*Tropical & Subtropical Agroecosystems*

# INTEGRATING FODDER TREES INTO ANIMAL PRODUCTION SYSTEMS IN THE TROPICS

## [INTEGRANDO ÁRBOLES FORRAJEROS A LOS SISTEMAS TROPICALES DE PRODUCCIÓN ANIMAL]

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**RESUMEN**

Uno de los principales problemas para la producción animal, característico en los trópicos es la estacionalidad de las lluvias y los periodos secos. Como respuesta a los periodos secos, en países de África, Asia, Latino América y Australia se han venido utilizando los árboles como fuente de forraje. Mayor énfasis se ha dedicado a especies leguminosas con capacidad de fijar nitrógeno atmosférico. Existe una gran diversidad de estas plantas que pueden integrarse exitosamente en los sistemas de producción animal, sobre todo, en aquellos sistemas de baja escala o pequeños productores. Sin embargo, existe poca literatura con información detallada sobre el manejo de árboles y de la información existente mucha se encuentra enfocada principalmente a especies como Leucaena leucocephala y Gliricidia sepium. De aquí la necesidad de trabajar con otras especies arbustivas y arbóreas y su uso en forma integrada, lo cual tendría mayores beneficios aparte de los ya conocidos en la alimentación animal, tales como reducir el impacto de plagas y enfermedades y mejorar las condiciones físicas y químicas del lugare donde crecen. En este sentido, los árboles desempeñan un papel fundamental en la reducir la demanda existente por alimentos para la producción animal al mismo tiempo que pueden reducir el impacto de la degradación del suelo.

**Palabras clave:** Manejo de árboles, frecuencia de corte, pastos tropical, estación seca.

**SUMMARY**

A shortage of high-quality dry-season fodder supply has been widely recognised as one of the main constraints to animal production in the tropics where long drought periods frequently occur. Tropical trees have been used over many years as sources of fodder, fuelwood, and timber in Africa, Asia, Latin America and Australia. Increasing attention has been given to species which fix atmospheric nitrogen such as *Leucaena* spp.; *G. sepium* and *Acacia* spp. which are now an important component in the farming system in many countries in the tropics. A great diversity of tree species could be integrated successfully into the small farming systems around the world. However, there are few sources of detailed information on tree management and many of these research is focused only in few tree fodder species, such is the case of *L. leucocephala* and *G. sepium*. Therefore the urgency of screening more species and the use of mixed species of trees and shrubs would lessen the impact of insects and disease as well as better use of soil and climate factors. It is likely that fodder trees and shrubs will have a major role to play in meeting future feed demands for both animal production and to arrest land degradation in the tropics.

**Key words:** tree management, cutting frequency, tropical grasses, dry season.

## INTRODUCTION

A major constraint to livestock production in the tropics is the seasonal fluctuation in forage yield and quality from grasses. There is usually adequate forage of fair to good nutritive value in the wet season, but in the dry season available forage from natural pastures are usually inadequate both in terms of quality and quantity to meet even the maintenance requirements of livestock. Tropical grasses mature more rapidly and contain less CP than temperate grasses, as tropical grasses mature, they become less palatable because the lignin content rises and CP content falls (Norton, 1982).

For extensive systems in areas with less than 800 mm annual rainfall and heavy soils, perennial herbaceous legumes have proved less persistent than deep-rooted tree or shrub legumes such as *L. leucocephala* (Addison *et al.*, 1984). Trees and shrubs legumes have been shown to be capable of providing high quality fodder in the dry season (Adejumo, 1992; Costas *et al.*, 1992). This has aroused interest in their use in pastures leading to the development of tree based forage production systems such as alley farming system, intensive feed gardens, scattered trees on pastures or fodder bank, in which *G. sepium* and *L. leucocephala* feature prominently (Atta-Krah and Sumberg, 1988; Kang *et al.*, 1990).

Small holder farmers raising livestock under traditional systems in West Africa have shown little interest in planting pasture, but tree-grass combinations have great potential for improved management systems (Kang *et al.*, 1990). In the more extensive grazing areas of Australia, southern Africa and South America, tree legumes are increasingly being planted in association with improved grasses to increase their carrying capacity and the productivity of grazing cattle (Gutteridge and Shelton 1994) In the Philippines, Moog (1983) reported that leaf production from *L. leucocephala/Imperata cylindrica* pastures is three times that from native *Imperata* grasslands, and LWG from *L. leucocephala/P. maximum* pastures have been of the order of 440 kg $ha^{-1}$. Alley farms are expected to supply a high quality, low cost supplement to the normal diet of animals belonging to smallholder farmers. In drier areas Singh *et al.*, (1989) suggested that forage from prunings and crop residues may be the major attraction to the farmer practising alley farming, when fodder availability is recognised as a major constraint.

In addition, trees in managed species mixtures have a great potential to bring about 'micro-site enrichment' through processes such as efficient cycling of plant nutrients and nutrient pumping (Haines and DeBell 1979). Nitrogen fixing trees have the additional potential of bringing in substantial quantities of atmospheric nitrogen into the ecosystem (Huxley 1999). Interference of trees, however, is a major constraint in the integration of trees with field crops, as trees mature and canopy is formed the intensity of light at the ground level decreases and forage productivity may decline (Mathew *et al.*, 1992). A further disadvantage of the trees is the high proportion of inedible woody tissue that these plants produce as well as anti-nutritive and toxic factors which can produce toxic effects in ruminant animals (Gray, 1970; Norton 1994), as well as their slow establishment. The purpose of this paper is to review the most important ways to introduce shrubs and trees to the farming systems were the trees can be grown to provide fodder with high protein content for livestock.

## FORAGE TREE IN ALLEY FARMING SYSTEMS

### The Alley Farming System

Alley farming is a food-biased agroforestry system, which seeks to exploit the potentials of tree legumes, (Atta-Krah and Sumberg 1988), primarily for the maintenance of the soil fertility and consequently for improved crop and livestock production. In alley farming fodder trees are established in rows within arable crop farms and the crop or grass cultivated in the alleys between the tree rows. The trees are pruned at the end of the first year and subsequently managed through periodic prunings of the regrowth, such that the interplanted food crops do not suffer from shade.

Because of the rich nutrient content of most leguminous fodder trees (Table 1), a significant amount of nitrogen and organic matter is made available to ruminant livestock. Such feeding is usually done on a cut-and-carry basis. In alley farming the possibility exists for crop residues to be grazed during the dry season by livestock, with the tree fodder as a supplement to enrich the diet. There is also the possibility of deliberate short grazed fallow in rotation with cropping phases within alley farming cycles. During such fallow, no crop is planted and the previously cropped land is grazed by sheep or cows (Atta-Krah & Sumberg 1988).

### Choice of tree species

Basic characteristics required of an alley farming tree species include the following: fast-growing, nitrogen-fixing, nitrogen-rich leaves, tolerance to pruning, ability to coppice vigorously and good fodder value (Atta-Krah & Sumberg 1988). In addition to these, such other characteristics as high foliage productivity, vigorous tap root development, and dry season leaf retention are advantageous (Rachie 1983). A wide range of tree species has been used in alley cropping (Table, 2) however, *L. leucocephala* has been by far the most widely used specie (Kang *et al.*, 1990; Shelton and Gutteridge 1994). A number of comparative trials in humid and subhumid zones on high base status soil have shown *L. leucocephala* to be superior to other species and this may partly explain its widespread use (Kang and Reynolds 1986). However, on acidic low base status soils has not been as successful as species such as *Flemingia macrophylla* (Kang and Ghuman 1991) and *E. poeppigiana* (Kass *et al.*, 1992).

Table 1. Chemical composition (g/kg DM) of foliage from fodder trees species

| Species | CP | Fat | Ash | NDF | Crude fibre | ADF | Lignin |
|---|---|---|---|---|---|---|---|
| *Acacia aneura* | 107-156 | 34-56 | 35-49 | 498-511 | 286-341 | 396 | 194-206 |
| *Albizia chinensis* | 151-263 | 44 | 46-145 | 354-603 | 316 | 246-348 | 145 |
| *A. lebbeck* | 181-240 | 18-47 | --- | 46-90 | 265-377 | --- | --- |
| *A. saman* | 221-279 | 70 | 43-60 | --- | 294-480 | --- | --- |
| *Cajanus cajan* | 158-214 | 41-60 | 54-58 | 314 | 212-308 | 292 | 100 |
| *Calliandra calothyrsus* | 173-212 | --- | 40-43 | 259-302 | --- | 209-229 | 69-84 |
| *Desmanthus virgatus* | 115-146 | 24 | 58-85 | 256 | 393 | 195 | 91 |
| *E. cyclocarpum* | 168-250 | 53 | 50-55 | --- | 122 | --- | --- |
| *Faidherbia albida* | 147-197 | 16-17 | 57-72 | --- | 185-196 | --- | --- |
| *Gliricidia sepium* | 150-275 | 14-24 | 22-107 | 231-272 | 186 | 212-357 | 55-94 |
| *Leucaena diversifolia* | 173 | --- | --- | 475 | --- | 370 | 220 |
| *L. leucocephala* | 203-269 | 55 | 57-93 | 309-383 | 183 | 226-234 | 68-99 |
| *Sesbania grandiflora* | 206-348 | 30-42 | 90-125 | 244-371 | 75-190 | 217-258 | 81 |
| *S. sesban* | 152-263 | 9-16 | 74-100 | 219 | 122-353 | 153 | 36 |

Source: Norton 1994; Nsahlai et al., 1995

### Management of trees in the alley system

Although fodder tree species differ in their effects on understorey production; some species have a beneficial effect, at least up to certain tree densities and when the canopy is managed appropriately (Bahiti, 1981). On the other hand, some species may have a variable influence depending on their age or size and some species may have a detrimental effect even at very low densities (Beale, 1973). Also, the extent to which trees influence pasture production, and the nature of their influence, can differ between years (Walker, 1974). Tree foliage production may compensate, not just in terms of quantity but also in terms of quality, for the production lost in the pasture component. In a well-balanced mixed tree-pasture system, the total production may be better distributed over the year (Goldson, 1973; Kennard & Walker, 1973). Thus, some fodder trees can be successfully integrated with pasture production, while others should ideally by grown separately, for example *A. aneura* (which have a detrimental effect on grass production) stands for drought reserves (Pressland, 1975).

Management of alley on a tree-grass mixtures aims at striking a balance between the productivity of the components of the mixture. In this sense, tree spatial arrangement and harvesting regimes can be manipulated to achieve the balance (Huxley, 1985). Tree management could be such that it would preserve foliage on the tree and assure high fodder yields at the onset of the dry season (Ezenwa *et al.*, 1995), in addition to maintain their crude protein contents at higher levels than in grasses.

Table 2. Potential trees and shrubs for the practice of alley farming systems in the tropics

| **Species (Legumes)** | **Countries** |
|---|---|
| *Acacia auriculiformis* | Sahel & West Africa |
| *Cassia siamea, C. spectabilis* | Kenya, Nigeria, Sahel & West Africa |
| *Callinadra calothyrsus* | Indonesia, Western Samoa & Costa Rica |
| *Erythrina poeppigiana, Inga edulis* | Costa Rica |
| *Flemingia macrophylla, F. congesta* | Nigeria, Rwanda & South Asia |
| *Gliricidia sepium* | Nigeria, Costa Rica, Sri Lanka, Philippines |
| *Leucaena leucocephala* | Mexico, Kenya, Philippines, Sri Lanka, Indonesia, Australia, India, Thailand, Australia & Cuba |
| *Prosopis cineraria, P. pallidad* | Kenya, Ethiopia & Somalia |
| *Sesbania sesban* | Rwanda, Kenya, Australia, Ethiopia |
| *S. grandiflora* | Nigeria, Western Samoa |
| ***Non-legumes*** | |
| *Gmelina arborea* | Nigeria, American Tropics & Pacifics Islands |
| *Grevilea robusta* | Kenya, American Tropics & East Africa |
| *Azadirachta indica* | Thailand, Senegal, Asia & India |

Source: Modified from, Kang and Gutteridge (1994)

Table 3. Liveweight (LW) gains from cattle grazing grass only and *L. Leucocephala*/grass pastures

| Grass species | LW(kg/head/day) | | Duration of the experiment (days) |
|---|---|---|---|
| | -leucaena | +leucaena | |
| Native pasture | 0.25 (0.7) | 0.56 (0.7) | 365 |
| *Imperata cylindrica* | 0.22 (0.75) | 0.35 (1.5) | 315 |
| *Digitaria decumbens* | 0.39(3.3) | 0.49 (3.3) | 364 |

Source: Jones 1994. Stocking rate as head/ha in brackets.

## FODDER BANK

In many areas of the subhumid and semi-arid tropics livestock production is seriously constrained by the limited amount and poor quality of animal fodder during the dry season. Low crude protein content is the most common limitation to animal production from native pasture and some systems have been developed to supplement or improve the crude protein intake of animals grazing native pastures by providing access, either seasonally or all year, to limited areas of sown tropical tree legumes which form a protein bank. This form of provision of a high quality fodder to livestock has been used successfully with *Leucaena leucocephala* as a supplement to cattle on native pasture.

Fodder banks, protein bank or intensive feed gardens, consist of trees alone or in combination with grasses such as *Pennisetum purpureum* or *Andropogon gayanus* with the objective of provide high quality feed to livestock mainly during the drought season. Jones (1994) reviewed 13 experiments of this type and concluded that cattle liveweight gains can be substantially improved by complementary grazing of *L. leucocephala* (Table 3), especially when the base grass pasture is low in quality and *L. leucocephala* intake is high. Increases in growth rates up to 0.3 kg $d^{-1}$ have been recorded.

Several authors have noted that gains from *L. leucocephala* pastures compare favourably with those from other grass/legume or even those from nitrogen fertilised pastures. Jones and Jones (1984) found that in subtropical southeast Queensland, *L. leucocephala*/grass pastures produced from 310 to 430 kg liveweight gain/ha.

### Fodder bank management

For grazing purposes seasonal rather than year-round complementary grazing of protein bank is likely to be more effective in utilizing a limited resource. The smaller the protein bank relative to the total forage demand, the greater the degree of control required in managing or rationing the protein bank (Coates, 1995). Controlled access allows the protein bank to be utilized and rationed when it is likely to be most beneficial usually in the mid to late dry season. Furthermore, access can be restricted to selected animals according to the priorities of the livestock producer. Protein bank, or fodder bank, have been advocated as a means of providing renewable supplementation for traditionally managed cattle in developing countries such as those in Africa and Latin America. Table 4, show some tree species with potential to be used as a fodder bank. It can be seen that fodder bank is practised more frequently in humid and sub-humid regions, it is due in part to the high moisture requirement by the trees in association with crops or grass.

In fodder banks trees and shrubs can be grown in dense planting in single or multiple rows to produce high-quality forage, this forage can be harvested or grazing regularly and fed to animals as supplement to poorer quality forage or crop residues (Reynolds and Atta-Krah 1989). In such systems, perennial tree species are required that can maintain high regrowth rates, high leaf production, high leaf nutrition and resistance under repeated cutting management and compatibility with companion forage species.

**Table 4. Some fodder trees which are used as fodder bank (Nair et al., 1984)**

| Species | Major eco-zone | Countries |
|---|---|---|
| *Dalbergia sisso* | tropical highlands | India, Nepal |
| *Derris indica* | arid/semi-arid | India |
| *Erythrina abyssinica* | tropical highlands | Ethiopia |
| *Gliricidia sepium* | humid/sub-humid | Panama |
| *Leucaena leucocephala* | humid/sub-humid | Philippines, Cuba, Mexico |
| *Albizia lebbeck* | humid/sub-humid | India, Nepal |
| *Pithecellobium dulce* | arid/semi-arid | Philippines |
| *Prosopis cineraria* | arid/semi-arid | India |
| *Sesbania bispinosa* | humid/sub-humid | India, Paksitan |
| *S. grandiflora* | Humid/sub-humid | Indonesia |

## Three-strata forage system

Other grazing system which can be considered as a fodder bank due to its high content of protein and availability all the year around is known as the three-strata forage system (TSFS) developed for smallholders in Indonesia (Nitis *et al.*, 1990). The TSFS is a technique of planting and harvesting grass, ground legume, shrub and fodder trees, so that ruminant feed is available all the year around. The first stratum consist of grasses and pasture legume to supply ruminant feed during the wet season; the second stratum, which consists of shrub legumes such as *G. sepium* and *L. leucocephala,* is to supply ruminant feed during the mid-dry season; while the third stratum consists of fodder trees to supply livestock feed during the late dry season. In addition, the second and third strata can also contribute to the supply of fuelwood and improve the soil fertility through the root nodule contribution of the legume species.

Compared with the traditional system of using natural pastures for tethered grazing, the TSFS had substantial advantages in terms of quantity and quality of forage production. Higher cattle gains and higher stocking rates, increased soil fertility and less erosion, and increased income, are some of the most important benefits of this system. In the tree-grass systems, tree hedgerows may be established 4 m apart, with four rows of grasses sown in between. Tree hedgerows may also be established 2.5 m apart with two rows of grasses. Using *L. leucocephala* and *G. sepium* mixed with *P. maximum* in such system, productivity of over 20 t DM/ha of mixed tree-grass fodder is available from both design under humid zone conditions (Atta-Krah and Reynolds 1989).

### LIVING FENCES

The International Center for Research in Agroforestry (ICRAF) defines live fencing as, "a way of establishing a boundary by planting a line of trees and/or shrubs at relatively close spacing and by fixing wires to them" (Huxley, 1999). Living fences refer to those areas established not only by planting large or short cutting of woody perennial but also the establishment by seedling or direct seeding (Table 5) in lines with the purpose of keep livestock in or out. Species such as *Leucaena*, *Sesbania* and *Calliandra* are commonly established by direct seeding, while others like *G. sepium* and *Erythrina* spp., can be established vegetatively by stakes. Trees are planted to provide boundary fences to fields or land holdings which give stock control and stock protection. Living fences may also be planted around residential blocks or home gardens to provide shade and shelter in addition to providing forage. The fodder from such living fences provides a good daily feed supplement for the livestock.

Budowski (1987), Simons and Stewart (1994), reported the wide use of living fences planted in both dry and wet sites throughout Central America. The cutting height of these living fences are commonly set at 1.0-2.5 m and generally cut twice per year (depending on rainfall). Lopping may be used as fodder, fuelwood or as shelter to livestock. The living fences, acquire particular relevance under grazing/browsing systems (Torres 1983), either under arid to semi-arid conditions, or in the more humid regions, where the poles have to be replaced quite often.

Planting is usually by insertion of hardwood cuttings 3-7 cm in diameter and about 1.0-1.5 m long (Chadhokar, 1988). The basal 20-30 cm is inserted into prepared ground so as to leave 1 m of shoot above ground. If inserted at the start of the wet season rooting will begin almost immediately and a first flush of foliage occurs about 6 to 8 weeks later (Evans 1992). The benefit of using long stakes is that they are not grazed out and compete better with other vegetation relative to seedlings. Preston (1992), reported, however, that living fences production from seedlings will be more productive (figure 1), especially when established at high plant densities, than those derived from cuttings.

Farmers have tended to create a living fence around their household from shrubs and tree species to provide not only human food and fuelwood but also animal feed. In north-eastern Thailand, *L. leucocephala* was widely promoted for the household living fence in rural villages during the early 1980s. The fence will normally established by direct seeding or transplanted seedlings (Table 5) at close spacing. In Indonesia, Latin America and Philippines *G. sepium* has been used extensively in village households (Nitis *et al.*, 1985; Budowski 1987; Gonzal and Raros 1988).

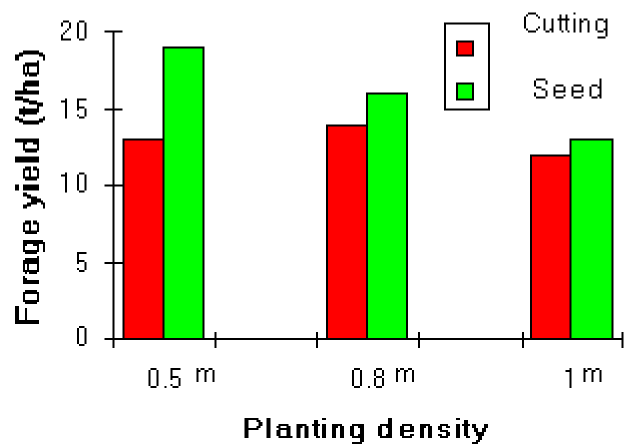


**Figure 1.** Effect of plant density and method of establishment on forage yield of *G. sepium* (Preston, 1992).

Table, 5. Trees and shrubs species used as living fences to provide fodder to livestock Ecological adaptability and management aspects

| Species | Altitude (m.a.s.1.) | Rainfall range (mm/yr) | Max. dry period (month/yr) | Establishment method |
|---|---|---|---|---|
| *Albizia lebbeck* | up to 1600 | 500-2000 | 4-5 | Seedling/cutting |
| *Cajanus cajan* | up to 3000 | 400-2500 | 5-6 | Direct seeding |
| *Gliricidia sepium* | up to 1600 | 700-2300 | 2-3 | Seedling/cutting |
| *Erythrina poeppigiana* | up to 2000 | 1000-3000 | 3-5 | Seedling/cuttings |
| *Leucaena leucocephala* | below 500 | 250-1700 | 5-6 | Direct seeding/seedling |
| *Mimosa scabrella* | up to 1500 | 400-1600 | 4-5 | Seedling/cutting |
| *Pithecellobium dulce* | up to 1500 | 400-1600 | 4-5 | Seedling/cutting |
| *Sesbania grandiflora* | up to 800 | 1000-2000 | 2-3 | Seeding/seeding/cutting |

Source: Topark-Ngarm 1990; Benge 1987; and Nair *et al.*, 1984.

In a study in Costa Rica cited by Pezo *et al.*, (1990) on the productivity of G. *sepium* or *E. berteroana* as live fences, different pruning intervals were evaluated at four sites in the lowland humid tropics, they found that the total biomass yield increased as the pruning interval was delayed, but the proportion of edible biomass declined with age (Table, 6). Also, tree survival was negatively affected by frequent pruning. This study suggested that to maintain the productivity at an acceptable rate in such systems, the pruning interval has to be at least 4 months.

Table 6. Fodder production (kg DM/km) from live fences of *E. berteroana* and *G. sepium* pruned at different frequencies intervals (Pezo *et al.*, 1990).

| Pruning intervals | Edible biomass | Total biomass |
|---|---|---|
| months | *Erythrina berteroana* | |
| 2 | 1,058-2,168 | 1,058-2,168 |
| 4 | 1,769-3,132 | 3,132-6,201 |
| 6 | 1,435-4,218 | 3,189-8,273 |
| | *Gliricidia sepium* | |
| 2 | 139-1,244 | 139-1,244 |
| 4 | 1,001-5,580 | 1,581-7,771 |
| 6 | 353-3,546 | 589- 7,483 |

## TREE FODDER ESTABLISHMENT AND MANAGEMENT

### Planting methods

#### Direct seeding

Trees such as *Gliricidia* spp., *Sesbania* spp. and *Leucaena* spp., can be planted by direct seeds in rows into fully prepared seed beds or into cultivated strips in existing grasslands. Seeding rates of 1-2 kg/ha at depths of 2-3 cm are usually recommended in rows 3-10 m apart. For example, the current recommendation in central Queensland is single or double rows 1 m apart with approximately 4-5 m between centres (Gutteridge and Shelton 1993). If plant spacing within rows is 30-50 cm, this gives a population of 13,000-33,000 plants/ha. Smaller plant populations, in wider rows, may provide better rationing of limited water supply and an opportunity to intercrop the rows with grass.

**Vegetative propagation**

The seedling growth of many fodder trees is often slow, making young plants susceptible to weed competition (Maasdorp and Gutteridge, 1986) and grazing by livestock and wildlife (Wilding, 1989). Slow seedling growth of these trees can be related to their rooting characteristics, which have developed for long-term survival rather than high initial growth rates. Most of the tree fodder species can be propagated by seed but a number, including *G. sepium and Erythrina spp*., can also be established vegetatively using stem cuttings (Table, 3).

*G. sepium* is commonly planted vegetatively from cuttings and is ideal for shade trees, support trees or living fences. Cuttings should be mature branches >7 cm in diameter which are brownish-green in bark colour. The cutting is normally cut obliquely at both ends, discarding the younger tips, and the base inserted 10-20 cm into the soil depending on the length of the cutting. The *Sesbania* species seed prolifically and are normally planted from seed, although research suggest that some sesbanias can be established from cuttings (Evans and Macklin 1990; Oduol and Akunda 1988). Results indicate that there are differences in rooting percentages from the material obtained from the tip of seedlings grown in the nursery and the cuttings obtained from field-planted young trees. The cuttings obtained from young seedlings in the nursery had a high rate of rooting (above 70%) while those obtained from the field had a low percentage (15%). Success of rooting from cuttings depends on the retention of original leaves that are essential providing photosynthetic surface and thus accelerate rooting, (Oduol and Akunda 1988).

Vegetative propagation has the advantage of more rapid establishment of new stands which are genetically identical to the parent lines without the need for seed collection. Disadvantages are that it requires more hand labour and the root development of cuttings may be shallow and devoid of a strong taproot compared with seedling grown trees. Shallow rooted trees are more susceptible to drought and wind damage.

**Seedlings**

Most tree fodder species are readily established from transplanted seedlings. Seedlings are first grown in nurseries in polythene bags or in small plastic dibble tubes until they reach a height of 30-50 cm. After that seedlings are directly transplanted into the field into moist soil. Weeds need to have been previously controlled either mechanically or chemically. In areas with prolonged drought periods watering of seedling will be necessary until trees become well established.

Some nitrogen fixing trees can be planted from stump cuttings which are easier to transport into the field. The NFTA *Establishment Guide* (Anon. 1989) cited by Shelton (1994) reports that *A. lebbeck, C. calothyrsus, D. sisoo, Enterolobium cyclocarpum, G. sepium, Leucaena* spp., *Paraserianthes falcataria* and *Pterocarpus indicus* can be planted in this way. Stump cuttings can be made from seedlings which reach 60-90 cm in height and 10-20 mm diameter in nursery seedbeds. They are carefully removed when the seedbed is thoroughly wet and stem and roots cut 15-20 cm above and below the crown.

**Seed treatment**

***Scarification***

The hard coats on the seed of many trees inhibits the absorption of water and prevents uniform germination. The seed coat must be broken or scarified before germination will occur. Without scarification, the germination percentage may be < 10%, Shelton (1994). A guide on the seeds treatment for some of the most tree legumes is giben by Shelton (1994). The most common method is the immerse of the seed on boiling water for 30 seg., but sulphuric acid or mechanical scarification methods are also used. Seed scarification could increase germination rate at 50% (Misra and Singh, 1981).

Untreated seed usually commences germination 5 days after sowing, but further germination of seed can continue for months. However soaking in cold water for 48 hours or submerging seed in boiling water and allowing it to cool for 24 hours improves germination (Prinsen 1986).

**MANAGEMENT OF TREES**

**Age of first cutting**

The age of first cutting tree for fodder is very important factor to consider, as the subsequent productivity and persistence depend on it. The benefit of a long period before first cut has been demonstrated (Stur *et al.*, 1994). They showed that age of trees at first harvest was positively related to yield at subsequent harvests. The positive effect of a long establishment period was more pronounced for *L. leucocephala* and *G. sepium* that for *C. calothyrsus*. The better growth from older trees may be have been related to larger stumps, more carbohydrate reserves, and a deeper, more extensive root system, compared to the younger trees (Ivory, 1990; Gutteridge and Shelton, 1993).

Cutting forage trees at different seasons of the year (dry or wet season) and at different stages of development (flowering or vegetative) may also influence subsequent regrowth (Stur *et al* 1994). However, there are few documented cases on these topics. It may be speculated that although trees are usually deep-rooted and have access to moisture in the deeper soil layers cutting at the beginning of a dry season or during the dry season could result in the exhaustion of reserves, as growth and replenishment may be restricted by moisture availability. However it may be expected to have a large amount of reserves in stems and root system, which may not easily be exhausted.

Where there are distinct wet and dry seasons some considerations has to be given to the timing and type of defoliation. If the dry season is prolonged it 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 (Ivory, 1990). This may be combined with more regular, complete defoliation during the wet season.

**Cutting frequency**

Cutting frequency is how often the trees are cut or grazed. Defoliation (cutting or grazing) frequency and intensity interact, with more severe defoliation intensity requiring longer intervals between defoliations to allow the trees to recover. Conversely, under lenient defoliation systems, trees can be harvested more frequently (Stur *et al.*, 1994). Research on cutting frequency treatments show that harvest intervals range from 4 weeks up to 17 weeks (Perez and Melendez 1980; Osman 1981; Blair 1990). Therefore most experiments have set fixed cutting intervals, but it has been agreed that in areas with large variability in climate conditions, optimum production is more likely if trees are cut on the basis of regrowth (Evensen, 1984) cited by Blair (1990).

Recently, Barnes (1999), found that herbage production of *G. Sepium*, *C. Calothyrsus* and *F. macrophylla* increased from 6 week's regrowth to the 12 week's regrowth in the first lopping. This trend of yield was however not noted in the second 12 week regrowth harvest compared with to the third and fourth six week regrowth harvest. Similar result were found by Karim *et al.*, (1991) in a study on *L. leucocephala* at two frequencies of cutting (1 and 3 months), the dry matter yields resulting from monthly cutting were significantly lower than those from three-monthly cutting. While Osman (1981) observed that frequent cutting often leads to stool death, and similar observations have been reported by Guevarra *et al.*, (1978). It would be related with the decrease of concentrations of starch and total reserve carbohydrates in the remaining stems and roots after harvests (Latt *et al.*, 2000).

There are differences among tree species in their ability to cope with repeated cutting. *S. grandiflora*, for example, does not tolerate repeated cutting of the main stem above a certain height (Horne *et al.*, 1986; Ella *et al.*, 1989). Others trees with a poor tolerance to regular cutting of main stems include *P. falcataria* and *Acacia cunninghamii* (Gutteridge, 1990). Their poor ability to coppicen is related with their lack of branching close to the ground and a lack of lateral buds.

Stur *et al.*, (1994) has delineated the effect of defoliation into three distinct phases. They illustrate these phases with *C. calothyrsus*, similar responses can be expected for other fodder trees such as *Leucaena* spp., and *G. sepium*. The first is a commonly observed lag phase after cutting (weeks 0-4) when regrowth is slow due to low leaf area. This is followed by a period of maximum productivity (second phase, weeks 4-10) when leaf production increases markedly. The sigmoidal curve then plateau as full light interception is approached and older leaves begin to senesce (third phase, weeks 10-24). During the third stage, the trees increase in height and woody biomass increases, while leaf yield remains steady or increases only slightly. Guevarra *et al.*, (1978) reported that *L. leucocephala* did not reach full light interception until 3 months after planting. This period may be shorter when cutting well established trees or very dense plantings.

However, it is difficult to draw general conclusions from experiment investigating the effects of cutting frequency on leaf yields, as the results are much less consistent. Pathak *et al.*, (1980); Das and Dalvi (1981) found that the most frequent cutting treatments studied (40-day and 60-day intervals, respectively) gave the best yields of *L. leucocephala* leaf. In contrast, Semali *et al.*, (1983) found that infrequent cutting (110 days) resulted in the highest leaf yields. Table 7, show some experimental result on effect of cutting interval on the fodder production of *L. Leucocephala*.

In summary, the range of defoliation intervals for maximising leaf production from forage trees species such as *Leucaena* or *Calliandra* appears to be around 2-4 months in the humid tropics, but may be longer in drier areas or the cooler subtropics (Gutteridge and MacArtur 1988). However, such a practice is dependent on the nature of the farmer's tree resource and forage requirements, a smallholder with a limited number of trees will have to cut each tree more frequently to obtain a continuos supply of forage. Also, site characteristics such as soil fertility and soil water regimes are know to have a bearing on the way species respond to different rates of defoliation (Jones & Harrison 1980).

Table, 7. Effect of cutting interval on edible fraction and stem yield of *L. leucocephala*

| Cutting Interval (weeks) | Edible (t/ha) | Wood (t/ha) | Edible (%) |
|---|---|---|---|
| 6 | 8.6 | 2.0 | 8.1 |
| 8 | 9.2 | 7.8 | 54 |
| 11 | 9.4 | 2.6 | 78 |
| 12 | 10.5 | 9.2 | 53 |
| 18 | 12.0 | 8.8 | 58 |
| 41 | 11.5 | 5.4 | 68 |
| 16 | 10.3 | 18.6 | 36 |
| 12 | 10.3 | 5.1 | 67 |

modified from Stur et al., (1994)

**Planting Density**

The density employed in cutting height and frequency experiments is usually determined with a view to intended practical application. Rarely has equidistant spacing been used, but rather trees species such as *L. leucocephala* has been planted in rows to simulate hedgerow or alley cropping management system and, as such, density expressed as a number of trees per unit area is less significant than specifications of inter-and intra- row tree spacing (Blair *et al.*, 1990).

In general, higher densities cause an increase in leaf and wood yield per unit area and a decrease in individual tree yield. Generally most researchers have found that yield per unit area has been highest at the highest densities used and therefore, few experiments have defined optimum tree densities for maximising yield per unit area. Pathak *et al.*, (1980) reported higher leaf dry matter yields (5.4 t $ha^{-1}$ $year^{-1}$) from trees at a density of 40,000 trees $ha^{-1}$ than at a density of 15,000 trees $ha^{-1}$. Castillo *et al.* (1979) compared four densities (3000, 5000, 6000, and 10,000 trees $ha^{-1}$) and obtained significantly higher yields from the two highest densities. Three densities (10,000, 30,000, and 60,000 trees $ha^{-1}$) were compared by Savory and Breen (1979), they reported that 60,000 trees $ha^{-1}$ gave the highest yield. However, it is important to mention that most of this research measures had been done with young stand of trees and that perhaps this high densities of trees could have a different response at different age of tree's stand and may be interference between trees and tree-crop could be great.

In hedgerow situations (in situ grazing or alley cropping), wide row spacing are required with higher intrarow densities. Kang and Reynolds (1986) found that when within-row seedling spacing varied from 4 to 50 cm in an alley cropping system, the production of *G. sepium* per unit row length remained relatively constant, although stem diameter were larger with increasing distance between plants. However if there is a choice of spatial arrangement a reduction in rectangularity will favour yield and N fixation (Humphreys 1994). For example in the study by Karim and Savill (1991), the N yield from leaves of *G. sepium* plants grown at 0.5 m-2 for the establishment year was 96, 128 and 271 kg $ha^{-1}$ as the ratio of between-row spacing was reduced respectively from 16:1 to 8:1 to 2:1 (i.e. 8x0.25 m, 4x0.5 m or 2x1 m spacing). These differences were also reflected in height, collar diameter, branch number and biomass.

## CONCLUSION

An inevitable decline in availability of grazing areas however, has occurred in the last few years and on farm feed sources. A major research and development initiative is required to improve the supply as well the acceptance of quality feed at the farm level. Without such an approach followed by trials the animal production of both small and large ruminants will result in decrease yield and therefore affects the farmers welfare. The literature on potential of trees as fodder has been growing. Such potential of trees has been demonstrated in a controlled experimental basis and on-farm trials are required on management options that can best exploit the potential of various species of trees and shrubs. Information on other multipurpose are required in order to maintain diversity and productivity and have alternative sources of fodder when insects and disease are present in addition to wide alternatives for the different environmental and management conditions.

Trees and shrubs have the advantage over herbaceous plants in as much they are persistent, produce more edible DM (mainly during the dry season) and usually retain their leaves during prolonged drought periods; indeed, they can be properly managed to optimise leaf DM during this period. Management techniques developed to maximise production and persistence include short periods of intense grazing followed by long periods of recovery dependent on the climatic conditions as well as on the soil fertility; adjusting the frequency and intensity of lopping so that an increase in leafy shoots will be greater than could have been obtained without pruning appears to be another alternative. With respect to the defoliation management it is recommended to allow 3-4 months intervals between cuttings to give the best foliage production while 6-12 months periods gave better wood production. In general total biomass usually decreased with increased frequency of cutting.

High tree densities result in increased production and in some cases with the advantage of weed suppression and improved soil fertility. Fodder tree species also offer the advantage of integrating crop and livestock production and a potential for improving the overall productivity of farmers in the tropics. However, research is need on synchronisation (in term of time and spacing) of both hedgerow and crop growth and nutrient relation of fodder off take with crop response to mulch application and the balance of these components in the farming system are of critical importance to long term sustainability (Kang et al. 1990). The age of first cuttings is also of relevant importance in the management of trees in order to maintain productivity and persistence. It appear that the first cutting could commence the first year after tree establishment, although older trees may have a well developed and deeper root system which can contain more carbohydrate reserves therefore accommodating a more frequent defoliation or browse.

Very little has been reported on the effect of cutting management on subsequent growth habit and tree form. It is likely that regrowth will be more rapid from shoots remaining after cutting than if regrowth arises solely from new buds (Horne *et al.*, 1986). Few information is available to compare cutting systems employing total vs partial removal of leaf trees. Other factors which have received little attention is the effect of age or size of tree at the time of the first harvest on subsequent yields. In addition to this, no attention has been given to whether initial cuts should be made at a lower height at subsequent harvest in order to promote a multi-branched stem with theoretically more potential bud sites from which regrowth can arise.

Finally, most of the studies investigating the influences of defoliation (cutting intervals, defoliation intensity, etc.) on subsequent productivity have been carried out over only a few years, therefore having a unrealistic response of trees at long term, in addition to different site characteristics, differences in the ways in which tree (individual or populations) were manipulated, which together make more difficult the better understanding of trees manipulation to their integration in the farming systems.

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