FODDER TREES AND SHRUBS IN ARID AND SEMI-ARID LIVESTOCK PRODUCTION SYSTEMS

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ABSTRACT

Arid and semi-arid lands constitute a large proportion of available agricultural and rangeland in the world. These lands are characterised by low and unreliable rainfall, low land productivity, and low socio-economic status of the inhabitants. Livestock plays a very significant role in their economies. Leguminous trees and shrubs, which dominate the natural rangelands, are often higher in crude protein and other nutrients and play a vital role as dietary supplements to the low quality grasses in the dry seasons.

In addition to the fodder potential, the role of tree legumes in the sustainability of agricultural and pastoral production systems is increasingly being recognised and explored. This role and importance of legume trees for livestock production, their nutritional quality and factors which limit their use in livestock production are reviewed. Fodder tree and shrub integration into agricultural and pasture production systems is emphasised. Identified constraints to effective use are highlighted and the needs for increased research and development are discussed.

KEYWORDS

Fodder, Trees, Shrubs, Arid, Semi-arid, Livestock

INTRODUCTION

Arid and semi-arid lands constitute about 50% of the total land area of the world. These areas are characterised by low and unreliable rainfall, low productivity, large human and livestock populations. Livestock production plays a vital role in the production systems and in the livelihood of the people in the arid and semi-arid zones. Fodder trees and shrubs, often called 'browse' are used as supplements to livestock especially during the dry seasons and fodder stress periods (Le Houérou, 1980, Otsyina and McKell, 1984; Dicko and Sikena, 1992a, Lefroy et al., 1992, Atta-Krah, 1993). They also serve other useful purposes such as the provision of food, drugs, firewood and building poles and recycling of nutrients. Over the past decade, much information has been accumulated on the potential of browse trees and shrubs as sources of feed in grazing systems. In the humid tropics, genera such as leucaena, gliricidia and erthyrina have proved to be most useful, and research is now being focussed on other species of these genera to extend the range of adaptation to new environments and disease and pest challenges (Shelton and Brewbaker, 1994, Simons and Stewart, 1995). Fodder trees and shrubs form a major component of the diet of livestock in the arid (25 -200 mm) and semi-arid (200-800 mm) zones of Africa, India, Australia and South America. In the arid zone, shrubs from the genera atriplex, acacia, prosopis and artemisia have proved to be the most valuable introductions (Dicko and Sikena, 1992b). In the semi-arid zones, tree and shrub genera with potential are acacia, albizia, faidherbia and ziziphus, with many other species which have particular local significance as sources of feed. For example, Tagasaste (*Chamaecytisus palmensis*) was introduced to Australia from the Canary Islands, and has been recently shown to be a valuable fodder source on deep sandy soils in low rainfall areas (<600 mm) of Western Australia, and may have application in similar environments elsewhere (Oldham et al., 1991). Leucaena (*Leucaena leucocephala*) is recognised as the most successful fodder tree for the tropics, but this is only one of some 21 species of leucaena which have been identified. Although leucaena does grow relatively well in semi-arid zones (>600 mm) when well managed, there is a high probability that other species may be better adapted to these environments (Bray, 1994). The successful adaptation of trees and shrubs to arid environments is associated with characteristics which limit predation by grazing animals. The presence of thorns, prickly leaves, volatile oils, suberised and highly lignified leaves, alkaloids and tannins ensure survival in these environments, but decrease the palatability and nutritive value of the foliage from these trees for animals.

Despite the recognised importance of trees and shrubs, especially, in the arid and semi-arid areas, research and development work on them have been minimal until recent years. Increasing interest is now being shown by researchers and policy makers in the introduction and management of fodder trees and shrubs on range and agricultural lands for grazing and other multiple uses (NAS, 1979). This paper discusses the role and importance of leguminous trees and shrubs as fodder for livestock in arid and semi-arid lands. Production, fodder quality and other factors which influence integration, management and utilization of browse species into existing agricultural and rangeland systems in the arid and semi-arid environments are discussed. Research and development needs are highlighted.

EXTENT AND DISTRIBUTION OF ARID AND SEMI-ARID LANDS

Arid and semi-arid lands refer to those parts of the world where rainfall is insufficient or barely sufficient for satisfactory crop growth. Arid lands in the tropics refer to areas receiving between 25-200 mm; semi-arid lands refer to those areas with mean annual rainfall totals of 200-800 mm (Grove, 1977).

Arid and semi-arid lands are widespread and constitute a very important component of the total land area of the world. Generally, arid and semi-arid lands are characterised by low, erratic and unreliable rainfall, unusual extremes of temperatures, high evaporation and evapotranspiration rates and low land productivity. These conditions create very harsh environments for crops, humans and livestock. Pastoralism and nomadism are important land use systems with a high degree of dependence on browse trees for livestock production, especially in the dry season (Le Houérou, 1980; Jahnke, 1982; Atta-Krah, 1990).

LIVESTOCK PRODUCTION

The role and importance of livestock in arid land management systems in Africa have been extensively reviewed (Jahnke, 1982). Livestock populations are concentrated in the arid and semi-arid regions in all continents. These high stock populations indicate the high demand for fodder in both dry and wet seasons. Livestock management is generally extensive and semi-intensive on communal and private rangelands.

Importance of tree legumes as fodder for livestock. Several recent reviews and studies in various parts of the world, have shown that browse trees and shrubs play a very significant role, mostly as supplements, in the nutrition of livestock in the arid and semi-arid lands of the world (Le Houérou, 1980; Otsyina and McKell, 1984; Tothill et al., 1989; Atta-Krah, 1990; Lefroy et al., 1992; Otsyina and Dzowela, 1995). The most important role of browse has been to provide valuable fodder as supplements to low value fodder in the dry seasons. In Australia for example, stands of Mulga (*Acacia aneura*) sustain the sheep industry in times of drought. The branches and leaves are lopped to provide feed for livestock. *Faidherbia albida* (Syn *Acacia albida*) has been reported to be extremely important in livestock diets in the dry seasons. It provides both leaves and palatable pods, especially, to sheep and goats (NAS, 1979). In South America, natural stands of prosopis species provide the only available forage, fuelwood and poles in the dry parts of Argentina. Similar observations have been reported in other countries, Brazil and Chile for instance, where *Prosopis juliflora* plays an important role in animal nutrition (Riveros, 1992).

Although leguminous fodder trees play significant roles in the supplementary feeding of livestock, their sustained productivity and management on rangelands remains a serious problem mainly due to poor accessibility and improper management. Improvements in the productivity of rangelands could be achieved through enrichment planting of adapted trees and shrubs and effective education of the local communities in proper management of these resources.

Browse production in arid and semi-arid lands. Browse production is generally low and is influenced by factors such as the climate, soil type, management and history of exploitation by man and animals. For an *Acacia aneura* community in Queensland, Beale (1973) reported foliage production per tree from 3 to 5 kg per season depending on tree density. Leaf and fruit production from the Sahelian zone of west Africa are presented in Table 1. Productivities range from 0.7 to 3 kg per tree per annum for leaves and 0.08 to 2.5 kg for pods and depends greatly on tree species and rainfall. In general, fodder production from trees and shrubs differs significantly in different ecological zones and ranges between 1-5 tonnes per tree per year.

CHEMICAL COMPOSITION AND NUTRITIVE VALUE

The chemical composition of leaves and fruits consumed by animals has been extensively reported in the literature (Le Houérou, 1980; Devendra, 1986; D'Mello and Devendra, 1995). In most cases, proximate composition (crude protein, crude fibre, ether extract, ash) and mineral content is presented as a guide to nutrient value. When the macro-element content of browse leaves and fruits is compared with recommended requirements for ruminants, calcium and magnesium contents are usually in excess, phosphorus content is often marginal (< 1.2 g/kg DM) and with the exception of the halophytes (*Atriplex spp.*), sodium is often low (< 0.8 g/kg DM). The presence of oxalic acid in the leaves of some acacia species may decrease the availability of calcium during digestion. There is only very limited data on the trace element content of browse, but where available, trace elements (Cu, Co, Mn, Zn) appear to be adequate. Since browse usually forms only a small proportion of the diet, macro and micro-element deficiencies are unlikely to arise specifically from the consumption of browse.

In the dry season, browse leaves and fruits often have higher protein and mineral contents than available grasses, and provide valuable supplements for animals at this time. However, whilst most tropical tree legumes have lower cell wall contents than grasses and herbaceous legumes, the cell walls are more highly lignified and are often of lower digestibility than herbaceous species (Norton and Poppi, 1995). There are also differences between species in cell wall lignification, for example, *A. senegal* and *A. hockii* have low and constant proportion of lignin in their cell wall (0.22 to 0.23 g/kg) when compared with *A. tortilis* and *A. gerrardii* which have more highly lignified cell walls (0.32 to 0.38 g/kg) and which increases with leaf age (Pellew, 1980). Table 2 shows the ranges of values reported for the crude protein, fibre, condensed tannin and *in vivo* dry matter digestibilities for some arid and semi-arid zone browse species. Although the protein content of browse generally exceeds that required for the maintenance of ruminal fermentation, the availability of protein (and cell wall components) is decreased in the presence of tannins.

Nutritive value and animal production. The nutritive value of a feed is measured by its ability to deliver nutrients to an animal for maintenance and growth, and in the absence of toxic factors, is a function of feed digestibility and voluntary feed consumption. It is now recognised that unlike grasses, there is often little relationship between feed intake and digestibility, thus, the nutritive value of browse can only be accurately determined by feeding trials (Norton, 1994). Browse leaves and fruits are often more valuable as a supplement to low quality feeds than as a sole feed due to their high nutrient contents and limited supply. Table 2 shows results from the literature where the supplementary value of various browse trees has been investigated.

Mulga (*Acacia aneura*) occurs over a wide geographical range in Australia, and lopped branches provide a valuable drought fodder for sheep and cattle. Declining reserves of mulga have prompted management studies aimed at optimising use and improving nutritive value. As shown in Table 3, mulga leaves alone provide more digestible nutrients than sorghum hay, and although adding mulga leaves to sorghum hay increases digestible intake by 22%, urea added to sorghum hay increased digestible intake by 68%. Mulga leaf proteins are bound to condensed tannins and rendered unavailable for rumen fermentation and subsequent absorption in the lower digestive tract. The nutritive value of mulga may be improved by the provision of supplements of N, S and P (Hoey et al., 1976; McMeniman, 1976), or by treatments which inhibit the action of tannins. Polyethylene glycol (PEG) has been used to bind feed tannins and significantly improve weight gains and wool growth of sheep fed mulga (Pritchard et al., 1988). Urea has also been reported to deactivate tannins and there is a possibility that tanninase enzymes may be secreted by some ruminal micro-organsisms and these may be used in future to inoculate animals consuming high tannin feeds.

In many parts of Africa and India, fallen leaf and pods of Acacia species are valuable feeds for ruminants. Table 3 shows results from two trials where the leaves and pods were used to supplement (40% of diet) low quality hay for sheep. *A. tortilis* pods and *A. seyal* leaves proved to be the most valuable supplements in these studies, with *A. nilotica* and *Faidherbia albida* also promoting modest weight gains in sheep. *A. sieberianna* varied in its value, and was possibly related to varying levels of hydrolysable tannins and/or cyanogens (Tanner et al., 1990). It would also seem that not only are there significant differences between Acacia species in nutritive value, but there are also differences within species from different environments. These differences are worthy of further study.

In India, tree leaves are often harvested and stored for later use. Both *Prosopis cineraria* and *Ziziphus nummularia* leaves alone used as concentrate feed promoted weight gains in kids, but resulted in weight losses in lambs. Concentrate diets containing 50-75% prosopis leaves maximised weight gains in kids, but increasing levels of ziziphus beyond 20% resulted in decreased weight gains in lambs given concentrate diets. *Prosopis juliflora* pod flour can fully replace wheat bran in poultry rations, and *P. tamarugo* is being promoted as a salt tolerant species good for rehabilitation of degraded ecosystems in

Chile. However, the leaves have very high tannin contents, and sheep lose weight when offered a diet of leaf and fruit (Riveros, 1992). *Z. nummularia* and *P. cineraria* have comparatively high condensed tannin contents (105-130 g/kg DM), but the tannins of prosopis inhibit cell wall digestibility to a greater extent than those of ziziphus (Kumar and D'Mello, 1995). These results again suggest that tannin concentrations are not necessarily a reliable guide to effects on nutritive value.

The value of leucaena as a supplement for cattle, sheep and goats is well known (Wahyuni et al., 1982; ILCA, 1987; Norton et al., 1992). *L. leucocephala* contains moderate concentrations (40-70 g/kg DM) of condensed tannins which appear to be effective in protecting protein from excessive degradation in the rumen. However, other leucaena species with greater drought tolerance and insect pest resistance have higher tannin content (80-110 g/kg DM) and appear to be of lower nutritive value (Norton et al., 1995), and care needs to be taken that selection for adaptation to the environment is not at the expense of nutritive value. Due to the high mimosine contents, optimum use of *Leucaena leucocephala* as a supplement to low quality straw was found when leucaena represnted only 33% of the diet.

Anti-nutritive and aversive factors. Fodder tree leaves and fruits often contain anti-nutritional factors, and the scope, nature and action of tannins, cyanogens, saponins, alkaloids and non-protein amino acids has been extensively reviewed recently (Kumar and D'Mello, 1995). The previous section considered tannins as a major factor affecting the nutritive value of many arid zone species, and the need for better characterisation of condensed tannins was noted. A clear distinction needs to be made between hydrolysable tannins (esters of gallic acid), condensed tannins (proanthocyanidins) and other phenolic compounds (lignin, sterols, etc.) in browse leaves and fruits. Hydrolysable tannins are usually toxic and have effects over a short period of time. Condensed tannins, depending on nature and concentration, may be beneficial or detrimental. Both condensed tannins and/or high levels of phenolic compounds may depress intake through effects on feeding behaviour. In some Acacia species, soluble phenolics can account for 37-40% of organic matter (Tanner et al., 1990), suggesting that condensed tannins may only be part of the problem in feeding these leaves to ruminants. Lyon et al. (1988) found that for six species of Prosopis, in-vitro digestibility of leaf decreased as leaf phenolic acid content increased. Tagasaste contains no condensed or hydrolysable tannins, and the high phenolic content of its leaves has been associated with seasonal changes in palatability. Similarly, *Gliricidia sepium* has only low concentrations of condensed tannin which are inactivated by drying (Ahn et al., 1989) but residual phenolic compounds are suspected of causing the variable acceptance of dried gliricidia by ruminants. Wilting or drying decreases phenolic content and is often prescribed to increase the palatability of poorly accepted browse.

The selection of fodder trees for the arid and semi-arid zones is determined, firstly on agronomic criteria (survival, productivity) and secondly on nutritive value. Well adapted species have protective mechanisms such as fibrous highly lignified leaves for water conservation, and high phenolic and alkaloid contents as herbivore deterrents. These characteristics are associated with poor palatability and low nutritive value, and presents farmers and scientists with the problem of optimising the use of these often scarce resources. Management options to improve and optimise utilisation by combining with other forages and using specific supplements to overcome deficiencies and toxicities include harvesting and treatment of browse leaves and fruits. As knowledge accumulates on the nutritional limitations of browse, and as the range of species tested increases, new provenances of existing species may be developed to overcome these limitations.

FODDER TREE AND SHRUB INTEGRATION INTO AGRICULTURALSYSTEMS

Integration of trees and shrubs into existing farming and land use systems has been advocated by several workers and has been an important area of research in the last decade (Le Houérou, 1980; Torres, 1983; Atta-Krah, 1993). Under this section various traditional and improved agroforestry systems of fodder production, management and utilization are discussed.

The term agroforestry in this paper implies land use systems in which shrubs/trees/crops and livestock are integrated in space and time to improve and sustain land productivity. The growing interest in the use of leguminous trees and shrubs in various agroforestry systems is due to their distinct and desirable characteristics. Some of which include:

- fast growth
- high quality forage for livestock
- nitrogen rich mulch for crop production
- easy management and persistence under pruning, cutting and grazing conditions.

Fodder tree integration into crop and pasture production systems would improve the quality and quantity of fodder in the wet and dry seasons leading to improved animal production. The success and degree of tree integration into agropastoral systems through agroforestry depends on several factors such as climatic and environmental conditions (amount and reliability of rainfall), soil fertility factors, compatibility of the associated crops and management of components for sustainability. The arid and semi-arid zones, by virtue of the importance of livestock, depend greatly on browse, however, the low rainfall and the harsh environmental conditions pose a great challenge to tree growing in these areas. Some potential agroforestry systems and technologies which could integrate leguminous fodder trees and shrubs are discussed below.

Improved silvopastoral systems. Silvopastoral systems involve both intensive and extensive management basically as a function of tree density and arrangement. In extensive pasture systems, browse species are planted in scattered widely spaced arrangements in already established grass or legume pastures. Fodder trees are lopped periodically for grazing by animals. In addition to providing fodder, leguminous browse trees also provide shade for livestock and influence the productivity of the associated grasses. For example the productivity of *Faidherbia albida* trees have been observed to double the yield of *Pennisetum* species in the Sahel region and further increased the green vegetative period by 3-4 weeks (Bille, 1980). The yield of buffel grass (*Cenchrus ciliaris*) under eucalyptus (*Eucalyptus populnea*) in semi-arid environment in Queensland was reported to be much higher under the tree than in pure stands (Christie, 1975).

In more intensive grazing areas of Australia, Southern Africa and South America, tree legumes have been integrated into improved grass pastures to increase fodder quality and carrying capacities. In Queensland alone, 20,000 hectares of improved pastures have been sown to *Leucaena leucocephala*. The leucaena is often sown in wide spaced rows of 4-10 m apart and an improved grass such as *Chloris gayana*, *Cenhrus ciliaris*, *Panicum maximum* or *Bracharia decumbens* sown between the leucaena rows (Wildin, 1981).

Significant increases in stocking rate up to 3-4 animals per hectare and live weight gains of up to 300 kg/ha/head/year have been reported in this system (Jones, 1994). Other tree legume species under evaluation in this system include *Albizia chinensis, Calliandra calothyrsus, Leucaena diversifolia, Tipuana tipu* and *Chamaecytisus palmensis*. In a similar trial in the semi-arid areas of North Western Tanzania, good survival rates (80-90%) and biomass production (2.5 tonnes/ha) have been obtained in two year old hedgerows of *Leucaena leucocephala, Gliricidia sepium and Acacia angustissima* (Otsyina et al., 1996).

Fodder Banks. Fodder banks are practically intensive feed gardens of leguminous fodder trees and/or grasses and herbaceous legumes planted at high densities and managed to provide fodder either on a continuous basis or for particular periods such as the dry season (Mohamed Saleem et al., 1986; Atta-Krah and Raynolds, 1989). Fodder banks have been designed for more humid and sub-humid tropics, however, the concept has good relevance to the arid and semi-arid zones where rainfall is adequate to support plant growth for at least two months of the year. Fodder banks can be grazed directly by livestock or in used cut and carry systems where stock numbers are low. Very often fodder bank grazing is deferred to the dry seasons.

Alley Farming. Alley farming or hedgerow intercropping is a system in which leguminous trees are grown in rows of 4-8m apart on croplands and food crop cultivation is done in the alleys between the hedges (Atta-krah, 1993). In alley farming, trees are pruned periodically to provide mulch and green manure to maintain soil fertility. Alternatively, alley farming can be managed to provide fodder. The system is managed intensively by frequent pruning (cut and carry system) or as a grazing system (Sunberg, 1985). The alley farming system, especially with leucaena for maintenance of crop production has been found to be unsuitable for arid and semi-arid areas below 1000 mm rainfall. However, fodder hedgerows can be intercropped with herbaceous forage legumes or grasses in rotation with crops to meet fodder and food production needs of small-holders farmers. Fodder hedgerow systems in rotation with herbaceous fodder legumes seem to hold promise for livestock production, especially in the semi-arid sedentary agropastoral systems. Suitability of species and appropriate management systems will need to be developed for these environments. Other suitable niches for fodder production include farm boundaries and homegardens.

CULTURE AND MANAGEMENT OF FODDER TREES.

Plant establishment and management for sustained productivity are major challenges to browse production and utilization in the arid and semi-arid lands. Generally, most tree legumes can be propagated by seed. However, due to the slow growth of tree seedlings, especially in the arid and semi-arid environments, they are more susceptible to weed competition and grazing by domestic livestock wildlife. Tree legumes are often raised in nurseries before transplanting to the field. Initial seedling growth and vigour greatly influence subsequent growth and production. Seedling vigour of tree legumes can be improved by the application of nutrients such as phosphorus, nitrogen and *Rhizobium* specific to the tree species.

Associations between tree legume roots and vesicular arbuscular mycorrhizae (VAM) have been shown to be important for tree growth, nodulation and phosphorus. Other nutrients important for tree legume growth and vigour include P, Ca, S and micro-nutrients. Important requirements for improved growth and establishment of tree legume seedlings include:

- Selection of genotypes with more vigorous seedling growth.
- Inoculation with appropriate *Rhizobium* strains.
- Careful attention to weed control.
- The use of fertilizers or manures to correct nutrient deficiency especially that of phosphorus.

Cutting time, height and frequency. Fodder production and quality are influenced by cutting management (time of first cutting, cutting height and frequency). Studies by Ella et al. (1991) on calliandra, leucaena and gliricidia in Australia have clearly shown that real size or the period before first cutting was positively related to leaf biomass yields at subsequent harvests. The yield differences between older and younger trees was related to more carbohydrate reserves and presumably larger and deeper root systems.

Cutting height and frequency greatly influence wood and leaf yields in tree legumes. Generally, tree foliage biomass yields increase with height of cutting up to 2 m. Also, longer cutting intervals resulted in greater biomass yields (Horne et al.1986). Cutting frequency, also influences quality and quantity of fodder for supplementary feeding of livestock in the dry seasons. In the dry miombo woodlands of Tabora in western Tanzania, Karachi (1991) reported significantly higher quality and amount of fodder produced from leucaena provenances cut in April, at least two months before the onset of the dry season. This is particularly important in the dry areas where most tree legumes lose their leaves under water stress. Proper timing of cutting is critical to maintain nutritious fodder supply.

PESTS AND DISEASES

Various diseases and pests are known to attack different tree legumes both in their natural range and in introduced systems. Some of the most important pests include aphids, grasshoppers, scale insects, viruses, bacteria and termites. Pests and diseases cause considerable economic damage to tree legumes. In Africa, termites are one of the most devastating pests which limit establishment and growth of trees in the arid and semi-arid lands. Observations on tree survival on both farmlands and rangelands in northeastern Tanzania (Otsyina et al., 1996) attributed 90% of seedling mortality to termite attacks alone. In recent times, the leucaena psyllid *(Heteropsylla cubana)* has been the insect of greatest concern to L*eucaena leucocephala* in Asia, Australia and Africa. Prior to 1984, very little attention was given to this insect in its natural range in Mexico and Central America. Between 1984 and 1992 the psyllid had spread from its native range across the pacific Islands to Asia and finally to Africa (NFTA, 1987; Van Den Beldt and Napompeth, 1992). The psyllid damage on leucaena has greatly affected livestock and fodder enterprises in tropical Australia, Africa and Asia destroying large tracts of leucaena plantings on farms and rangelands (Heydon and Affonso, 1991). Several control measures have now been introduced to arrest the situation. These include: screening and selection of naturally resistant species and provenances, breeding for resistance and biological control using introduced natural enemies. The psyllid experience has, however, taught us several lessons, for example to avoid over-dependence on single species in fodder systems.

CONSTRAINTS LIMITING TREE PRODUCTION AND UTILISATION

Although the role and importance of tree legumes in arid and semi-arid areas have been widely recognised, especially, for livestock feed supplementation during the dry seasons, this potential has not been effectively exploited due to several agronomic, social and technical problems and limitations. Some of the most important limitations include:

1. The narrow range of proven tree species in cultivation, especially in the arid and semi-arid zones. A wide range of germplasm has been identified but only a few species have been adequately studied for use in existing and improved agro-silvopastoral systems.

2. Lack of knowledge on propagation, establishment and management of various browse species.

3. Effective management of browse trees in the natural rangelands is influenced by land and tree tenure practices. Most arid land ranges are communally owned and thus no one takes responsibility for their management. This often leads to gross misuse and eventual depletion of trees.

4. Poor knowledge of anti-nutritional substances which limit efficiency of use of leguminous browse. This knowledge has been limited only to a few species such as leucaena. There is a need to broaden the scope of research in this area to include a wider range of useful browse species.

5. Incidences of pests and diseases in leguminous browse have become a major concern in agroforestry. The leucaena psyllid and the mesoplatys beetle in sesbania are good examples.This is probably due to poor species diversification.

RESEARCH AND DEVELOPMENT NEEDS

In order to promote the use of leguminous browse species in rangelands, pasture and mixed cropping systems in the arid and semi-arid regions, there is great need for research into aspects of species domestication and evaluation for specific land-use systems, improved and appropriate propagation methods and management techniques to optimise utilization of these trees. Other research issues include integrated pest and disease management, the value and contribution of fodder trees to livestock productivity and the social and economic impact analysis of fodder improvement practices need to be thoroughly evaluated.

Research should focus specifically on the following:

1. Domestication and evaluation of fodder tree species adapted to the harsh environmental conditions in the arid and semi-arid environments. Effective propagation and establishment methods need to be evaluated for pasture and rangelands conditions.

2. Appropriate tree management techniques such as time of cutting and pruning to promote fodder (leaf and pod) production and reduce anti-nutritional effects. These should be evaluated for potential species.

3. The contribution of fodder trees to livestock nutrition and production especially the manipulation of ruminant flora and fauna to more efficiently utilise browse in rangelands, needs more research.

4. Effective methods of tree introduction and integration into agricultural systems need to be developed.

5. Economic analysis of fodder production and browse supplementation systems need to be evaluated over a wide range of conditions and production systems.

6. Species screening and evaluation for suitable species with special reference to production, quantity and anti-nutritional factors need to be done.

7. The need to create awareness on the multiple benefits and role of fodder trees in pasture and cropping systems among pastoral people in arid and semi-arid regions, should be coupled with training and extension on sustainable use of the valuable tree resources.

CONCLUSION

Arid and semi-arid lands throughout the world are endowed with indigenous and adapted introduced fodder trees and shrubs which play an important role in livestock feeding; by virture of their high crude protein and mineral contents, soil fertility regeneration and environmental rehabilitation. Traditional management systems coupled with high grazing pressures and inefficient land use policies have led to a gradual disappearance of desirable fodder species. This situation is further aggravated by prolonged droughts.

There is increasing awareness of the use of fodder legumes in systematic agroforestry systems to improve both fodder quantity and quality and to provide other products and services such as fuelwood and soil fertility enhancement. The use of tree legumes is, however, influenced by incidences of diseases and pests, anti-nutritional factors which limit their usefulness as fodder and poor knowledge of the culture and management of tree and shrubs in various farming systems. This calls for increased research to address these issues before tree can be effectively integrated into agricultural systems.

Research and development efforts should be intensified to evaluate the existing germplasm in order to broaden the resource base. More information is needed on compatibility of grass and tree species in potential tree/pasture systems and management options to optimise fodder production of all components. It is recommended that more effort be made to expand the use of more researched and adapted species in existing rangeland and farming systems. This should, however, consider farmers' needs and other socio-economic factors inherent in farmers' production systems.

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Table 1
Foliage and fruit production of selected fodder trees in west Africa.

Species	Country	Rainfall (mm)	Leaves (g DM)/tree	Fruit/ pods (g DM)
Acacia senegal	Senegal	250	3840	1340
Balanites agyptiacum	Senegal	250	1850	1030
Adansonia digitata	Senegal	250	22000	2400
Comiphora africana	Senegal	250	290	80
Acacia laeta	B/Faso	440	2500	-
Acacia seyal	B/Faso	440	1700	-
Acacia tortilis	B/Faso	440	700	-
Balanites aegypticum	Mali	600	2500	-
Acacia albida	Mali	600	3100	-
Ptero carphus lucens	Mali	600	3980	-
Ziziphus mauritiana	Mali	600	360	-

Source: Bille, 1980; Dicko and Sikena, 1992

Table 2
Crude protein, crude fibre, condensed tannin and *in vivo* digestibility of browse leaves and fruits commonly fed in the arid and semi-arid zones.

Species	Plant part	Crude protein (g/kg DM)	Crude fibre (g/kg DM)	Condensed tannins* (g/kg DM)	*in vivo* dry matter digestibility (g/kg DM)
Acacia					
A. aneura	phyllode	92-203	238-366	44-70	0.44-0.63
A. cyanophylla	leaf	112-212	192-241	40-70	0.51-0.53
A. nilotica	leaf	112-167	104±29	76±10 (89.2)[2]	0.69±0.05
	pod	88-112	154±59	55±15	0.66
A. senegal	leaf	141-336	155-292	(4.1)[2]	-
	pod	111-204	112-292	-	-
A. seyal	leaf	111-293	84-228	(1.6-3.7)[2]	-
	pod	171-213	186-216	-	-
A.sieberiana	leaf	123-158	236-292	(37.4)[2]	-
	pod	98-116	220-247	-	0.54
A. tortilis	leaf	103-210	251-383	40-61	-
	pod	104-178	175-259-	0.54	
Prosopis					
P. juliflora	leaf	142-222	142-222	-	-
	fruit	117-120	117-120	-	-
P. cineraria	leaf	119-154	99-316	105[1]	0.39±0.06
P. tamarugo	leaf	90-357	134-203	105	0.32
	fruit	115-133	133-315	0.55	
Albizia lebbek	leaf	181-240	265-377	*ND*	0.43-0.64
Faidherbia albida	leaf	171-197	124-215	-	0.53
	pods	56-143	144-296	-	0.58
Chamaecytisus palmensis	leaf	164-264	220	ND	0.60-0.76
Leucaena leucocephala	leaf	203-268	183	14-67	0.51-0.68
Ziziphus nummularia	leaf	141	170	130[1]	0.41
Ziziphus mauritania	leaf	111-163	145-206	-	0.53

Sources: Le Houerou, 1980; Norton, 1994; Carter, 1994; Speedy and Pugliese, 1992; Gohl, 1981.
[1.] Kumar and D'Mello, 1995 (condensed tannin standard). 2. Tanner et al., 1990.
* Tannic acid equivalents. ND not detected.

Table 3
Feeding values of selected tree leaves and fruits for sheep and goats

Browse species	Basal diet	% browse in diet	Dry matter intake		Diet digestibility (g/kg)	Livewt change (g/d)
			g/kg/d	g/d		
Acacia phyllodes for sheep[1]						
A. aneura	sorghum hay	0	15		0.39	-
		0 + urea	28		0.35	-
		13	18		0.32	-
		27	23		0.31	-
		42	23		0.28	-
	nil	100	21		0.47	-
Acacia browse for sheep[2]						
Eragrostis teff	teff hay	0 + urea		480	0.51	10
A. cyanophylla (phyllodes)	35		488	0.41	-14	
A. sieberiana (pods)	42		464	0.54	26	
A. seyal (leaves)	40		478	0.54	45	
Acacia pods for sheep[3]						
A. nilotica	maize stover	37		551	-	16
A. sieberiana		40		531	-	0
A. tortilis		32		636	-	32
Faidherbia albida		33		595	-	22
Prosopis leaf for goats[4]						
P. cineraria	concentrates	25		619	-	94
		50		732	-	100
		75		779	-	81
	nil	100[5]		672	-	46
	nil (sheep)	100[5]		539	-	-28
Ziziphus leaf for sheep[6]						
Z. nummularia	concentrates	20	-	648	-	37
		50	-	654	-	24
		80	-	548	-	-3
	nil	100[7]	16	632	0.41	-
	nil (goats)	100[7]	33	1103	0.46	-
Leucaena leaf for goats[8]						
L. leucocephala	barley straw	0 + urea	17.9		0.48	51
		33	29.5		0.61	71
		65	30.9		0.57	66
		100	27.0		0.62	46

Source:
1. Goodchild and McMeniman, 1986
2. Reed et al., 1990
3. ILCA, 1988
4. Parthasarathy, 1986
5. Singh and Bhatia, 1982
6. Bhatia and Ratan, 1981
7. Singh, 1981
8. Norton et al., 1992.