SHRUBS AND TREE FODDERS OR FARM ANIMALS

PROCEEDINGS OF A WORKSHOP IN DENPASAR, INDONESIA, 24 – 29 JULY 1989
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Shrubs and tree fodders for farm animals

Proceedings of a workshop in Denpasar, Indonesia, 24–29 July 1989

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Abstract

This publication presents the results of an international meeting held in Denpasar, Bali, Indonesia, 24–29 July 1989, that focused on the use of shrubs and tree fodders by farm animals. Through 26 papers, the workshop addressed feed-resource availability, use by ruminants and nonruminants, processing methodology, economics, and development issues. These aspects and the current knowledge on shrubs and tree fodders were further highlighted by country case studies detailing prevailing situations and policy matters. A special session was held to discuss the successful development and results achieved in the three-strata forage system in Indonesia. The workshop concluded with important working group discussions on the priorities for further research and development, and on the potential for the wider use of shrubs and tree fodders in the developing world.

Résumé

Cette publication présente les résultats d’une rencontre internationale tenue à Denpasar, Bali, Indonésie, du 24 au 29 juillet 1989 et qui a porté sur l’utilisation des arbustes et fourrages végétaux par les animaux d’élevage. Les 26 communications qui y ont été présentées traitaient de la disponibilité des ressources alimentaires pour les animaux, de leur utilisation par les ruminants et les non-ruminants, des méthodes de transformation, des aspects économiques et des questions du développement. Ces sujets et les connaissances actuelles sur les arbustes et les fourrages végétaux ont ensuite été étudiés plus à fond dans le cadre d’études de cas de divers pays exposant les circonstances particulières de chacun et les questions liées aux politiques. Une séance spéciale a porté sur la mise en place et les résultats des systèmes de production de fourrages végétaux en trois strates en Indonésie. L’atelier s’est terminé par d’importantes discussions des groupes de travail sur les priorités de recherche et de développement pour l’avenir et sur les possibilités d’utilisation élargie des arbustes et des fourrages végétaux dans les pays en développement.

Resumen

Esta publicación presenta los resultados de una reunión internacional celebrada en Denpasar, Bali, Indonesia, del 24 al 29 de julio de 1989, y la cual centró su atención en la utilización de forrajes elaborados a partir de arbustos y árboles para alimentar a animales de granjas. En 26 trabajos presentados al seminario, los participantes abordaron temas tales como la disponibilidad de recursos alimentarios y la utilización de los mismos por rumiantes y no rumiantes, metodologías de procesamiento y cuestiones de economía y desarrollo. Estos aspectos y el conocimiento que se tiene actualmente sobre los forrajes de arbustos y árboles se vieron subrayados aún más por estudios de casos por países en los que se detallaron situaciones existentes y cuestiones de políticas. Se celebró una sesión especial para discutir el desarrollo y resultados exitosos alcanzados en Indonesia con el sistema de forraje de tres niveles. El taller concluyó con importantes discusiones de los grupos de trabajo sobre las prioridades existentes en el campo de la investigación y el desarrollo y sobre el potencial que encierra la amplia utilización de arbustos y árboles en el mundo en desarrollo.
## Contents

**Foreword** ........................................................... vii  
**Acknowledgments** ................................................. ix  
**Introduction** .......................................................... xi  

### Session I: The Resources

- The diversity and potential value of shrubs and tree fodders
  - G.J. Blair .................................................. 2  
- Shrubs and tree fodders in farming systems in Asia
  - A. Topark-Ngarm ........................................... 12  
- Major characteristics, agronomic features, and nutritional value of shrubs and tree fodders
  - D.A. Ivory ........................................... 22  
- Discussion ...................................................... 39  

### Session II: Use by Farm Animals

- The use of shrubs and tree fodders by ruminants
  - C. Devendra .................................................. 42  
- The use of shrubs and tree fodders by nonruminants
  - P.D. Limcangco-Lopez ...................................... 61  
- Toxic factors and problems: methods of alleviating them in animals
  - J.B. Lowry .................................................. 76  
- Discussion ...................................................... 89  

### Session III: The Three-Strata Forage System

- The concept and development of the three-strata forage system
  - I.M. Nitis, K. Lana, W. Sukanten, M. Suarna, and S. Putra ........ 92  
- Research protocols appropriate to the development of methodology for the three-strata forage system
  - K. Lana, I.M. Nitis, M. Suarna, S. Putra, and W. Sukanten ........ 103  
- Socioeconomic aspects of the three-strata forage system in Bali
  - I.W. Arga .................................................. 118  
- Communication aspects and research extension linkages of the three-strata forage system in Bali
  - N.K. Nuraini .................................................. 130  
- Discussion ...................................................... 136
Session IV: Country Case Studies

<table>
<thead>
<tr>
<th>Availability and use of fodder shrubs and trees in tropical Africa</th>
<th>A.N. Atta-Krah</th>
<th>140</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential of legume tree fodders as animal feed in Central America</td>
<td>D. Pezo, M. Kass, J. Benavides, F. Romero, and C. Chaves</td>
<td>163</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in Pakistan</td>
<td>M. Akram, S.H. Hanjra, M.A. Qazi, and J.A. Bhatti</td>
<td>176</td>
</tr>
<tr>
<td>Agrosilvipasture systems in India</td>
<td>P. Singh</td>
<td>183</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in India</td>
<td>G.V. Raghavan</td>
<td>196</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in Nepal</td>
<td>N.P. Joshi and S.B. Singh</td>
<td>211</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in Bangladesh</td>
<td>M. Saadullah</td>
<td>221</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in Sri Lanka</td>
<td>A.S.B. Rajaguru</td>
<td>237</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in Thailand</td>
<td>M. Wanapat</td>
<td>244</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in Malaysia</td>
<td>Wong C.C.</td>
<td>255</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in Indonesia</td>
<td>M. Rangkuti, M.E. Siregar, and A. Roesyat</td>
<td>266</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in the Philippines</td>
<td>L.T. Trung</td>
<td>279</td>
</tr>
<tr>
<td>Availability and use of shrubs and tree fodders in China</td>
<td>Xu Zaichun</td>
<td>295</td>
</tr>
<tr>
<td>Discussion</td>
<td></td>
<td>303</td>
</tr>
</tbody>
</table>

Session V: Processing, Methodology, and Economics

<table>
<thead>
<tr>
<th>Opportunities for processing and using shrubs and tree fodders</th>
<th>M.R. Reddy</th>
<th>308</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development and evaluation of agroforestry systems for fodder production</td>
<td>A.N. Abd. Ghani and K. Awang</td>
<td>319</td>
</tr>
<tr>
<td>Economic aspects of using shrubs and tree fodders to feed farm animals</td>
<td>P. Amir</td>
<td>331</td>
</tr>
<tr>
<td>Discussion</td>
<td></td>
<td>340</td>
</tr>
</tbody>
</table>

Conclusions and Recommendations | 341 |

Participants | 347 |
Major characteristics, agronomic features, and nutritional value of shrubs and tree fodders

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Abstract — Shrubs and trees, particularly leguminous species, are increasingly being used to provide a strategic source of high-quality forage for supplementary feeding to farm animals. This paper reviews research aimed at identifying suitable species for forage and other multipurpose uses. Research has concentrated on evaluating species adaptation to various climatic and edaphic conditions, defining optimum cutting and grazing strategies, defining fertilizer requirements, developing systems for the use of trees as forage and for other uses, and assessing the nutritive or feeding value of tree and shrub species. Areas for further research on these various aspects are suggested.

Résumé — Les arbustes et les arbres, particulièrement ceux des espèces fourragères, s'emploient de plus en plus comme source stratégique de fourrage de haute qualité à donner au bétail en complément de sa ration alimentaire. L'auteur passe en revue la recherche visant à trouver des espèces qui pourraient, entre autres usages, servir de fourrage. Les chercheurs se sont surtout attardés à évaluer l'adaptation des espèces aux diverses conditions climatiques et édaphiques, à définir les stratégies optimales de rabattage et de pâturage, à établir la fertilisation requise, à élaborer des systèmes dans lesquels les arbres servent de fourrage et ont d'autres usages également et à évaluer la valeur nutritive des espèces arbustives et ligneuses. Il suggère dans quelle direction pousser la recherche sur tous ces sujets.

Resumen — Los arbustos y árboles, particularmente las especies leguminosas, se están utilizando cada vez más como fuente estratégica de forraje de alta calidad, para complementar la alimentación de animales de granja. Este trabajo analiza la investigación destinada a identificar especies apropiadas para forraje y para otras aplicaciones múltiples. Se ha centrado la investigación en: evaluar la adaptación de las especies a diversas condiciones climáticas y edáficas, definir las formas óptimas de pastoreo y corte, definir las necesidades de fertilizantes, elaborar sistemas para el uso de árboles como forraje y para otros usos, y evaluar el valor nutritivo o alimenticio de especies de rboles y arbustos. Se hacen sugerencias con respecto a sectores donde se debe efectuar una mayor investigación sobre estos diversos aspectos.

The leaves, pods, seeds, and edible twigs of shrubs and trees have been used as supplementary feed for domesticated animals for centuries. This feed source has been used by browsing animals or through the deliberate cutting of shrubs and trees and supply of forage to free-grazing, tethered, or confined animals. The use of shrubs and trees as a source of forage for domesticated animals has been mostly
opportunistic, based on farmers' knowledge that some indigenous shrubs or trees are palatable and have a reasonable or good nutritive value for livestock, particularly during periods of feed shortage. It is only recently that there has been a deliberate policy to plant selected trees and shrubs around houses or on farms to supply feed to livestock and improve animal productivity throughout the year. Usually, the species chosen have other desirable, multipurpose characteristics.

In this context, there is a need to better understand the management, agronomic features, and nutritive value of these shrubs and trees so that the production and use of feed can be more efficient. There is also a need to identify shrub and tree species that are able to maintain a high level of productivity in intensive production systems. The development of intensive uses of shrub and tree forages for animal production is relatively recent in comparison to intensive forms of animal production based on grass and herbaceous legume species. Thus, the scientific knowledge on agronomic factors that affect the productivity of tree and shrub forages is less well known and confined to relatively few species. In addition, the species that have received the most attention are leguminous species, which have shown an ability to remain productive under repeated cutting at frequent intervals, to have good nutritive value, and to be reasonably well eaten by animals. The information provided in this paper will, therefore, refer mainly to comparatively few leguminous shrubs or trees that are commonly used or have a potential for use in more intensive production systems.

Species

There are many desirable agronomic characteristics of shrubs and trees that are relevant to their potential as animal feed. In general, the more important or desirable agronomic features of a species are that it

- be reasonably easily and reliably established,
- exhibit a good competitive ability against weeds (particularly during establishment),
- remain highly productive under repeated cutting or grazing and browsing,
- be well adapted to the particular climatic and edaphic features of the environment,
- require no or little fertilizer,
- be resistant to local pests and diseases,
- have adequate seed production or be reliably vegetatively propagated, and
- have a good nutritive value and reasonable palatability and acceptability to animals.

There has been considerable interest in the Asian region and, more recently, in Africa and tropical America in the selection and evaluation of shrub and tree species, that meet these criteria and have a potential for multipurpose use. Particular interest has been shown in leguminous species that have potential for wood and forage production, and green manuring on degraded or infertile land.
MacDicken (1988) — the better soils and environments are mostly used for cropping.

A wide range of tree species, both leguminous and nonleguminous, has been identified as suitable for feeding to animals in Africa (Le Houerou 1980), Australia (Turnbull 1986, 1987), India (Tejwani 1988), Indonesia (Ivory and Siregar 1984; Soedomo et al. 1986), Nepal (Sapkota 1988), the Philippines (Hensleigh and Holloway 1988), and Thailand (Topark-Ngarm and Gutteridge 1986). Nonleguminous species have mainly been used where they are indigenous and have rarely, if ever, been deliberately planted as sources of forage for livestock. Leguminous trees have been preferred for planting; this may be because they can form an effective nitrogen-fixing capacity through rhizobial symbiosis; thus, these species do not require large inputs of nitrogen fertilizer to sustain high levels of production under repeated cutting. An additional advantage of leguminous species is their high protein content, which is usually the most deficient component of an animal’s diet. Thus, research has concentrated on the evaluation of suitable leguminous species and agronomic practices that maximize their productivity.

Brewbaker (1986) has listed a wide range of leguminous tree species that can be used as animal feed. However, most research has been confined to a few species. Genera that have shown promise include *Acacia* (NAS 1979; Turnbull 1987), *Calliandra* (NAS 1983), *Desmodium*, *Gliricidia* (Chadhokar 1982; Falvey 1982; Withington et al. 1987), *Leucaena* (Pound and Martinez-Cairo 1983; NAS 1984), *Sesbania* (Wood and Larkens 1987), and *Prosopis* (NAS 1979). *Leucaena* has received the most attention and is the most widely planted tree species for animal feed; however, it is ill-adapted to acid soils, particularly when associated with high exchangeable aluminium and manganese and low exchangeable calcium, and has suffered recently from severe attacks by the *Leucaena psyllid*, *Heteropsylla cubana*. Because adverse soil conditions are prevalent in Asia, there has been a more widespread evaluation of alternative tree species (Ivory and Siregar 1984; Panjaitan and Blair 1984; Catchpoole et al. 1985; Ivory et al. 1986; Topark-Ngarm and Gutteridge 1986; Bray et al. 1988; Ella 1988; Blair et al. 1989).

**Establishment**

Shrubs and trees are usually propagated from seed but some species can be reliably propagated from stem cuttings. The seeds of leguminous species usually have a hard seed coat that requires some form of treatment for the imbibition of water and germination. This can include treatment with hot water, chemical agents (acids and alkalis), or mechanical scarification. Some variation occurs between species in the need for scarification and in the most effective form of treatment.

One of the major problems in the establishment of shrubs and trees is competition from weeds. Seedling growth rate is often slow, resulting in high plant mortality. Therefore, there are considerable advantages in germinating seed and raising young plants in a nursery before transplanting to the field. Although the costs are higher, a more vigorous plant can be produced through better nursery care and by using an appropriate strain of *Rhizobium* with leguminous species and a small amount of fertilizer. The trimming of shoots and roots at the time of transplanting reduces transpiration and stimulates root development (Pound and Martinez-Cairo 1983). Following transplanting, such a seedling is better able to
compete with weeds. In Asia, most animal producers are small-scale landholders and, therefore, are only interested in establishing small areas of trees for forage production. Local materials, such as bamboo, can be used to make a seedling tube at little cost to a smallholder. Where large areas are to be established, however, this procedure may be logistically and economically unfeasible. In such a situation, direct drilling into a prepared seedbed or into cultivated strips or rows are better than broadcast sowing.

Some species can be vegetatively propagated. *Gliricidia sepium* is usually established from stem cuttings. Studies on the effect of age, diameter, and length of stem cuttings; their position on the parent tree; type of cut; length of storage time; and depth of planting have shown that cuttings should be taken from stems that are at least 6 months old, 0.5-2.0 m in length, and from the lower part of the tree. Stem sections should be planted as soon as possible after cutting (Falvey 1982). Establishing cuttings in a nursery improves the survival rate of stem cuttings. The use of 2,4-dichlorophenoxy acetic acid (2,4-D) and naphthaleneacetic acid (NAA) may improve root development (Kempana and Chandrasekhariah 1959; Kempana et al. 1961; Chaudhuri 1965) and thereby improve survival. Stem cuttings can also be propagated by air layering with the aid of growth regulators (Kempana et al. 1961).

**Productivity and management**

Agronomic practices and management of shrubs and trees for forage production depend on the type of production system being employed. Major production systems include

- trees planted in single hedgerows (around houses or on the edges of cultivated fields),
- trees planted in multiple rows (widely spaced on uncultivated land with planting on the contour if the land is sloping, or more closely spaced in cultivated fields used for annual cropping (alley cropping) or in sown pasture areas), and
- intensive systems of production (more equal inter- and intra-planting distances at higher plant densities).

The most important factors affecting the productivity of these systems relate to plant density, planting configuration, cutting management (time of first cutting and height, frequency, and season of cutting), and fertilizer use. However, practices that maximize forage productivity may have to be modified to meet other particular purposes of using the trees and shrubs.

**Tree plant density**

The effect of tree density on leaf and wood yield has not been extensively studied. The majority of plant-spacing studies have been with *Leucaena*. In general, higher densities cause an increase in leaf and wood yield per unit area and a decrease in individual tree yield. Often, yield per unit area has been highest at the highest densities used in experiments and, therefore, few experiments have defined
optimum tree densities for maximizing yield per unit area. The highest yields of *Leucaena* have been obtained at 1 tree/m² (Castillo et al. 1979), 4 trees/m² (Pathak et al. 1980), 6 trees/m² (Savory and Breen 1979), 10 trees/m² (Relwani et al. 1982), and 13 trees/m². Ella (1988) studied the effect of tree density on leaf and wood yield in *Leucaena, Gliricidia, Sesbania,* and *Calliandra* and found that yield per unit area for all species was highest at the maximum density used, 4 trees/m². Hegde (1983) recommended an optimum planting density for *Leucaena* of 10-15 trees/m². It is apparent, therefore, that where high leaf yields per unit area are required, tree densities should be high. However, optimum tree densities will depend on rainfall and would be expected to be lower in less humid environments. Dense stands are only suitable for cut-and-carry systems, not for animal grazing.

High plant densities also reduce weed competition, but require much higher initial costs where seedlings are raised in nurseries for subsequent transplanting. Also, Obando (1987) found that *Gliricidia* was able to suppress the growth of weed species through allelopathic effects.

Ella (1988) found that wood yield per unit area of all species increased with increasing density; the leaf/stem ratio increased with increasing density in *Gliricidia* and *Calliandra,* but showed little difference in *Leucaena.* Differences in leaf and wood yields at different tree densities were observed mainly during the wet season; only small differences were observed in the dry season.

In hedgerow situations (e.g., in situ grazing or alley cropping), wide row spacings are required with higher intrarow densities. For *Gliricidia,* there appears to be equal compensation between lower tree productivity and increased plant density within the row over a range of spacing intervals. Kang and Reynolds (1986), as cited by Atta-Krah and Sumberg (1987), found that when within-row seedling spacings varied from 4 to 50 cm in an alley cropping system, the production of *Gliricidia* per unit row length remained relatively constant, although stem diameters were larger with increasing distance between plants.

There has been some research on the interaction between inter-and intra-row spacing on yield per unit area; however, no definitive experiments have examined the effect of plant spacing configurations on tree productivity at constant plant densities. It is, therefore, difficult to define optimum planting configurations and densities for intensive tree-production systems based on existing information.

**Cutting management**

Cutting management of tree and shrub legumes has been reviewed by Horne et al. (1986). The management factors that can affect tree productivity include age at first cutting, cutting height, cutting frequency, and season of cutting. Most research on cutting management has emphasized the effect of height and frequency of cutting, particularly with *Leucaena.*

**Age of first cutting**

It has been generally stated that where trees are older at first cutting, higher rates of regrowth will be observed. This would be expected because older trees would have thicker stems, more carbohydrate reserves, and a deeper, more extensive root system. Both Bhumibhamon et al. (1984) and Pathak et al. (1980) concluded that regrowth of *Leucaena* was positively related to basal diameter (stump size).
However, the optimum age of first cutting would be expected to interact with plant density. In addition, certain species (e.g., *Sesbania grandiflora*) have shown poor regrowth following cutting; this may be because the tree is too large at the first cutting.

Ella (1988) examined the effect of age of first cutting (13, 15, 17, 19 and 21 months from planting seed) on the productivity of widely spaced *Calliandra*, *Leucaena*, *Gliricidia*, and *Sesbania*. Increasing plant age at first cutting increased leaf and wood yields over five subsequent harvests in *Leucaena* and *Gliricidia*. A smaller increase was observed with *Calliandra* and there was a slight decrease in *Sesbania* yield. These species have very different rates of early growth and, therefore, were very different sizes at the imposed age of first cutting. Experiments need to be conducted on the time of first cutting in relation to the physiological age of individual species. Other factors requiring consideration are the degree of interaction between age of first cutting and plant density, and the initial loss in production from later cutting in relation to total long-term productivity.

**Cutting height**

Many studies have examined the effect of cutting height on *Leucaena* yield (Horne et al. 1986). The highest yields have been obtained from cutting heights of 5–300 cm. This is a wide range and suggests that cutting height has a considerable interaction with other factors — plant type or cultivar, plant density, cutting interval, and perhaps environmental factors. In experiments with other tree and shrub species, Siregar (1983) found the optimum cutting height for *Flemingia congesta* and *Calliandra calothyrsus* was 1 m; Lazier (1981) found that cutting heights of 25 and 50 cm for *Codariocalyx gyroides* gave higher yields than cutting at 5 cm; and Munegowda and Krishnamurthy (1984) found that a cutting height of 50 cm for *Sesbania aegyptica* (syn. *S. sesban*) gave higher yields than higher cutting heights.

Because of the conflicting results and for convenience, a standard cutting height of 1 m is often used to compare species performance (Catchpoole et al. 1985; Panjaitan 1988; Ella 1988; Bray et al. 1988). More research is required to better define optimum cutting heights for promising species in relation to species differences in plant growth habit and other management or cultural parameters.

**Cutting frequency**

Studies concerned with defining an optimum cutting interval for *Leucaena* have given extremely variable results (Horne et al. 1986). This is partly because of the strong interaction with other cultural factors as well as the problem that measured yield has referred both to leaf only and total (leaf + stem) yield. Generally, total yield is increased by longer cutting intervals; however, because of a general decrease in the leaf/stem ratio with longer cutting intervals, there is a less pronounced effect of cutting interval on leaf yield. Both Catchpoole et al. (1985) and Ella (1988) have studied the effect of cutting frequency on the leaf and stem production of *Leucaena*, *Calliandra*, *Gliricidia*, and *Sesbania*. Catchpoole et al. (1985) found that cutting frequency, which varied from 7 to 18 weeks, had little effect on leaf production, except for a slight decrease in *Calliandra*. Longer cutting intervals increased wood production and total yield in all species. At a range of lower plant densities, Ella (1988) found that increasing the cutting intervals from 6 to 12 weeks increased leaf yield in *Leucaena*, *Gliricidia*, and *Calliandra* in some
wet-season harvests; there was no effect on cutting frequency with *Sesbania*. Wood and total yields increased substantially in all species with longer cutting intervals.

It would seem, therefore, that cutting interval will be dictated by the purpose for using trees. In humid climates, where the major emphasis is on leaf production for feeding to animals, shorter cutting intervals (6-10 weeks) will be preferred — this will produce feed of a higher nutritive value with little loss in annual production. Where wood production is also an important output from the system, however, longer cutting intervals (10-14 weeks) would be appropriate. These regrowth intervals would approximate to regrowth heights of 1.5 m for leaf production or 2.5 m for leaf and wood production (Catchpoole et al. 1985). In less humid environments, longer cutting intervals may be required.

**Season of cutting**

Where there are distinct wet and dry seasons, some consideration has to be given to timing and type of defoliation. If the dry season is prolonged, this will be a more critical period for feed supply for animals. Timing of cutting may be determined by what can be done to use the surplus production in the wet season for dry-season feeding and dry-season management. Strategies for seasonal feed management may include carrying over leaves on trees into the dry season, with the successive cutting of branches during the dry season. This may be combined with more regular, complete defoliation during the wet season. Other possibilities include storing dried feed or producing silage (Kass and Rodriguez 1987) in the wet season. There has been little research on these aspects of feed utilization in relation to developing a complete cutting-management strategy.

In grazed situations, research has demonstrated the value of deferring the grazing of tree legumes (protein banks) for dry- or winter-season grazing (Jones 1979; Bamualim et al. 1980), when the protein component of the animal diet is more critically deficient.

**Fertilizer requirements**

There is little use of fertilizers for forage production in smallholder systems in Asia. This is because of the generally extensive nature of the forage-production systems used, the relatively high input cost of fertilizer, the relative unimportance of animal production compared with crop production, and a general lack of knowledge of the farmer about the nutrient requirements for forage production. Therefore, tree species that are adapted to the particular soil conditions have to be selected. It is known, for example, that *Leucaena* is only well adapted to more neutral or alkaline soils with high Ca availability. Therefore, it is more appropriate on acid soils, particularly soils with a low Ca supply and a high Al saturation, to select species that are well adapted to these conditions rather than use large quantities of lime to ameliorate the soil conditions so that they are suitable for *Leucaena*.

Despite the selection of generally better adapted species for particular soil conditions, specific nutrient deficiencies can still be identified. The use of N-fixing tree legumes removes the need for N fertilizer. However, Ca and P are often insufficient for tree growth on the infertile soils generally used for forage production. Most research on fertilizer requirements of tree legumes has been with
Leucaena. The largest growth responses in *Leucaena* have been obtained from Ca and P application, with some responses to S, and no responses to K (Pound and Martinez-Cairo 1983). On acid soils, significant responses have also been obtained from lime pelleting seeds and fertilizer application of P, S, Ca, and Mo at planting. Where trees are planted in rows, banding of P is more efficient than broadcast application and on acid soils rock phosphate will provide a cheaper, longer-term supply of P than superphosphate.

The application of fertilizer at planting will enhance the establishment and efficiency of the *Rhizobium* symbiosis. More rapid, early growth rates for many tree legumes species have been obtained from P and Ca application on infertile, acid soils in Indonesia (Bray et al. 1988; Panjaitan 1988).

Because tree legumes can provide valuable, high-quality forage to the diet of livestock, there is justification for using fertilizer if needed. In intensive cutting systems, there is a large demand by the plants for soil nutrients. Fertilizer inputs may be required to sustain high levels of forage production. There is a need, therefore, to better characterize the nutritional requirements of a range of promising tree legumes under intensive repeated cutting as well as define the soil factors that limit their growth and edaphic adaptability.

**Plant characteristics and use**

**Protein banks or intensive feed gardens**

Trees and shrubs can be grown in dense plantings in single or multiple rows to produce high-quality forage. This forage can be harvested regularly and fed to animals as a supplement to poorer quality forage or crop residues (Manidool 1984; Ivory and Semali 1987). In such systems, perennial tree species are required that can maintain high regrowth rates, high leaf production, high leaf nutritive value, and strong perenniality under repeated cutting and possibly compatibility with companion forage species.

Highly productive grasses can be combined with trees in dense plantings. In West Africa, *Gliricidia* and *Leucaena* were planted in alternate rows with a 2.5 or 4 m interrow spacing and two or four rows of grass planted between the trees (Atta-Krah and Sumberg 1987). With frequent cutting, these systems annually produced 20 t/ha of mixed grass–legume forage. Several studies in Indonesia have also examined the productivity of densely planted tree–grass systems for intensive cutting. Ella (1988) studied the interaction of tree species, tree density, and cutting interval on companion grass production (*Panicum maximum*). Up to 15 t dry matter/ha of grass and tree forage was produced over 8.5 months. In the dry season, density and cutting interval had little effect on grass production; in wet season harvests, however, grass yield was inversely related to tree leaf yield, particularly at higher tree densities. Home (1989) also studied the effect of various cutting strategies that manipulated the *Leucaena* canopy structure and the relationship of this to the production of *Leucaena* and the two interplanted grasses (*Pennisetum purpureum* and *Setaria splendida*). *Leucaena* mixed with *P. purpureum* gave a lower total yield than grass alone; however, when mixed with *S. splendida*, there was a higher total yield. Higher yields of *Leucaena* in mixtures were given with
higher cutting heights of *Leucaena* with *P. purpureum* but lower cutting heights with *S. splendida*.

Tree legumes have also been combined in more complex systems. Nitis et al. (1987) used a three-level, forage-production system that combined grasses and herbaceous legumes at ground level, a tree legume (*Gliricidia*) at the intermediate level, and large trees at the highest level.

Trees can also be used for more strategic special purposes. Some species, particularly *Sesbania*, *Cajanus*, and *Codariocalyx* spp., have shown high early growth rates but poor perenniality under repeated cutting. These species are potentially useful when planted in cropping systems late in the wet season to produce dry-season feed. *Sesbania grandiflora* is used for this purpose in rice-cropping systems in East Java, Indonesia.

**Alley cropping**

In alley cropping systems, tree legumes are usually used for green manuring. Therefore, leguminous trees are required that produce leaves with a high nitrogen content, rapid rate of regrowth with a high leaf/stem ratio, a dense, erect canopy and deep root system (to minimize competition with the crop), and leaves that have moderate rates of decomposition.

In tropical soils, leaf material is rapidly decomposed. Wilson et al. (1986) found that with an annual rainfall of 1 200 mm, 50% of the nitrogen in *Gliricidia* leaves was decomposed in 3.6 weeks; with 2 400 mm/year, it was decomposed in 1.6 weeks. Thus, it is difficult for a crop to use fully this N source if tree leaf is applied before planting, although incorporation and banding provides a more efficient recovery than leaves that are surface broadcast. It is possible, however, to include livestock in this system — the animal retains little of the ingested N and most can be returned to the crop either from in situ grazing before planting or as animal manure from feeding pens. This may improve the N economy of the crop–animal system as N release from manure is slower and more attuned to the needs of the growing crop. Catchpoole (1989) showed that little of the nitrogen contained in \(^15\)N-labeled *Gliricidia* and *Leucaena* leaves fed to goats was retained and 45 and 10% of \(^15\)N was recovered by grass from excreted urine and dung, respectively. There is a need, therefore, to consider the opportunity costs of using tree foliage in alley cropping systems solely as an animal feed with manure returned, solely as a green manure, or in different proportions for each purpose. Tree leaves in alley cropping systems can also be used as a supplement for animals grazing crop residues between successive crops.

Forage trees can also be combined with perennial tree crops. In the Philippines, Moog (1986) found that when *Leucaena* planted in hedgerows 2–3 m apart (with fruit trees in the alleys) was harvested every 40–60 days, the system produced more than enough feed for 20 cattle from 2 ha.

**In situ grazing**

Tree legumes have been planted in widely spaced rows in grass pastures for both beef (Jones and Bray 1982) and dairy (Plucknett 1970; Stobbs 1972) production. The most widely used tree species in grazing systems is *Leucaena* (Jones and Bray
1982); *Gliricidia* has been used for dairy production (Chadhokar and Lecamwasam 1982; Chadhokar 1983). Continued production from such systems depends on a rotational system of grazing that allows rapid tree regrowth. Thus, tree species must tolerate complete defoliation and damage from grazing animals as well as sustain rapid rates of regrowth from numerous growing points on the remaining stems following grazing. Leaves should have a high N content, high nutritive value, be readily eaten by animals when fresh, and have good leaf retention for deferred grazing, particularly in the dry season.

**Seed production**

Although seed production is an important prerequisite for maintenance and expansion of planted areas of trees and shrubs, except for species that are readily vegetatively propagated, there has been little research on this aspect. There is considerable variation in the amount of seed produced by tree species and, whereas some species produce seed throughout the year (e.g., *Leucaena*), others produce seed at restricted periods because of photoperiod or dry-season stimuli (e.g., *Gliricidia*). Obviously, the production of adequate, good-quality seed is a desirable attribute for a tree species used for forage or multipurpose uses.

For many species, actual harvested yields of seeds are considerably lower than potential seed yields because of the inaccessibility of higher branches or through seed loss from the shattering of pods. In addition, for some shrub and tree species, seed quality may be poor during the wet season because of susceptibility to fungal diseases.

Seed storage is another aspect of seed production that has received relatively little attention from research on shrub and tree species. In general, it is known that seed keeps longer if the moisture content is reduced to a low level after harvest and the seed is stored in a dry environment.

**Nutritive value**

There is extreme variability in the nutritive value of the shrub and tree species used as livestock feed. This variation is due to greatly varying inherent nutritive values between species as well as the variation found within species because of differences in plant parts, age of tissue, and the soil and climate in which the plant is growing. The nutritive value of forage is a function of its digestibility, chemical (mineral) composition, and presence of toxins or antinutritive factors. Discussion here will be confined to nutritive value; a subsequent paper (Devendra, this issue) discusses feeding value and the use of trees and shrubs by livestock.

**Digestibility**

Considerable variation in proximate analyses and digestibility have been recorded for tree species used for animal feeding (Gohl 1981; Bulo et al. 1985; Brewbaker 1986; Vercoe 1987; Goodchild and McMeniman 1987; Little et al. 1989). Vercoe (1987) found that in vitro dry matter digestibility (IVDMD) varied from 16.9 to 66.9% and crude protein from 8.6 to 22.6%. Brewbaker (1986) listed a
wider range of crude protein contents (6.9–33%) and Little et al. (1989) found a range of 10–29% for N tree legume species. Bulo et al. (1985) found that the IVDMD of leaf and edible stems of 12 shrub or tree legumes varied from 36.0 to 63.4% and 34.5 to 58.2%, respectively; crude protein varied from 11.3 to 30.6% and 9.4 to 18.1%, respectively. Panjaitan (1988) found that the crude protein content of leaves tree legumes grown at four sites in Indonesia varied from 22.5 to 29.4% in the wet season and from 19.4 to 28.8% in the dry season. Leucaena cultivars had higher crude protein contents during the dry season; however, Gliricidia, Calliandra, Sesbania grandiflora, S. sesban, and Albizia falcataria had higher crude protein contents during the wet season. The crude protein content of N-fixing leguminous trees are usually high compared with mature grass fodder and crop residues; even nonleguminous trees can have reasonable protein contents (Le Houerou 1980; Soedomo et al. 1986; Little et al. 1989).

Fruits and pods of leguminous species can also have a high protein content (10–20%) (Brewbaker 1986; Goodchild and McMeniman 1987). Generally, pods have a lower crude protein content but a higher organic matter digestibility than leaves. Milled Acacia pods with seeds have provided a supplement of similar value to maize bran (Gohl 1981).

Among leguminous species, phyllodinous leaves tend to have higher crude fibre and lower crude protein, phosphorus, and organic matter digestibility than bipinnate leaves (Brewbaker 1986; Goodchild and McMeniman 1987). Compared with other sources of forage, trees generally have a high ether extract and moderate ash content; nitrogen-free extracts are generally lower (Brewbaker 1986; Goodchild and McMeniman 1987).

Cutting management and soil fertility status will also affect the nutritive value of trees. More frequent cutting will reduce fibre content and increase crude protein (Chadhokar 1982) and IVDMD. Any nutrient deficiencies in the soil will decrease the protein content of leguminous species. Thus, tree forage can provide a valuable source of supplementary protein to the diet of animals and can also improve the overall use of forages. For example, the addition of energy sources, such as cassava peel and cassava tubers, raised the dry matter digestibility of Gliricidia from 54–57% when fed alone to 70–74% in the mixture (Ademosum et al. 1985). Conversely, the addition of legume leaves can increase the digestibility of low-quality forages. It has been generally recommended that tree forage should make up 30% of the total animal diet if its higher protein content is to be used most effectively.

**Chemical composition**

Tree forage can also provide an important source of nutrients for the animal’s diet. Vercoe (1987) analyzed the foliage of 23 species of trees used for livestock feeding or browsing in Australia, most of which were leguminous species, and found considerable variation in their chemical composition: P, 0.05–0.18%; K, 0.41–1.78%; Ca, 0.29–3.52%; S, 0.21–1.13%; Na, <0.01%–0.41%; Mg, 0.21–0.62%; Cu, 4–152 ppm; Zn, 22–123 ppm; Mn, 30–917 ppm; Al, 26–325 ppm; B, 16–59 ppm; Ti, 0–9 ppm. Brewbaker (1986) also listed chemical analyses for P, Ca, Mg, K, and Si for the edible parts of 23 leguminous tree species used for animal feeding. Higher upper values were recorded for P and K, lower upper values for Ca, and lower values for Mg compared with the values of Vercoe (1987).
et al. (1989) measured the concentration of essential dietary mineral nutrients in 11 species of tree legumes and 9 species of nonleguminous trees or shrubs used for feeding ruminant animals in five regions of Indonesia. Wide ranges of essential minerals were also recorded in these feeds. They concluded that low concentrations of Na and Cu were widespread, marginal levels of P and Zn occurred with moderate frequency, and potential deficiencies existed for Co, Se, and Mo. Vercoe (1987) found that all species satisfied the minimum animal requirements for Ca (0.18%) and S (%); however, each species tested was found to have low concentrations of at least one essential element for animal growth. The most generally deficient element was P; it was below the estimated requirements for sheep and cattle (%) in 86% of species tested. Sodium values were low, as also found by Bulo et al. (1985) and Little et al. (1989) for other tree species. *Leucaena* has low levels of both Na and I (Jones 1979).

The nutrient values listed by Vercoe (1987), Brewbaker (1986) and Little et al. (1989) are for species growing in many different environments and do not necessarily reflect inherent species differences. Where the chemical composition of leaves and edible stems of 12 tree legumes were compared at the same site, considerable variation was found between species (Bulo et al. 1985). Nutrient concentrations were generally higher in leaves than in edible stems, except for *Desmodium salicifolium* and *Codariocalyx gyroides*, and for sulfur, which showed inconsistent results. Jones (1979) also observed considerable variation in nutrient concentrations in various plant parts for *Leucaena*.

The growing interest in tree legumes as sources of fodder has led to a more intensive examination of their digestibility and mineral composition. There is now a need to form a comprehensive data base of chemical analyses of tree species with potential as animal feeds. Adequacy ratings can then be established for individual species for the elements essential to animal growth.

**Toxins and antinutritive factors**

Many tree species are not useful or have problems associated with feeding to livestock. In addition to low digestibility, some tree species have low palatability or acceptability to livestock or contain toxins. High levels of phenolic compounds (tannins) in many tree species have been implicated as reducing palatability or acceptability (Hegarty et al. 1986; Brewbaker 1986), as well as strong odours in crushed leaves, such as in *Cassia* spp. and *Gliricidia*. The wilting or drying of tree fodders has been a method used by farmers to overcome or reduce palatability or toxicity problems in some tree species.

Several toxic compounds have been identified in tree species, such as robitin in *Robinia* and cyanogenic glucosides in *Acacia* spp. (Maslin et al. 1987). Some compounds that have caused toxicity problems, such as mimosine in *Leucaena*, have been found to be detoxified by specific rumen bacteria (Jones 1985). It may be possible to find other rumen organisms that can degrade phenolic compounds in tree species that are very productive and adapted to adverse soil conditions but have low palatability.

Toxic levels of particular elements can also cause problems with animal health. Vercoe (1987) found high contents of some trace elements in *Acacia* spp. For
example, Cu concentrations were high for some species. Copper concentrations as low as 40 ppm can poison sheep if levels of Mo and S are low (Underwood 1981); cattle are more tolerant.

References


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