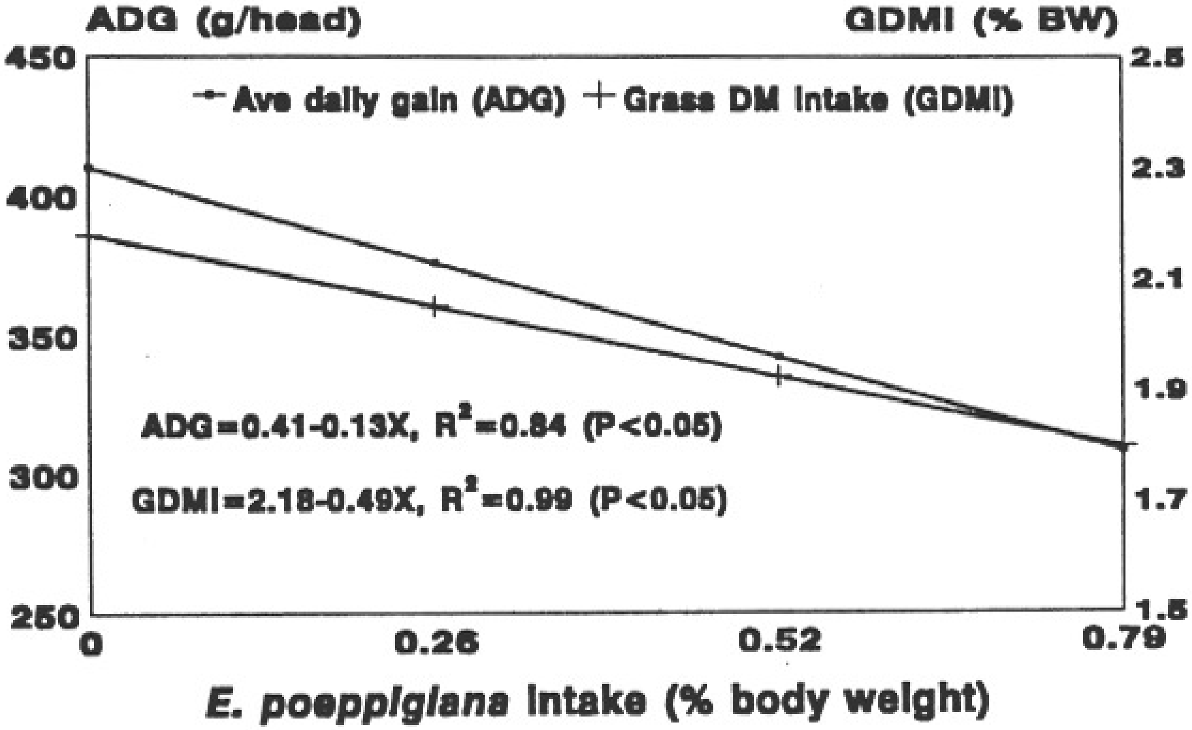


TABLE 4. **Dry matter (DM) intake and daily milk production in cows grazing African star grass, supplemented with either fish meal or *E. poeppigiana* foliage as the protein source.**

	Fish meal	***E. poeppigiana***
DM intake (% body weight)		
African star grass	1.93[a]	1.24[b]
Supplement	1.08[a]	1.55[a]
Total	3.01[a]	2.79[a]
Milk production (kg/head)	9.0	8.2
Milk composition (%)		
Total solids	13.4[b]	12.7[a]

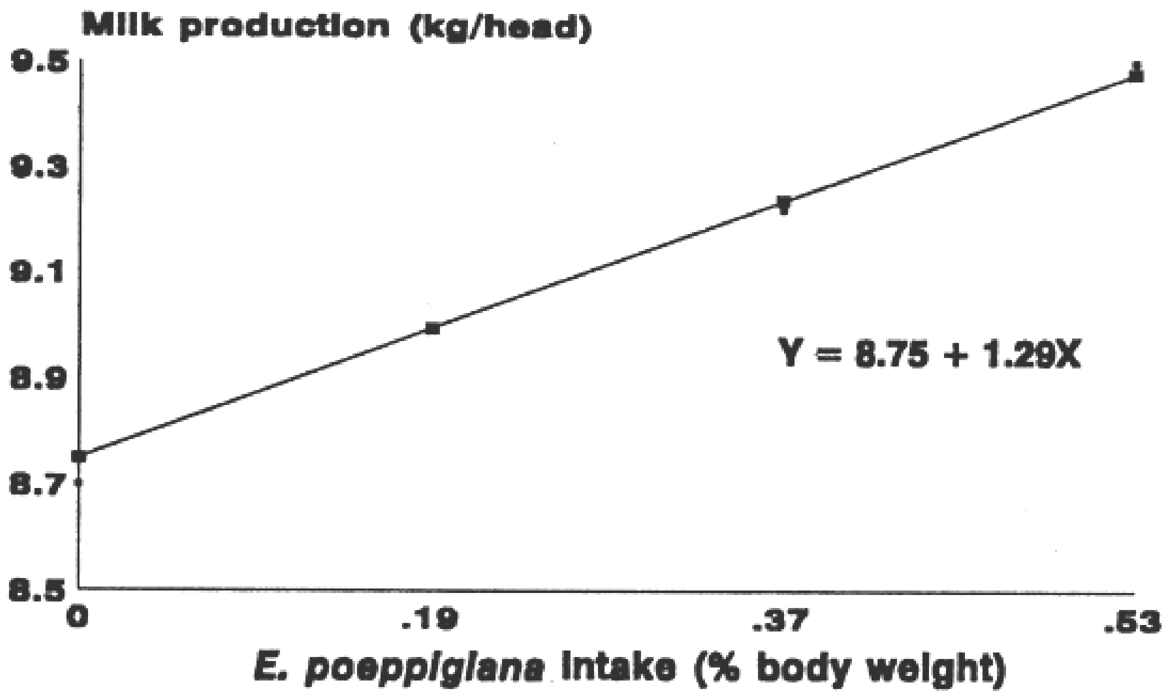
Protein	3.2[a]	3.3[a]
Fat	4.1[a]	4.3[a]

Source: Abarca (1989)

Note: Sugar cane molasses was the energy supplement. Means in the same row followed by the same letter do not differ significantly (P< 0.05).

Following this finding, Vargas (1987) fed grazing steers different levels of *E. coleata* foliage and observed increased average daily gains when *E. cocleata* was offered at a level equivalent to 0.05 x body weight (398 and 524 g/day for the control and tree foliage). The addition of an energy supplement (green banana fruits) to the same level of *E. cocleata* resulted in a slight increase in daily gain (579 v. 524 g/head), but, again benefit/cost relationship favoured the foliage as the only supplement. The same beneficial effect of tree foliage supplementation was observed by Tobon (1988) when milking cows grazing African star grass (*Cynodon nlemfuensis*) and receiving a constant level of energy (1 kg molasses/head/day) where supplemented with increasing levels of *E. poeppigiana* foliage (Figure 3).

FIGURE 3. Milk production of grazing cows in relation to levels of *E. poeppigiana* intake.



Although the protein quality of *Erythrina* spp. was shown in both experiments to be less than that of traditional protein supplements, the economic analyses indicated that the net profit obtained using the foliage supplement plus locally available energy sources, such as sugar cane molasses, was better than concentrates. This is important to the small farmer because the availability of cash is one of the farmer's main constraints.

Taking into account this situation and in view of the fact that the addition of energy improves milk production, Corado (1991) carried out a study utilizing another locally available feed resource, rice bran, as a supplement to grazing dairy cows receiving a constant level of *E. poeppigiana* foliage equivalent to 0.05 x BW. The results, showed in Table 5, indicated that increasing the level of rice bran supplementation increased milk production. Although there

were very little differences in crude protein and digestible energy intakes between the control diet and rice bran supplementation equivalent to 0.02 x BW, daily milk yield increased from 8.7 kg/head to 9.7 kg/head, with a net marginal increase of 266%, showing that bypass nutrients (protein and energy) are needed to obtain higher milk production when *E. poeppigiana* foliage is the nitrogen source.

TABLE 5. **Crude protein and digestible energy intakes and milk production in grazing cows supplemented with *E. poeppigiana* (0.5 % BW) and different levels of rice bran.**

	Rice bran intake (% BW)			
	0	**0.2**	**0.4**	**0.6**
Crude protein intake (g/day)	1037	1071	1159	1262
Digestible energy intake (Mcal/day)	24.4	24.1	26.7	28.9
Milk yield (kg/head/day)	8.8	9.7	9.9	10.5

Source: Corado (1991)

There is an evident need for protein supplementation during the dry season in sub-humid systems, when low quality and low protein forages (mature grass, crop residues or sugar cane) are the main feed resources. Alagon (1990), comparing *E. poeppigiana* foliage with conventional nitrogen sources with different rumen degradation rates (urea, fish meal and soyabean meal) as protein supplements to dairy cows fed on chopped sugarcane plus rice bran, concluded that daily milk yields in cows supplemented with this tree foliage were similar to urea but inferior to soyabean meal and fish meal (Table 6). Also, animals supplemented with *E. poeppigiana* foliage and urea had a lower sugar cane intake than fish meal and soyabean meal supplements. However, urea-supplemented diets resulted in inferior milk composition and the cows lost weight in the experimental period, as compared to *E. poeppigiana*

supplementation. Although the crude protein degradability was the same for *E. poeppigiana* foliage and soyabean meal (68%), *E. poeppigiana* was shown to contain high amounts of nitrogen in the ADF fraction, which could be influencing its bypass protein availability. The different protein supplements did not effect the total income but the variable costs were lower for diets where tree foliage and urea were the nitrogen sources.

TABLE 6. **Sugar cane intake and milk production and composition in cows fed on sugar cane supplemented with *E. poeppigiana* foliage and traditional nitrogen sources.**

	Erythrina poeppigiana	Fish meal	Soyabean meal	Urea
Sugar cane intake (% BW)	1.45	1.61[a]	1.64[a]	1.49[b]
Milk yield (kg/day)	9.60[a]	11.02[b]	10.54[b]	9.29[a]
Milk composition (%)				
Total solids	12.58[a]	12.43[a]	12.48[a]	11.96[b]
Fat	3.63[a]	3.37[b]	3.50[ab]	3.59[b]
Protein	3.27[b]	3.42[a]	3.38[ab]	3.05[b]
Average daily gain (g/head)	468[ab]	892[a]	287[b]	-461[c]

Means followed by the same letter do not differ statistically (P>0.05). Source: Alagon (1990).

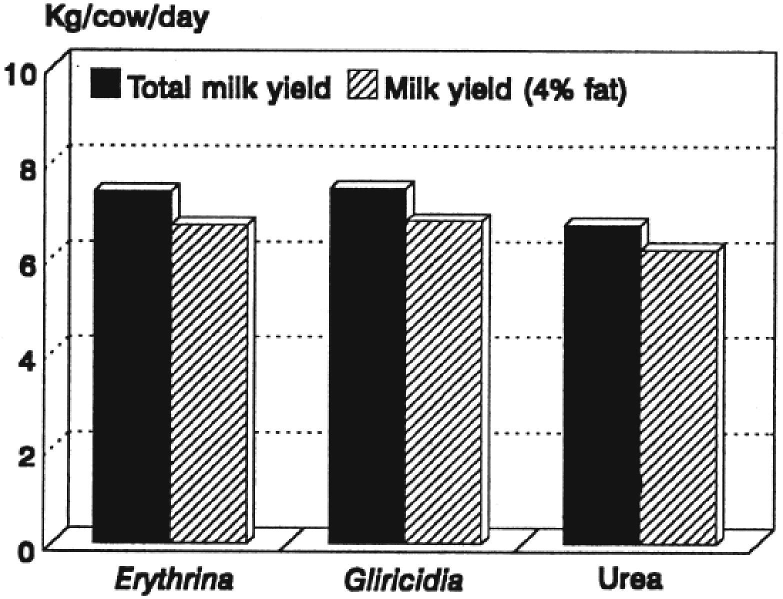
However, when the same diets were used for growing daily heifers (Vasquez, 1991), daily gains of 763, 648 and 592 g/head were obtained for fish meal, *E. poeppigiana* edible biomass and urea, respectively. The supplementation with tree forage decreased sugarcane DMI, but increased total DMI, and had no effect in the sugar cane dry matter disappearance from the rumen, in spite of increased rate of passage of the diet in the gastro-intestinal tract.

In the dry season, crop residues and hays with very low nutritive values play a major role in the feeding of livestock. Traditionally, these feed resources are supplemented with urea and molasses which slightly improves feed intake and digestibility of the diet but has very little effect in the animal productivity. Camero (1991) showed that the supplementation of *Hyparrhenia rufa* hay (3% crude protein and 35% *in vitro* dry matter digestibility) with *E. poeppigiana* or *Gliricidia sepium* foliages improved the milk yield as compared to urea supplementation (Figure 4). Also, the animals were in better body condition and had higher dry matter intakes with foliages supplementation.

In summary, the results obtained with grazing daily cows under lowland humid tropical conditions suggest that the direct benefits on milk production derived from the use of *E. poeppigiana* foliage are small but that there might be important indirect benefits such as increased carrying capacity as a result of substitution effects on grass intake and increased recycling of nutrients in the areas grazed, as a result of richer animal excreta. But, in sub-humid systems, supplementation of poor quality roughages with tree foliage seems to be an attractive method of improving animal productivity.

FIGURE 4. Milk production in cows fed H. rufa hay and supplemented with *G. sepium, E. poeppigiana* and urea.

Kg/cow/day



	Erythrina	Gliricidia	Urea
total milk yield	7.33	7.44	6.68
milk yield (4% fat)	6.68	6.75	6.16

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