This is to certify that the

thesis entitled

ESTABLISHMENT AND NUTRITIVE VALUE
OF NATIVE AND EXOTIC FODDER TREE SPECIES
IN JAMAICAN PASTURE SYSTEMS

presented by

James Michael Roshetko

has been accepted towards fulfillment
of the requirements for

Master degree in Forestry

Major professor

Date September 4, 1991

ESTABLISHMENT AND NUTRITIVE VALUE OF NATIVE AND EXOTIC FODDER TREE SPECIES IN JAMAICAN PASTURE SYSTEMS

By

James Michael Roshetko

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree

MASTER OF SCIENCE

Department of Forestry

1991

ABSTRACT

ESTABLISHMENT AND NUTRITIVE VALUE OF NATIVE AND EXOTIC FODDER TREE SPECIES IN JAMAICAN PASTURE SYSTEMS

By

James Michael Roshetko

An experiment was conducted to investigate fodder tree establishment in Jamaican grass pastures. Results demonstrated that *Gliricidia* and *Leucaena* can be established by direct seeding, and that adequate weed control improves fodder tree survival and growth. Circle weeding greatly enhanced survival and growth over bush weeding alone. Fertilization and larger planting pits had little positive effect on fodder tree performance. The use of these treatments is not recommended.

In a second experiment the approximate nutritive value of native and exotic Jamaican fodder tree species were determined and compared to the approximate nutritive values of the main pasture grass species used in Jamaica. In general, tree species are inferior to grass in digestibility and mineral content, but superior in crude protein content. These characteristics make tree fodder a good livestock feed supplement for the dry season when grass or of poor quality.

ACKNOWLEDGEMENTS

This thesis is the result of two and a half years of work in both Jamaica and East Lansing. During that period many people gave me support and advice for which I am genuinely grateful. Drs. Douglas Lantagne and Michael Gold were instrumental in helping me design and complete my research project. Even more importantly their advice and tutelage instilled in me an appreciation for the "learning process" of a thesis program. I certainly would not have benefitted so much from this process if it had not been for them.

Drs. Oran Hesterman and Robert Deans both served on my graduate committee and deserve my thanks. Their comments and advice were very useful in improving my research design, analysis, and write-up. Also, I would like to thank Drs. George Wilson and Lyndon McLaren, as well as the entire Jamaican Agricultural Research Program staff for their steady and cheery support during my year residence in Jamaica. Additionally, Mrs. Gayle, Knight, Malcolm, Simmonds, and Dr. Wellington of Alcan Jamaica Co., Agricultural Division deserve my thanks for the logistical and technical support they gave me during my study.

I am also indebted to my parents, Don and Dolores, and my siblings, Tim, Lois, Debby, Tom, Mary, and Ellen, for their material, moral, and emotional support. Their encouragement and love have been with me since my earliest memories. I feel truly blessed to have them as family, and hope that I am as supportive of them as they have always been of me.

Finally I would like to thank my follow graduate student and other friends in East Lansing. Their comradery, friendship, and spirited engagement of Friday Afternoon Club activities have made my time here truly enjoyable.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

INTRODUCTION

The main premise of this thesis is that fodder trees are extremely valuable livestock feed resources, which are presently under-utilized in Jamaica. Given appropriate testing and investigation, tree fodder could be incorporated into the Jamaican livestock production system particularly to improve dry season feed availability. On-farm production of tree fodder resources is not capital intensive. Thus, tree fodder production is specially well suited for incorporation into the farming systems of small-scale farmers who have limited financial resources.

The text is divided into three chapters. Chapter 1 discusses the impact of soil cultivation, fertilization, and weed control as establishment techniques for fodder trees in grass pasture ecosystems. Chapter 2 discusses the evaluation of fifteen different exotic fodder tree species for potential incorporation into the pasture component of the Jamaican livestock production system. Chapter 3 presents approximate analysis nutritive values for the more promising exotic fodder tree species in chapter 2 and some commonly used native Jamaican fodder tree species.

The basis for chapter 1 and 2 was research conducted in Jamaica between March of 1990 and March of 1991. The data in chapter 3 were determined between January and April of 1991.

This research was part of a cooperative Silvo-pastoral Research and Development Project between the Department of Forestry, Michigan State University and the Jamaican Agricultural Development Foundation. The project goal is to integrate tree fodder growth and management knowledge with current small-scale farming systems to develop a sustainable small-scale silvo-pastoral management system. The project has already completed a survey of the indigenous knowledge of small-scale cattle farmers in Trelawny Parish (Morrison 1991), and is currently funding a study on the socio-economic conditions and farming systems of the same group of farmers. Additional biological research and the initial testing of different tree fodder production systems are scheduled to begin in the same community in the fall of 1991.

EFFECT OF WEED CONTROL, FERTILIZATION, AND PLANTING PIT SIZE ON SURVIVAL AND GROWTH OF DIRECT SEEDED AND SEEDLING TRANSPLANTS OF *CALLIANDRA*, *GLIRICIDIA*, AND *LEUCAENA*.

Abstract. In Jamaica, a field experiment was designed to determine the feasibility of establishing fodder trees in grass pastures by direct seeding, and to investigate the affect of planting pit size, fertilization, and weed control on the survival and growth of direct seeded and transplanted trees. Results demonstrate that *Leucaena* and *Gliricidia* can be established by direct seeding. The potential of direct seeding for *Calliandra* was not thoroughly tested.

Of the three experimental factors tested only weed control yielded consistent and positive effects on fodder trees. Circle weeding was superior to bushing alone at improving tree survival and growth. Circle weeding also decreased insect predation when compared to bushing alone. Initial investigation showed that grass mulch is ineffective as a weed control. Planting pit size produced contradictory results. In most instances, larger planting pits had neutral or negative affects on tree survival and growth. The preparation of larger pits is not justified. Nitrogen fertilization eight weeks after sowing or transplanting had little positive influence on tree survival or growth. Fertilization is not advocated.

INTRODUCTION

Trees can be extremely valuable animal fodder resources. Torres (1983) described the widespread reliance on tree fodder as a dry season emergency feed in Australia. Le Houerou (1980) edited a thorough compilation on the importance of tree browse to animal production in Africa. In Nepal, over fifty percent of fodder needs are supplied from trees (Pandey 1982). Surveys show that up to 93 percent of Nepalese farmers cultivate fodder trees (Malla 1988), and that trees are the single most important fodder source on some farms (Rusten 1989). In other countries tree fodder is currently receiving attention as a means of increasing livestock production on small farms (IDRC 1990, Logan and Radcliffe 1985).

In the past, tree fodders have had little impact on Jamaican livestock production (JLA 1983). Pasture grasses are the main source of livestock feed (Kaplan et al. 1976). These grass resources are nutritious and able to sustain high levels of animal production during the wet season (JLA 1983). However, during the annual December to March dry season (CRIES 1982) grasses lose much of their nutritional value.

Incorporating fodder trees into pastureland can help overcome this dearth of quality dry season feed (Robinson 1985). Trees have extensive root systems that tap subsoil water throughout the year (Sanchez et al. 1985). This enables trees to retain foliage in the dry season, providing a timely supply of fresh succulent fodder when grass resources are dry. Tree fodders are also nutritious throughout the year (Reynolds and Adeoye 1986, Akkasaeng et al. 1989), containing crude protein levels of 10-20% with some species having levels as high as 25-30% (IDRC 1990).

Calliandra calothyrsus, Gliricidia sepium, and Leucaena leucocephala are three widely used fodder tree species. The literature clearly documents their value as livestock feed resources, particularly for the dry season. In Australia, cattle grazing pastures containing Leucaena gained 84% more weight annually then those grazing pure grass pastures (Quirk et al. 1990). In West Africa, Gliricidia and Leucaena are used to increase dry season production of small ruminants (Reynolds and Adeoye 1986). In Thailand, Vearasilp (1981) reports the use of Gliricidia and Leucaena as dry season rations to increase sheep production. In Sri Lanka, the use of Gliricidia with rice polish is as efficient as fresh grass and concentrates in producing weight gain in dairy heifers (Chadhokar and Sivarsupiramajam 1983). Research on Calliandra is not as extensive, but indicates that it is a productive feed when used as a mixed ration (NRC 1983, NFTA 1989a).

Researchers, development organizations, and large livestock producers in Jamaica have recently become interested in Calliandra, Gliricidia, and Leucaena as forage crops for livestock production (JADF 1988, Wellington 1989, Ruegsegger 1990). The successful use of these species as dry season feeds in other parts of the Caribbean (Paterson et al. 1987, 1988), has lead to the expectation that they could also be used in Jamaica. Before these species are widely recommended or used in Jamaica, establishment techniques which maximize survival and growth, and minimize cost and effort should be developed.

The objectives of this study were; 1) to determine the feasibility of direct seeding Calliandra, Gliricidia, and Leucaena in Jamaican grass pastures, and 2) to investigate the effect of soil cultivation, fertilization, and weed control on the survival and growth of direct seeded or transplanted Calliandra, Gliricidia, and Leucaena trees.

Literature Review

Soil Cultivation. In tropical climates competition between crop trees and weeds (i.e. grass, herbaceous, or woody plants) is often intense. Tree establishment can be improved by practicing full site cultivation (Evans 1982). Soil cultivation reduces weeds and enhances soil aeration and water infiltration (Karlan et al. 1990). Under these improved conditions, root growth is easier and plant energy inputs necessary for establishment are reduced (Lal 1979). Full site cultivation is common in South Africa with short rotation tree crops (Germishuizen and Marais 1980, Schonau et al. 1980).

After establishment, annual soil cultivation also improves survival and growth. White (1985, 1986) reported that five years of annual soil cultivation increased fuelwood production up to 25 times. In south Texas, Felker et al. (1986) found that annual surface cultivation doubled Leucaena and Prosopis seedling biomass in the first 21 months. A two year study in Egypt found that monthly cultivation to 15 cm increased Casuarina height and diameter growth by 30% and 100% respectively (Badran et al. 1986).

Although full site or annual cultivation benefits tree survival and growth, long-term negative effects can occur. Repeated cultivation reduces soil moisture and organic matter levels, and destroys soil structure and pore stability (Lal 1979). Reduction of vegetative cover also increases the risk of soil erosion (Hamilton and Pearce 1987).

To avoid these hazards, partial site cultivation during establishment is commonly practiced. In many places, tree seedlings are transplanted into planting pits of various sizes (Evans 1982, Germishuizen and Marais 1980, Shrestha 1980). A planting pit is an area, normally prepared shortly before planting, where the soil is finely cultivated to certain dimensions. In Nepal (Neville 1987) and semiarid West Africa (Nicou 1986) studies indicate that wider and deeper planting pits improve seedling survival and growth of various species in the first two years after establishment. Studies in South Africa by Schonau et al. (1980) demonstrated that pit width is more important then depth for increasing Eucalyptus grandis seedling growth.

All studies do not show that increased pit size significantly improves tree survival or growth. Sloan (1988) tested three different pit sizes with Pinus ponderosa in southern Idaho, and Nair et al. (1986) tested six pit sizes with Eucalyptus grandis in India. In neither study was tree survival or growth positively affected by planting pit size. In summary, if soil characteristics are not limiting plant growth, then soil cultivation beyond that necessary for seed sowing or seedling planting is superfluous.

Fertilization. Nitrogen fixing trees increase the amount of available soil nitrogen through their symbiotic relationship with Rhizobium bacteria (Postgate 1987). This relationship often helps improve tree growth, but potential growth may still be limited by a shortage of nitrogen. Hill (1970) found that the application of 30 kg N/ha improved survival and growth of Leucaena. Aziz and Habte (1989) found that nitrogen fertilization not only improved growth, but also increased mycorrhizal activity, phosphorous uptake, and nodulation of Leucaena on eroded soils. Saininga et al. (1988) reported that the application of nitrogen fertilizer improved establishment of Leucaena and hastened the nitrogen fixation process by eight weeks.

Other studies have reported that nitrogen fertilization can impede nitrogen fixation (Maasdorp and Gutteridge 1986, Faria et al. 1985, Umali-Garcia et al. 1988). The inhibition is not always complete or irreversible. Initial work with Robinia pseudoacacia indicated that nitrogen fixation rates returned to previous or higher levels once the chemical fertilizer was no longer available to the plant (Johnsen 1991).

Nitrogen fertilization is particularly important in improving the slow germination and early growth of some nitrogen fixing trees (Jones et al. 1983a). Moloney et al. (1986) found that the equivalent of 100 kg N/ha significantly increased the dry yields of 15 week old Adenanthera pavonina, Albizia falcataria, and Schleinitzia insularum seedlings by 100% when phosphorus was not limiting. Jones et al. (1983a) reported that nitrogen application at sowing hastened Leucaena emergence and improved growth at 10 weeks. Similarly, Jones

(1985) found that nitrogen fertilization improved Leucaena growth at both 10 and 30 weeks. In a field establishment study in Zimbabwe, Stewart and Gwaze (1988) reported NPK fertilization increased Acacia albida survival by 10 to 20% and shoot dry weight by 100% at 30 weeks.

Weed Control. Whether trees are being grown as timber, fuelwood, or fodder crops, weed control during establishment is a common practice (Evans 1982, Shrestha et al. 1980). Grass, herbaceous, and woody weeds all compete with crop trees for sunlight, soil moisture and nutrients. Control of weed species redirects the growth potential of the site towards the intended crop.

Weed control can be applied in many forms. Clean weeding is the removal of all vegetation on site. Strip weeding is the use of alternating weeded and unweeded strips across the site. Circle weeding is the removal of weed vegetation in a circle around the crop trees. With clean, strip and circle weeding control of competition includes the removal of weed root masses in the designated area. Bushing is the cutting of all above ground vegetation.

Studies have shown that clean weeding improves the survival and growth of trees (Cooksley 1987, Evans 1982, Sabas and Kalaghe 1986), however it also leads to increased soil erosion (Hamilton and Pearce 1987). Circle weeding and bushing also improves tree survival and growth (Evans 1982, Sabas and Kalaghe 1986), but without as great a risk of soil erosion. In addition, both methods retain grass species between fodder trees, thereby providing both wet and dry season feed from the same land (Paterson et al. 1987, 1988).

In the Philippines, Balmocena and Casa (1986) compared circle weeding, strip weeding, and clean weeding with a control. Although the dimensions of strip and circle weeding treatments were not reported, circle weeding was the most effective. After two years, circle weeding increased survival and diameter growth of Petersianthus quadrialatus seedlings by 12% and 400% respectively, over the control.

Besides directly competing with crop trees for site growth potential, weed vegetation may also mask the positive effect of other tree establishment techniques. Badran et al. (1986) reported that soil cultivation was effective at increasing Casuarina survival and growth only when combined with the control of competing vegetation. Squire (1977) found that Pinus radiata only benefit from fertilization and soil cultivation when weed control is practiced. Jones et al. (1983b) found that fertilization of Leucaena without weed control reduced growth. Similarly, in a study of five leguminous tree species, fertilization without weed control reduced growth of Calliandra, Leucaena, and Acacia angustissima (Maasdorp and Gutteridge 1986).

Summary: Tropical grass species grow fast and compete intensely, denying trees the chance to benefit from favorable nutritional and physical characteristics of the soil (Squire

1977). The slow early growth of nitrogen fixing tree species (Jones et al. 1983a), make them more susceptible to grass competition during establishment then other species (Hill 1970, Cooksley 1987). When establishing nitrogen fixing trees in tropical grass pastures measures must be taken to assure acceptable survival and growth.

Soil cultivation before planting, early fertilization and post-planting weed control all improve survival and growth of trees (Hill 1970, Squire 1977, Jones et al. 1983a, Badran et al. 1986, Maasdorp and Gutteridge 1986, Nicou 1986, Neville 1987, Stewart and Gwaze 1988). Their combined use should improve establishment of nitrogen fixing fodder trees in improved grass pastures.

Materials and Methods

Species: Three fodder tree species, Calliandra calothyrsus, Gliricidia sepium, and Leucaena leucocephala, were tested for survival and growth responses to three different establishment techniques. These species produce nutritious fodder and are well suited to the elevation, precipitation and soil type of the study site (Falvey 1982, NRC 1983 and 1984). Additionally, they are fast growing, nitrogen fixing species which establish well by direct seeding (NRC 1983 and 1984, NFTA 1989b).

Seed of Calliandra and Leucaena were provided by the Nitrogen Fixing Tree Association[1]. Gliricidia sepium seed

---

[1]Nitrogen Fixing Tree Association, P.O. 680, Waimanalo, Hawaii

was acquired from Bodles Agriculture Research Station, Ministry of Agriculture, Jamaica. Additional supplies of *Calliandra* and *Leucaena* were collected locally.

Site: The study site was located on a flat grass pasture at Alcan Jamaica Company's Rio Hoe Farms near Moneague, St. Ann Parish. The surrounding area is comprised of rolling pastures and steep forested hills. Elevation of the site is 500 meters. Annual temperatures vary from 15-25^{o}C, and average annual precipitation is 200 cm (Baker 1968). Holdridge (1967) classifies this area as a subtropical moist forest life zone. Suggested land use for the area is pasture and livestock production and natural forest cover (Baker 1968).

The predominate pasture species on site are guinea grass (*Panicum maximum*) and para grass (*Brachiaria mutica*). These species are considered "improved grasses" in Jamaica and are commonly used in livestock production (JLA 1983). The soil is classified as a St. Ann clay loam, a medium deep red clay over white limestone which contains rich deposits of bauxite (Baker 1968). Available phosphorus and potassium are considered low, while nitrogen levels are considered adequate (Hewitt 1964). Soil analysis determined a soil pH of 7.48, total nitrogen of 0.42%, and available phosphorus and potassium of 7 and 95 ppm respectively.

Treatments: Tree survival and growth were monitored in a 2x2x4 factorial experiment testing establishment techniques. The techniques investigated were weed control, fertilization, and soil cultivation.

Weed control was tested at two levels: 1) bushing - cutting back of all above ground vegetation within the replication, and 2) circle weeding - the above treatment combined with the removal of all vegetation, including roots, from a 40 cm diameter circle around each seedling. Weed control was applied on a monthly basis for six months, at which time the trees achieved a dominant position over the grass canopy (Roshetko et al. 1991).

Fertilization was also tested at two levels: 1) control (no fertilization), and 2) a single application of two grams of ammonium sulphate per planting location. Assuming 40 square cm of surface area per location, the approximate rate per hectare was 125 kgs. This is equivalent to the annual spring fertilization rate used on surrounding pasture lands (Malcolm 1990). To avoid burning the plants, fertilizer was applied in a circle 10-15 cm from the seedling (Malcolm 1990). Although fertilization was to occur immediately after germination, drought and logistical problems delayed application until eight weeks after sowing.

Soil cultivation was tested at four levels: 1) 0x0x0 cm (control), 2) 10x10x10 cm, 3) 20x20x20 cm, and 4) 40x40x40 cm. These levels will be referred to as planting pits for the remainder of the paper. Planting pits were prepared one week before sowing with hand tools. The soil was excavated, finely tilled and replaced before sowing.

Experimental Design: There were a total of sixteen treatments per tree species (2 weed control x 2 fertilization x 4 pit sizes). Each species was replicated three times in a split-split block design. This design facilitated application of the treatments and improved the precision of comparing treatment interactions (Little and Hills 1978). Weed control levels were allocated to the main blocks, fertilizer levels to the split blocks and planting pit sizes to the split-split blocks (Figures 1a and 1b). This arrangement provided for the strongest statistical comparison of planting pit size, followed by fertilization, and then weed control (Little and Hills 1978).

Each replicated block was 25.5 x 25.5 meters. Blocks were split to accomodate the two weed control levels, then split again perpendicular to the first division to accomodate fertilizer levels. The resulting quadrants were further subdivided to accommodate the four planting pit sizes. Each of the split-split blocks contained nine measurement trees at a 1.5 x 1.5 meter spacing. Border trees were used to separate the split-split blocks. Each main block contained 17 rows of 17 trees, for a total of 289 trees per replication.

Measurements and Analyses: Stewart and Gwaze (1988) reported shoot dry weight as superior to height as a measure

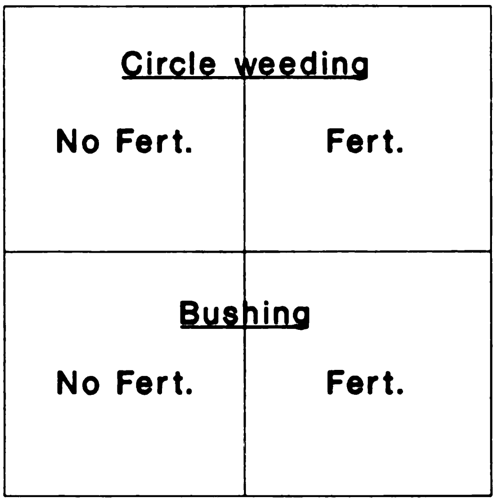
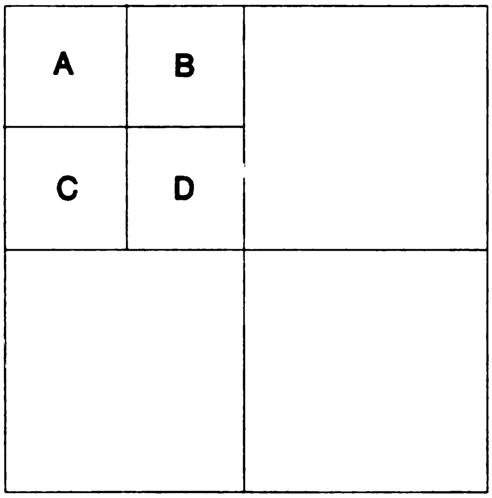


Figure 1a. Main block layout of fertilizer and weed control levels.



A. 40x40x40 cm

B. 20x20x20 cm

C. 10x10x10 cm

D. 0x0x0 cm

Figure 1b. Main block layout of planting pit size levels.

of growth but it requires destruction of the plant. Long-term monitoring plans for the study required that height and diameter be used to measure growth. Additionally, insect damage on Gliricidia seedlings was recorded at six months, insect damage data was not collected for Leucaena because of extremely low survival with some treatments. Analysis of variance (ANOVA) and contrast analysis with linear coefficients were used for statistical comparisons (Little and Hills 1978). Growth data was tested for violations of the assumptions of analysis of variance before analysis, results were non-significant. Survival data were converted from percentages to degrees using arcsine transformation before analysis (Little and Hills 1978).

Establishment: The site was mowed and planting pits excavated one week before seed sowing. Seeds were pre-treated and inoculated with species specific Rhizobium according to accepted guidelines (NFTA 1989a, 1989c), and then sown at a 1-2 cm depth (NFTA 1989b).

As a hedge against poor germination, three seeds were sown per pit (Halliday and Naiko 1984). After 2 months, seedlings were thinned to one plant per pit.

Seeding Failure: Although soil moisture and growing conditions were good before seed sowing (Thompson 1986), establishment of some species was poor. All Calliandra plots failed to germinate (3.5%) and two of the Leucaena plots germinated poorly (21%). Poor germination was assumed to be related to a three week drought that followed seed sowing (Roshetko et al. 1991). Excavation of seeds however, determined that Leucaena had been sown at twice the recommended depth in failed blocks. Calliandra seed, although sown properly, had not received the appropriate pretreatment due to conflicting information (NFTA 1989a, 1989c).

To achieve replication in the only surviving Leucaena block, the fertilizer treatments were not applied. This provided for two replications of Leucaena testing weed control and planting pit size.

Seedling Establishment: Five blocks with insufficient pit occupancy were re-established with seedling nursery stock four months after the initial sowing operations. Four blocks were planted with Leucaena seedlings, and one with Calliandra. All sixteen treatments previously described were applied to the four Leucaena blocks. Only soil cultivation was tested with Calliandra seedlings. The original single block was divided into four replications. Both Leucaena and Calliandra seedlings were established in four replications to increase the number of replications and therefore the precision of the statistical analyses (Little and Hills 1978).

Seedlings were raised in 5x5x15 cm polyethylene nursery tubes according to Liegel and Venator (1987). The tube soil mass of nursery raised seedling altered the size of the planting pit experimental control from zero to roughly 5x5x10 centimeters. Cultivation to 15 cm depth was not necessary due to soil settlement in nursery tubes. Other pit sizes were unaffected. As with direct seeding, three seeds were sown per tube (Halliday and Naiko 1984). Seedlings were thinned to one per tube after six weeks.

Before seedlings were transplanted, the blocks were treated with glyphosate herbicide applied as a 1.0% solution combined with a 1.0% surfactant, frigate (Monsanto 1985). Herbicide application effectively controlled weed growth for two months. Seedlings were transplanted after eight weeks in the nursery. Calliandra seedlings were 15 to 20 cm tall and Leucaena seedlings were 12 to 15 cm tall. Weed control treatments were applied monthly throughout the study period. Fertilizer was applied eight weeks after transplanting.

RESULTS

Germination. All germination percentages were based on three seeds per pit. Occupancy was determined by the number of pits with at least one living seedling. All Calliandra replications and two of three Leucaena replications germinated poorly due to methodological error (See Methods and Materials). In the surviving Leucaena replication germination was only 52%, however, pit occupancy was 86%. Gliricidia germination was 78% with pit occupancy of 96%. Gemination was recorded ten days after sowing and re-checked ten days later. Data was consistent between the two dates. Germination percentages for Calliandra and Leucaena grown in the nursery were not recorded.

Survival and Growth. **Direct Seeding:** ANOVA tables for survival analysis of direct seeded species are in Table 1. Results of survival and growth data analyses are given in Tables 2 and 3. Interactions between factors were not found to be significant in any case.

Weed control was the only practice tested that affected tree survival and growth in a consistent and positive manner. Survival of direct seeded *Leucaena* and *Gliricidia* were 73% and 14% greater, respectively, with circle weeding compared to bushing alone (Table 2 and 3). Total height and basal diameter growth of *Leucaena* and *Gliricidia* were also improved. *Leucaena* total height and basal diameter growth increased by 181 cm (197%) and 19.7 mm (229%) respectively (Table 2). *Gliricidia* total height and diameter increased by 44 cm (34%) and 8.2 mm (33%) respectively (Table 3). Additionally, circle weeding significantly ($P < .05$) decreased severe insect damage by 524% (from 19.4% to 3.7%) over bushing alone.

Fertilization and planting pit size had little effect on *Leucaena* or *Gliricidia* in the first ten months after direct seeding. Fertilization increased *Gliricidia* survival by 4% but had no significant affect on growth. Survival of *Leucaena* was higher in the largest planting pit sizes (Table 2), however contrast analysis determined no significant linear trend between means. Contrasts between treatment means or groups of means were not designated during experimental design, and thus not analyzed (Little and Hills 1978).

Table 1. ANOVA tables of survival data for *Gliricidia* and *Leucaena* trees ten months after direct sowing.

GLIRICIDIA

Factors	DF	Mean Square	F ratio
Main plot			
Replication (Rep)	2	820.83	
Weed Control (WC)	1	3185.02	313.59**
Error A (Rep x WC)	2	10.16	
Split plot			
Fertilization (Fer)	1	212.52	13.45+
Error B (Rep x Fer)	2	15.79	
Split-split plot			
Pit size (PS)	3	23.40	.32
Error C (Rep x PS)	6	72.16	
Interactions (Ints)			
WC x Fer	1	146.30	1.31
WC x PS	3	146.39	1.31
Fer x PS	3	82.84	.74
WC x Fer x PS	3	29.25	.26
Rep x Primary Ints	14	------	----
Error	6	111.93	

LEUCAENA

Factors	DF	Mean Square	F ratio
Mainplot			
Replication (Rep)	1	83.72	
Weed Control (WC)	1	14969.52	636.39*
Error A (Rp xWC)	1	23.52	
Split plot			
Pit size (PS)	3	244.72	5.61
Error B (Rep x PS)	3	43.58	
Interaction (Int)			
WC x PS	3	78.50	
Error	3	133.49	.59

* Significant at P< .05.
** Significant at P< .01.
\+ Significant at P< .10.

Table 2. Leucaena survival and growth by treatment, ten months after direct seeding.

Treatment		Survival -%-		Growth: Ht. -cm-		Basal Dm. -mm-	
Bushing		10*	(4.1)[1]	92+	(18.7)	8.6+	(1.6)
Circle weeding		83	(4.1)	273	(18.7)	28.3	(1.6)
Pit size (cm):	0x0x0	50+	(5.8)	198	(26.9)	20.0	(2.3)
	10x10x10	50	(5.8)	171	(26.9)	17.5	(2.3)
	20x20x20	47	(5.8)	168	(26.9)	16.9	(2.3)
	40x40x40	61	(5.8)	194	(26.9)	19.5	(2.3)

* - Significantly different by ANOVA at P< .05.
+ - Significantly different by ANOVA at P< .10.
[1] - Values in parenthesis are standard errors of the means.

Table 3. Gliricidia survival and growth by treatment, ten months after direct seeding.

Treatment		Survival -%-		Growth: Ht. -cm-		Basal Dm. -mm-	
Bushing		81**	(2.2)[1]	129*	(1.8)	24.9*	(0.3)
Circle weeding		95	(2.2)	173	(1.8)	33.1	(0.3)
Control		86+	(2.2)	147	(1.8)	28.5	(0.3)
Fertilization		90	(2.2)	156	(1.8)	29.4	(0.3)
Pit size (cm):	0x0x0	74	(3.0)	147	(2.6)	28.4	(0.3)
	10x10x10	72	(3.0)	158	(2.6)	30.5	(0.3)
	20x20x20	75	(3.0)	151	(2.6)	29.0	(0.3)
	40x40x40	73	(3.0)	149	(2.6)	28.1	(0.3)

** - Significantly different by ANOVA at P< .01.
* - Significantly different by ANOVA at P< .05.
+ - Significantly different by ANOVA at P< .10.
[1] - Values in parenthesis are standard errors of the means.

Seedling Establishment: ANOVA tables for survival analysis of Leucaena and Calliandra seedlings are in Table 4. Survival and growth data are given in Tables 5 and 6. The interaction between weed control and fertilization treatments was significant for Leucaena basal diameter growth. Fertilization improved diameter growth of Leucaena (by 12.9%) only when circle weeding was practiced. Bushing alone did not provide adequate weed control for seedlings to benefit from fertilization (Figure 2). Leucaena survival and height growth were unaffected by fertilization. All other interactions were non-significant.

As a single factor, weed control significantly affected growth of Leucaena seedlings but had no affect on seedling survival. Total height and basal diameter growth increased by 7 cm (6.6%) and 3.4 mm (29.6%) respectively (Table 5). Fertilization had no direct affect on Leucaena seedlings.

Planting pit size affected seedling transplants of both species. Larger planting pits positively affected Calliandra seedling survival, but negatively affected basal diameter growth of both Calliandra and Leucaena seedlings (Table 5 and 6). Contrast analysis using linear coefficients confirmed the linear relationships in all three of these data parameters, as well as for total height growth of Calliandra seedlings (Table 5 and 6). Although not significant under ANOVA or contrast analysis, Leucaena total height growth also showed a negative trend with increased pit size.

Table 4. ANOVA tables of survival data for **Leucaena** and **Calliandra** seedlings six months after transplanting.

LEUCAENA

Factors	DF	Mean Square	F ratio
Main plot			
Replication (Rep)	3	3271.62	
Weed Control (WC)	1	1756.66	3.16
Error A (Rep x WC)	3	556.10	
Split plot			
Fertilization (Fer)	1	17.33	.08
Error B (Rep x Fer)	3	321.39	
Split-split plot			
Pit size (PS)	3	278.14	.13
Error C (Rep x PS)	9	2091.51	
Interactions (Ints)			
WC x Fer	1	5.23	.01
WC x PS	3	198.70	.15
Fer x PS	3	242.42	.19
WC x Fer x PS	3	385.49	.30
Rep x Primary Ints	21	------	----
Error	9	432.57	

CALLIANDRA

Factors	DF	Mean Square	F ratio
Plot			
Replication (Rep)	3	4.12	
Pit size (PS)	3	477.40	3.69+
Error (Rep xPS)	9	129.46	

\+ Significant at P< .10.

Table 5. Leucaena survival and growth by treatment, six months after transplanting.

Treatment		Survival -%-		Growth: Ht. -cm-		Basal Dm. -mm-	
Bushing		68	(3.7)[1]	106+	(4.0)	11.5*	(0.3)
Circle weeding		81	(3.7)	113	(4.1)	14.9	(0.3)
Control		75	(3.7)	106	(4.1)	12.8	(0.3)
Fertilization		79	(3.7)	113	(4.0)	13.6	(0.3)
Pit size	5x5x10	69	(5.2)	118	(5.8)	14.3*ƒ	(0.4)
(cm):	10x10x10	74	(5.2)	108	(5.8)	13.8	(0.4)
	20x20x20	75	(5.2)	107	(5.6)	12.5	(0.4)
	40x40x40	77	(5.2)	105	(5.6)	12.2	(0.4)

* - Significantly different by ANOVA at P< .05.
\+ - Significantly different by ANOVA at P< .10.
ƒ - Significant linear relation by contrast analysis at P< .05.
1 - Values in parenthesis are standard errors of the means.

Table 6. Calliandra survival and growth by treatment, six months after transplanting.

Treatment		Survival -%-		Growth: Ht. -cm-		Basal Dm. -mm-	
Pit size	5x5x10	81+ƒ	(5.7)[1]	244ƒ	(4.9)	36.3+ƒ	(1.1)
(cm):	10x10x10	78	(5.7)	230	(4.9)	36.9	(1.1)
	20x20x20	92	(5.7)	232	(4.9)	34.3	(1.1)
	40x40x40	97	(5.7)	225	(4.9)	32.6	(1.1)

\+ - Significantly different by ANOVA at P< .10.
ƒ - Significant linear relation by contrast analysis at P< .05.
1 - Values in parenthesis are standard errors of the means.

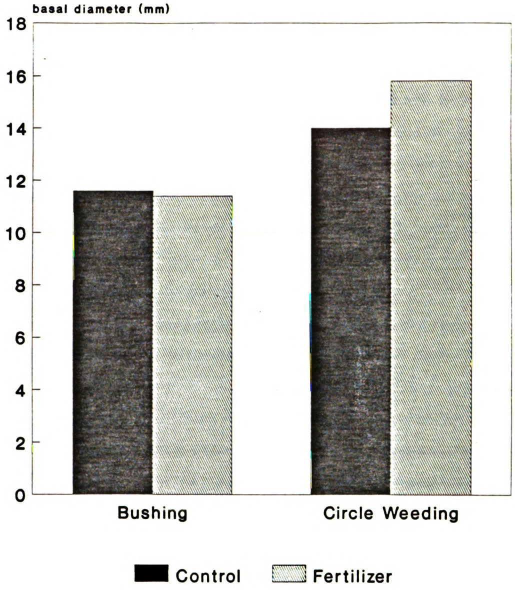


Figure 2. Effect of weed control x fertilizer interaction on Leucaena diameter growth at 6 months.

DISCUSSION

Germination. Despite a three week drought immediately following seeding, Leucaena and Gliricidia were successfully established by direct seeding into pastures where heavy grass competition exists. Appropriate seed scarification, Rhizobium inoculation, and seed sowing procedures were necessary for direct seeding to be successful. Depth of sowing is extremely important. Leucaena seeds were particularly sensitive to being sown too deep. Ruegsegger (1991) found similar results when direct seeding Leucaena and Gliricidia.

In this study, Calliandra did not successfully establish by direct seeding, probably because it was not properly scarified (NFTA 1989). When properly scarified Calliandra growth in both the nursery and field exceeded that of Leucaena. Results from other researchers recommend Leucaena, Gliricidia as well as Calliandra for establishment by direct seeding (Fields and Yassin 1990).

Weed control. This study clearly indicates that circle weeding is better than bushing alone when establishing Leucaena and Gliricidia trees in improved pastures. Tropical grasses compete intensely for sunlight, soil moisture, and nutrients (Squire 1977). Depending upon climatic conditions, monthly grass growth varied from 70 to 150 cm in height per month. Confronted with such intense weed growth, it is assumed that even bushing alone would significantly improve tree survival and growth over no weed control at all.

Circle weeding was very effective at improving survival and growth of both directly sown and transplanted species. Elimination of vegetation around each seedling provided a weed free zone in which seedlings could establish and grow. This weed free zone was very important to Leucaena. Only 10% of direct seeded Leucaena survived in bushing alone plots. The height increases provided by circle weeding enabled Leucaena and Gliricidia to achieve dominant positions in the pasture. Trees that received bushing alone were either suppressed by or equal to the grass canopy after ten month's growth.

Susceptibility of Leucaena to weed competition has been reported by others (Cooksley 1987, Hill 1980). Establishment of this species should not be attempted without weed control similar to the circle weeding used in this study. Gliricidia is also known to be sensitive to weed competition when established by direct seeding (NFTA 1989b). In this study, Gliricidia benefitted from circle weeding, but was much more competitive then Leucaena. Gliricidia can establish with bush weeding alone, but circle weeding is recommended.

Although the growth increases of Leucaena were biologically great, they were not highly significant ($P<.10$). This is partially due to the low number of replications, fewer replications decrease statistical precision (Little and Hills 1978), and the wide variation in the data. The low level of statistical significance should not cause the importance of these growth increases to be disregarded.

Besides directly decreasing weed competition, circle weeding also decreased insect predation on young trees. Severe insect damage of Gliricidia was over five times greater with bushing alone compared to circle weeding six months after seed sowing. Severe insect damage was defined as complete defoliation, topping, or mortality caused by insects. It is speculated that the removal of the vegetation in the circle weeded plots denied insects the access to the seedlings. Once trees achieved a dominant position in the pasture, six months after sowing, insect attacks greatly diminished. Survival in Leucaena plots was so skewed (survival only 10% in bushing alone plots) that quantifying insect damage was not attempted. However, as with Gliricidia, once Leucaena achieved dominance in the pasture, insect predation decreased greatly.

Studies have shown that complete weed control would increase tree survival and growth more then partial control (Evans 1982, Sabas and Kalaghe 1986). However the grass retained by circle weeding is a valuable forage asset. The two level forage production offered by a combination of grasses and fodder trees better utilizes site growth potential and distributes forage availability over the year. Grass production is used during the wet season when it is succulent and nutritious, and tree fodder is used in the dry season when grass nutritive values are low (Ahmed 1986, Paterson et al. 1987, 1988). Trees retain fresh nutritious foliage through the dry season because of their deep perennial root systems

(Sanchez et al. 1985, Wilson et al. 1986). The value of this grass/fodder tree system far exceeds the potential fodder tree growth increase possible with complete weed control.

Other means of weed control. In this study weed control was accomplished by manual means. In Jamaica the availability of agricultural labor is often tenuous (LeFranc 1981). When it became necessary to re-establish some of the study plots, herbicide was used as a pretreatment. Herbicide application was effective at controlling weed growth for two months, and made subsequent manual weeding applications less time consuming. Weed control treatments were applied monthly to the Leucaena seedling plots. Circle weeding significantly improved total height and basal diameter growth, but not as much as in the direct seeding plots where herbicide was not used. Circle weeding had no effect on Leucaena survival when herbicide was used as a pretreatment.

In Jamaica, both manual and chemical weed control methods can be expensive or difficult to acquire. Which method to employ is determined by availability workers and equipment, as well as the respective costs which often fluctuate. No economic comparison between manual weeding and herbicide use has been attempted because of this reason and the seasonal variation in plot establishment.

The use of mulch as a weed control was also investigated during the study. Four inches of grass mulch (Panicum maximum and Brachiaria mutica) was applied between plots where weed competition was similar to that within plots. For two weeks, mulch retarded grass growth almost 100%, but after one month grass growth was equal to that in the unmulched area. How this would affect tree survival and growth was not studied, but this method of mulching did not decrease the necessity of weed control. In the Philippines, Principe (1976) found that grass mulching at planting did not improve nine month survival or growth of Gmelina arborea seedlings, or decrease weed growth. The use of mulch as weed control is not suggested unless combined with complete weeding.

Planting pit size. Studies by Neville (1987) and Nicou (1986) have indicated that larger planting pit size improves establishment of tree species. Conversely, Sloan (1988) and Nair et al. (1986) found that planting pit size had no affect on tree survival or growth. In this study planting pit size had no straightforward affect on tree survival or growth. Trees established by direct seeding were unaffected by pit size. Survival of Calliandra transplants was positively affected by larger pits. Growth of Leucaena and Calliandra seedling transplants, however, were negatively affected by larger planting pits.

Although these results are conflicting, most evidence indicates that larger pit sizes have a negative or neutral effect on trees. Site soil characteristics do not appear to restrict tree survival or growth. The time and costs of preparing planting pits is not warranted. Soil cultivation beyond what is necessary for seed sowing or seedling planting is not recommended.

Fertilization. Fertilization had little affect on tree survival or growth in this study, even through soil analysis confirmed nitrogen deficiencies (Malcolm 1990). In one case, tree basal diameter growth was increased by fertilization, but only when combined with circle weeding. Trends towards increased survival and growth were apparent with fertilization, but improvements were inconsistent and biologically small. The costs of fertilizer and application were not justified.

When nitrogen fertilizers are applied at sowing, improved tree survival and growth can occur (Jones 1985, Moloney et al. 1986, Stewart and Gwaze 1988). In this study fertilizer application was delayed until the eighth week. The opportunity to accelerate germination and early tree growth, which can be slow and detrimental to establishment, may have been lost by this delay. In the future, fertilization should occur at sowing or planting.

General growth observations. Three and six month growth data for direct sown species have been reported elsewhere (Roshetko and Lantagne 1990, Roshetko et al. 1991). At both intervals, results were similar to those reported here. Circle weeding significantly improved survival and growth of Leucaena and Gliricidia, but fertilization and planting pit size had no significant affect. The effect of circle weeding on Leucaena survival and growth, and Gliricidia survival accelerated with time. The effect on Gliricidia growth remained constant.

Similar periodic growth data for these species are not available. However, growth rates of Leucaena in this study compare favorably with general information (NRC 1984), and other sites in Jamaica (Thompson 1985). Gliricidia growth rates for other Jamaican sites were not available.

Growth rates of Calliandra in this study parallel general information about this species (NRC 1983). Calliandra height and diameter growth were superior to those of both Leucaena and Gliricidia, even though the Gliricidia trees were four months older (Tables 3, 5 & 6). General observations determined that foliage biomass production were greatest for Calliandra followed by Gliricidia and then Leucaena. This suggests that Calliandra is well adopted to the study site, and potentially an excellent fodder tree species for Jamaica.

CONCLUSIONS

This study indicates that Leucaena and Gliricidia can be established in improved grass pastures by direct seeding, if proper seed scarification, inoculation, sowing procedures and weed control are followed. Direct seeding of Calliandra was not thoroughly tested, but other researchers recommend its establishment by direct seeding (Fields and Yassin 1990).

Weed control was the only factor in this study that had consistent and positive effects on fodder tree survival and growth in improved grass pastures. Results demonstrate that control of weed competition until fodder trees obtain a dominant position in the pasture ecosystem is important. Circle weeding was superior to bushing alone at improving tree survival and growth. Complete weed control would also improve tree survival and growth (Evans 1982, Sabas and Kalange 1986). However, the grass retained by circle weeding is an additional fodder resource. The value of this grass/fodder tree system far exceeds the potential fodder tree growth increases possible with complete weeding. Circle weeding is recommended for weed control.

Soil cultivation (i.e. planting pit size) contributed inconsistent results in this study. Under direct seeding, planting pit size generally had no affect on tree survival or growth. Larger pit size also had a neutral influence on survival of seedling transplants, but a negative affect on growth of transplants. For this site, soil cultivation beyond what is necessary for seed sowing or seedling planting is superfluous or deleterious, and not encouraged.

Nitrogen fertilization eight weeks after sowing or transplanting had little positive influence on tree survival or growth, it is not advocated. Survival and growth of nitrogen fixing trees can be positively affected by fertilization at sowing (Jones 1985, Moloney et al. 1986, Stewart and Gwaze 1988). If fertilization is desirable, it is recommended at sowing or planting.

Contrary to studies by Squire 1977, Jones et al. 1983b, and Badran et al. 1986, no additive or synergistic effects were realized by combining weed control and soil cultivation, or fertilization and soil cultivation treatments. Fertilization positively affected growth only when combined with adequate weed control. These results agree with those of others working on nitrogen fixing trees and fertilization (Jones et al 1983b, Badran et al. 1986, and Maasdorp and Gutteridge 1986).

ACKNOWLEDGEMENTS

The author would like to thank the Jamaica Agricultural Development Foundation and the United States Agency for International Development for financial support, Alcan Jamaica Co., Agricultural Division for logistical and technical support and use of the study site, and the Nitrogen Fixing Tree Association for the seeds.

BIBLIOGRAPHY

Ahmed, B. 1986. Growing forage legumes. CARDI Factsheet No. AP-F/21.86. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad. West Indies. 4 p.

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

Aziz, T., and M. Habte. 1989. Influence of inorganic nitrogen on mycorrhizal activity, nodulation and growth of Leucaena leucocephala in an oxisol subjected to simulated erosion. Communications in Soil Science and Plant Analysis 20:239-251.

Badran, O.A., A.B. El-Sayed, and M.H. El-Lakany. 1986. Effect of tillage and gramoxone weed spray on the growth of Casuarina species. Alexandria Journal of Agricultural Research 31:385-395.

Baker, G.H. 1968. Soil and landuse survey No. 24 Jamaica, Parish of St. Ann. Regional Research Centre, Department of Soil Science, University of the West Indies, Trinidad.

Balmocena, R.B., and E.V. Casa. 1986. Growth and development of established toog (Petersianthus quadrialatus (Merr.) Merr.) plantations under four different weeding methods. Sylvatrop 11:55-60.

Chadhokar, P.A., and S. Sivasupiramaniam. 1983. Gliricidia (Gliricidia maculata H.B.& K.) leaves as protein supplement to paddy straw in growing cross-bred heifers. Indian Journal of Animal Science 53:120-125.

Cooksley, D.G. 1987. Effect of weed competition on the early growth of Leucaena leucocephala. Tropical Grasslands 21:139-142.

CRIES. 1982. Jamaican resource assessment. Comprehensive resource inventory and evaluation system project (CRIES). Michigan State University - U.S. Department of Agriculture - The Ohio State University. Department of Resource Development, Michigan State University, East Lansing, Michigan.

Evans, J. 1982. Plantation forestry in the tropics. Oxford University Press. New York, New York. 472 p.

Falvey, J.L. 1982. Gliricidia maculata - A review. International Tree Crops Journal 2:1-14.

Faria, S.M. de, A.R.M. de Jesus, and A.A. Franco. 1985. Field establishment of nodulated Leucaena leucocephala K72. Leucaena Research Report 6:14-16.

Felker, P., D. Smith, and C. Wiesmann. 1986. Influence of mechanical and chemical weed contrrol on growth and survival of tree plantings in semiarid regions. Forest Ecology and Management 16:259-267.

Field, S.P., and M.Yasin. 1990. Improving the effectiveness of multiprurpose tree species research in Nusa Tengarra Timur, Indonesia. pp. 125-132. In: C. Haugen, L. Medema, and C.B. Lantican (eds.) Multipurpose tree species research for small farms: Strategies and methods. Winrock International Institute for Agricultural Development, and International Development Research Centre. Funny Publishing Limited Partnership, Bangkok, Thailand.

Germishuizen, P.J., and J.P. Marais. 1980. Site preparation: Establishment and re-establishment of conifer plantations in the summer rainfall region of southern Africa. pp. 26-46. In: Proceedings of the forest seed, nursery, and establishment research working group, third meeting. Saasveld Forestry Research Station, George, South Africa. South Africa Forestry Research Institute, Wattle Research Institute, University of Natal.

Halliday, J., and P. Nakao. 1984. Technical notes on the germination of leguminous tree seeds. pp. 231-234. In: Simposio Sobre Fixacao de Nitrogenio em Arvores Tropicais. Brazilian Journal of Agricultual Research Volume 19 (Special Issue).

Hamilton, L.S., and A.J. Pearce. 1987. What are the soil and water benefits of planting trees in developing country watersheds? Chapter 4 pp. 38-58. In: D.S. Southgate and J.F. Disinger (eds.) Sustainable resource development in the third world. Westview Press.

Hewitt .W. 1964. Soil technical sheets. Agric. Chem. Div., Ministry of Agriculture, Jamaica. 144 p.

Hill, G.D. 1970. Studies on the growth of Leucaena leucocephala: Effect of clean weeding and nitrogen fertilizer on early establishment. Papua New Guinea Agriculture Journal 22:29-30.

Holdridge, L.R. 1967. Life zone ecology. Tropical Science Center. San Jose, Costa Rica.

IDRC. 1990. Shrubs and tree fodders for farm animals. International Development Research Centre. Ottawa, Ontario, Canada. 349 p.

JADF. 1988. Jamaica Agricultural Research Program Annual Report 1988. Jamaican Agriculture Development Foundation. Kingston, Jamaica.

JLA. 1983. Livestock manual for the tropics. The Jamaica Livestock Association. Kingston, Jamaica. 406 p.

Johnsen, K. 1991. Petawawa National Forestry Institute, Canada. Personal Communication at the International Conference on Black Locust: Biology, culture, and utilization. Michigan State University, East Lansing, Michigan. June 17-21, 1991.

Jones, R.J., G. Vilamizar, and S.J. Cook. 1983a. The effect of seed treatments and nitrogen fertilizer on seedling growth of Leucaena. Leucaena Research Report 4:4-5.

Jones, R.J., G. Vilamizar, and S.J. Cook. 1983b. The effect of nitrogen fertilizer, weed competition, and CCC spray on seedling growth and nodulationof Leucaena. Leucaena Research Report 4:6-7.

Jones, R.J. 1985. Effect of nitrogen and inoculum levels on establishment and nodulation of Leucaena. Leucaena Research Report 6:8-10.

Kaplan, I., H.I. Blustein, K.T. Johnston, and D.S. McMorris. 1976. Area handbook for Jamaica. Foreign Area Studies of the American University. Washington D.C. 332 p.

Karlan, D.L., D.C. Erbach, T.C. Kaspar, T.S. Colvin, E.C. Berry, and D.R. Timmons. 1990. Soil tilth: A review of past present and future needs. Soil Science Society of America Journal 54:153-161.

Lal, R. 1979. Importance of tillage systems in soil and water management in the tropics. pp. 25-39. In: R. Lal (ed.) Soil tillage and crop production. IITA Proceedings No. 2. International Institute of Tropical Agriculture. Ibadan, Nigeria.

LeFranc, E. 1981. The utilization and organization of rural labor in Jamaica. In: H. Blustain and E. LeFranc (eds.) Strategies for organization of small-farm agriculture in Jamaica. Center for international Studies, Cornell University, New York.

Le Houerou, N.H. (Editor) 1980. Browse in Africa: The current state of knowledge. ILCA Addis Ababa. 491 p.

Liegel, L.H., and C.R. Venator. 1987. A technical guide for forest nursery managemant in the Caribbean and Latin America. General Technical Report SO-67. New Orleans, La: U.S. Dep. of Ag., Forest Service, Southern Forest Exper. Station; 156 p.

Little, T.E., and Hills, F.J. 1978. Agriculture experimentation - Design and analysis. John Wiley & Sons, Inc. New York. 350 p.

Logan, I.A., and J.E. Radcliffe (eds.) 1985. Fodder trees - A summary of current research in New Zealand. 49 p. Crop Research Division - Department of Scientific and Industrial Research. Christchurch, New Zealand.

Maasdorp, B.V., and R.C. Gutteridge. 1986. Effect of fertilizer and weed control on the emergence and early growth of fvie leguminous fodder shrubs. Tropical Grassslands 20:127-134.

Malcolm, C.A. 1990. Agronomist, Alcan Jamaica Company LTD. Manderville, Jamaica. Personal Communication.

Malla, Y.B. 1988. The case for placing more emphasis on private tree planting programmes. Forestry Research Paper Series No. 13. HMG-USAID-GTZ-FORD-WINROCK Project. Kathmandu, Nepal. 46 p.

Moloney, R.A., R.L. Aitken, and R.C. Gutteridge. 1986. The effect of phosphorus and nitrogen application on early growth of Adenanthera pavonia, Albizia falcataria, and Schleinitzia insularum. Nitrogen Fixing Tree Research Reports 4:3-6.

Monsanto. 1985 Roundup herbicide - Complete directions for use. Monsanto Company, St. Louis, Missouri. U.S.A. 104 p.

Nair, J.M., A.D. Deo, and T.J.C. Nair. 1986. Reclamation of grasslands at Kulamavu, Kerala. pp. 200-209. In: J.K. Shgarma, C.T.S. Nair (eds.) Eucalypts in India. Past present and future. Proceedings of the national seminar held at Kerala Forest Research Institute, Peechi, Kerala, India.

Neville, G.A. 1987. Site amelioration for the establishment of fodder trees. Banko Janakari 1:32-33. Nepal-UK Forestry Research Project. Kathhmandu, Nepal.

NFTA. 1989a. Calliandra calthyrsus - An Indonesian favorite goes pan-tropic. NFT Highlights. Nitrogen Fixing Tree Association. Waimanalo, Hawaii. 2 p.

NFTA. 1989b. Gliricidia production and use. Nitrogen Fixing Tree Association. Waimanalo, Hawaii. 44 p.

NFTA. 1989c. NFTA cooperative planting program: Establishment guidelines. Nitrogen Fixing Tree Association. Waimanalo, Hawaii. 36 p.

Nicou, R. 1986. Influence of ploughing on soil physical properties and growth of annual crops in semi-arid West Africa: Relevance to tree planting. Forest Ecology and Management 16:103-115.

NRC (National Research Council). 1983 Calliandra: A versatile small tree for the humid tropics. National Academy Press, Washington, D.C. 52 p.

NRC (National Research Council). 1984. Leucaena: Promising forage and tree crop for the tropics. Second Edition. National Academy Press, Washington, D.C. 100 p.

Pandey, K. K. 1982. Fodder trees and tree fodder in Nepal. Swiss Development Cooperation. Berne, Switzerland. 107 p.

Paterson, R.T., G.A. Proverbs, and J.M. Keoghan. 1987. The management and use of forage banks. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad, West Indies. 21 p.

Paterson, R.T., J.M. Keoghan, and G.A. Proverbs. 1988. Forage-based grazing systems for the drier parts of the caribbean region. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad. West Indies. 23 p.

Postgate, J.R. 1987. Nitrogen fixation. Edward Arnold LTD. London, Great Britain. 73 p.

Principe, E.B. 1976. Mulching and fertilization of out planted yemane (Gmelina arborea Roxb.) seedlings. Sylvatrop 1:223-236.

Quirk, M.F., C.J. Palon, and J.J. Bushell. 1990. Increasing the amount of Leucaena on offer gives faster growth rates of grazing cattle in South East Queensland. Australian Journal of Experimental Agriculture 30:51-54.

Reynolds, L., and S.A.O. Adeoye. 1986. Planted leguminous browse and livestock production. Paper presented at: International workshop on Alley Farming for humid and sub-humid regions of tropical Africa. Ibadan, Nigeria. March 10-14, 1986.

Robinson, P.J. 1985. Trees as fodder crops. pp. 281-300. In: M.G.R. Cannell, and J.E. Jackson (eds.) Attributes of trees as crop plants. 592 p. Institute of Terrestrial Ecology. Natural Environment Research Council. Huntingdon, England.

Roshetko, J.M., and D.O. Lantagne. 1990. Fodder tree establishment in Jamaican pastures: Three month results. Paper presented at the Second Annual Seminar for presentation of progress reports on Jamaican Agricultural Research Projects. The Jamaican Agricultural Development Foundation. Kingston, Jamaica. September 18-20, 1990.

Roshetko, J.M., D.O. Lantagne, and M.A. Gold. 1991. Influence of weed control, fertilization, and planting pit size on the survival and growth of Leucaena and Gliricidia establishment by direct seeding in pastures. Nitrogen Fixing Tree Research Reports 9:64-67.

Ruegsegger, G. 1990. On-farm evaluation of Leucaena, Gliricidia and legume/grass conserved fodder as high protein forages in dairy cattle rations. Paper presented at the Second Annual Seminar for presentation of progress reports on Jamaican Agricultural Research Projects. The Jamaican Agricultural Development Foundation. Kingston, Jamaica. September 18-20, 1990.

Ruegsegger, G. 1991. Personal communications.

Rusten, E. 1989. An investigation of an indigenous knowledge system and management practices of tree fodder resources in the Middle Hills of Central Nepal. Ph.D. Dissertation. Department of Forestry, Michigan State University. 282 p.

Sabas, E., and A.G. Kalaghe. 1986. The influence of weeding on early growth of Eucalyptus camaldulensis at Igwala Mwanza Tanzania. Tanzania Silviculture Research Note No. 44 7 p.

Sanginga, N., K. Mulongoy, and A. Ayanaba. 1986. Inoculation of Leucaena leucocephala (Lam.) de Witt with Rhizobium and its nitrogen contribution to a subsequent maize crop. Biological Agriculture and Horticulture 3:347-352.

Sanchez, P.A., C.A. Palm, C.B. Davey, L.T. Scott, and C.E. Rusell. 1985. Tree crops as soil improvers in the humid tropics. pp. 327-358. In: M.G.R. Cannell, and J.E. Jackson (eds.) Attributes of trees as crop plants. 592 p. Institute of Terrestrial Ecology. Natural Environment Research Council. Huntingdon, England.

Schonau, A.P.G., R.V. von Themaat, and D.I. Boden. 1980. The importance of complete site preparation and fertilizing in the establishment of Eucalypts grandis. pp. 1-18. In: Proceedings of the forest seed, nursery, and establishment research working group, third meeting. Saasveld Forestry Research Station, George, South Africa. South Africa Forestry Research Institute, Wattle Research Institute, University of Natal.

Shrestha, K.B., L.B.S. Tulaadhar, and P.K. Tyysljarvi. 1980. Manual on nursery and plantation management practices for Community Forestry Development Project. HMG/ UNDP/FAO Community Forestry Development Project. Kathmandu, Nepal. 102 p.

Sloan, J. 1988. Auger hole shape, size, and tree placement affect survival and root form of planted ponderosa pine in south central Idaho. Proceedings combined meeting of the Western forest nursery associations. Fort Collins, Colorado. Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Dept. of Agriculture. General Technical Report RM:167.

Squire, R.O. 1977. Interacting effects of grass competition, fertiliing, and cultivation on the early growth of Pinus radiata D. Don. Australian Forest Research 7:247-252.

Stewart, H.T.L., and D.P. Gwaze. 1988. Effect of fertilizer and sowing date on eswtablishment and early growth of direct-seeded Acaica albida in Zimbabwe. Nitrogen Fixing Tree Research Reports 6:40-42.

Thompson, D.A. 1985. Leucaena leucocephala trials in Jamaica. Leucaena Research Reports 6:60-62.

Thompson, D.A. 1986. Leucaena leucocephala and other fast growing trees. Organization of American States, Caribbean Region LEUCAENA project, and Department of Forestry and Soil Conservation, Kingston, Jamaica. 36 p.

Torres, F. 1983. Role of woody perennials in animal agroforestry. Agroforestry Systems 1:131-163.

Umali-Garcia, M., J.S. Libuit, and R.L. Baggayan. 1988. Effect of Rhizobium inoculatio on growth and inoculation of Albizia falcataria (L.) Fosh. and Acacia Manquim wild. in the nursey. Plant and Soil 108:71-78.

Vearasilp, T. 1981. Digestibility of rice straw rations supplemented with Leucaena leucocephala ansd Gliricidia maculata. Thailand Journal of Agricultural Science 14:259-264.

Wellington K.E. 1989. Agricultual Director, Alcan Jamaica Company LTD. Manderville, Jamaica. Personal Communication.

White, K.J. 1985. Intercropping strategies and practices in the Bhabar Terai of Central Nepal. Manual No. 1 Sagarnath Forest Development Project. Ministry of Forests. Kathmandu, Nepal. 57 p.

White, K.J. 1986. Tree farming in the Bhabar Terai of Central Nepal. Manual No. 2 Sagarnath Forest Development Project. Ministry of Forests. Kathmandu, Nepal. 199 p.

Wilson, G.F., B.T. Kang, and K. Mulongoy. 1986. Alley cropping: Trees as sources of green-manure and mulch in the tropics. Biological Agriculture and Horticulture 3:251-267.

DIRECT SEEDING OF FODDER TREE SPECIES IN JAMAICAN PASTURES

Abstract. A trial of fifteen fodder tree species was established by direct seeding in an improved pasture in St. Ann Parish, Jamaica. The objective of the experiment was to determine if any of the species have potential to be incorporated into the forage component of Jamaican livestock production systems. After ten months of growth Bauhinia variegata, Leucaena hybrid KX3, Sesbania grandiflora NFTA 835 and 872, and Sesbania sesban NFTA 812 and 873 showed satisfactory survival, height and diameter growth. Cajanus cajan performed satisfactorily for six months, but by study's end had been infected with a root rot and died. All other species performed poorly under direct seeding on this site.

INTRODUCTION

Trees can be extremely valuable animal fodder resources. Torres (1983) described the widespread reliance on tree fodder as a dry season emergency feed in Australia. Le Houerou (1980) edited a thorough compilation on the importance of tree browse to animal production in Africa. In Nepal, over fifty percent of fodder needs are supplied from trees (Pandy 1982). Surveys show that up to 93 percent of Nepalese farmers cultivate fodder trees (Malla 1988), and that trees are the single most important fodder source on some farms (Rusten 1989). In other countries tree fodder is currently receiving attention as a means of increasing livestock production on small farms (IDRC 1990, Logan and Radcliffe 1985).

In the past, tree fodders have had little impact on Jamaican livestock production (JLA 1983). Pasture grasses are the main source of livestock feed (Kaplan et al. 1976). These grass resources are nutritious and able to sustain high levels of animal production during the wet season (JLA 1983).

However, during the annual December to March dry season (CRIES 1982) grasses lose much of their nutritional value.

Protein is one of the most important nutrients for sustained animal maintenance and production (FAO 1988). Crude protein levels in tropical grasses, as high as 14% during the wet season, decline to 5 to 6% during the dry season. This is below the 7% maintenance requirement reported for mature cattle in the Caribbean (Ahmed 1986, Paterson et al. 1987). Low protein, dry forage diets are also low in digestibility and remain longer in the stomach (Minson 1980, Paterson et al. 1988). This reduces feed intake and causes corresponding deficiencies of minerals, vitamins, and energy. Restricted to a dry forage diet, livestock decline in health and may die (Vohnout and Jimenez 1975, FAO 1988).

For a variety of reasons, incorporating fodder trees into pastureland can help overcome this dearth of quality dry season feed (Robinson 1985). Trees have extensive root systems that tap subsoil water throughout the year (Sanchez et al. 1985). This enables trees to retain foliage in the dry season, providing a timely supply of fresh succulent fodder when grass resources are dry. Tree fodders are nutritous throughout the year (Reynolds and Adeoye 1986, Akkasaeng et al. 1989), and contain crude protein levels of 10-20% with some species having levels as high as 25-30% (IDRC 1990).

Although too many trees can decrease grass production by competing for light and moisture, at optimal spacing trees ameliorate environmental conditions which indirectly increase pasture and animal production (Torres 1983). Tree roots enhance soil aeration and water permeability, and tree shade helps decrease soil temperature and desiccation. These factors improve the microsite of the pasture plants (Nair 1983). Deep tree roots also recycle soil nutrients which have leached beyond the grass rhizophere and through litterfall redeposit them on the soil surface (Sanchez et al. 1985). If nitrogen fixing trees are used, the soil enriching ability of the tree litter may lead to increases in grass production (Lowry 1989, Lowry et al. 1988). Trees also provide animals with wind and sun protection. In the tropics, such stress reduction increases animal efficiency and productivity (Daly 1984).

There is increased interest by researchers, development organizations, and large livestock producers to incorporate fodder trees into Jamaican livestock production (Ruegsegger 1990, Wellington 1989, JADF 1988). To date most efforts have concentrated on Gliricidia sepium and Leucaena leucocephala. Considering the vast number of valuable fodder trees already identified (Pandy 1982, Singh 1982, Le Houerou 1980), it is reasonable to believe that many other species, both native and exotic, hold potential for Jamaica. The objective of this study was to identify other fodder tree species that may be useful in Jamaica and determine if they can be established by direct sowing. Fifteen fodder tree species were established by direct sowing in an improved grass pasture and evaluated by survival and growth measures ten months after sowing.

Materials and Methods

Species: Based on a search of the literature (Pandey 1982, Singh 1982, Le Houerou 1980), fifteen fodder tree species were included in the trial (Table 1). Only one of the species, Leucaena, is "native" to Jamaica (Adams 1972). Of the remainder all but two have been naturalized in Jamaica or the Caribbean for a long period (Adams 1972, Little and Wadesworth 1964, Little et al. 1974). The two newly introduced exotic species are Chamaecytisus palmensis and Flemingia macrophylla. Seed for thirteen of the species were provided by the Nitrogen Fixing Tree Association (NFTA)[1]. Seed of Bauhinia variegata and one of the Albizia saman sources were collected locally. All of the species except Bauhinia variegata are nitrogen fixing species (Allen and Allen 1981, Koul et al. 1989).

Site: The study site was located on a flat grass pasture at Alcan Jamaica Company's Rio Hoe Farms near Moneague, St. Ann Parish. The surrounding area is comprised of rolling pastures and steep forested hills. Elevation of the site is 500 meters. Annual temperatures vary from 15-25°C, and average annual precipitation is 200 cm (Baker 1968). Holdridge (1967) classifies this area as a subtropical moist forest life

---

[1]Nitrogen Fixing Tree Association, P.O. 680, Waimanalo, Hawaii

zone. Suggested land use for the area is pasture and livestock production and natural forest cover (Baker 1968).

The predominate pasture species on site are guinea grass (Panicum maximum) and para grass (Brachiaria mutica). These species are considered "improved grasses" in Jamaica and are commonly used in livestock production (JLA 1983). The soil is classified as a St. Ann clay loam, a medium deep red clay over white limestone which contains rich deposits of bauxite (Baker 1968). Available phosphorus and potassium are considered low, nitrogen levels are considered adequate (Hewitt 1964). Soil analysis determined a soil pH of 7.48, total nitrogen of 0.42%, and availalbe phosphorus and potassium of 7 and 95 ppm, respectively.

Establishment: Site preparation was conducted two weeks before sowing operations. First, the pasture was mowed with a tractor. Then, sowing pits of 10x10x10 cm were excavated with hand tools, the soil was finely tilled and replaced. Seeds were sown at a 1-2 cm depth. Before sowing, seeds were pre-treated and inoculated with species specific Rhizobium according to accepted guidelines (NFTA 1987-90). The only exceptions were: 1) Flemingia macrophylla, which was not pretreated with hot water due to conflicting information, and 2) the Desmodium species, which did not receive Rhizobium inoculum because none was available. As a hedge against mortality multiple seeds were sown per pit (Halliday and Naiko

1984). Depending on expected germination and available supplies the number of seeds sown varied from 4 to 10.

Competition from pasture grasses for moisture, nutrients, and sunlight was intense. Depending on climatic conditions, grass species grew from 70 to 150 cm in height per month. Manual weed control of these grasses occurred monthly and took two forms: 1) the cutting back of all above ground vegetation within the trial, and 2) the removal of all vegetation, including roots, from a 40 cm diameter circle around each seedling. This second operation maintained a weed free zone in which the seedling could thrive. Monthly weed control was conducted for six months.

Experimental Design: Each species in the trial was established in a single unreplicated block of twenty-five sowing positions at a spacing of 1.5 x 1.5 meters. The nine interior positions of each block were used to measure survival and growth. Eight weeks after sowing the interior pits were thinned to contain one seedling. Germination was measured three weeks after sowing. Nodulation was observed at eight weeks. Survival and growth were measured at ten months.

RESULTS AND DISCUSSION

Germination. Despite a three week drought immediately following seed sowing, most of the species exhibited satisfactory germination. Only *Albizia lebbeck*, *A. procera*, *Desmodium gyroides*, and *Flemingia macrophylla* had germination rates below 50 percent. Additionally, Albizia saman (local) and Chamaecytisus palmensis did not germinate (Table 1), and will not be discussed further.

Some species displayed delayed germination. This is discernible in Table 1 where survival is greater than germination. It is speculated that dry conditions during the drought temporarily suspended seedling emergence. Once the rains returned more germination was observed. Only with D. gyroides was delayed germination great, increasing from 5 to at least 20 percent. Hot and dry conditions during the drought had a negative effect on Desmodium nicaraguense, although germination was 60% at three weeks most of the germinants died before becoming established. This species appears very sensitive to heat stress and weed competition.

Nodulation. With the exception of B. variegata, field examination showed that all species in the study, including those not inoculated, formed root nodules. In all cases nodules were fresh, pink and appeared to be "effective" (Postgate 1987).

Survival and Growth. Subsequent survival after germination was satisfactory for only six of the species after ten months (listed in Table 1). All six, Bauhinia variegata, Leucaena, and the four Sesbania species, had survival rates that when combined with sowing multiple seeds per pit ensured high site occupancy. These species also demonstrated fast growth despite heavy vegetative competition. After three months these

Table 1. Germination (at three weeks), survival, height and diameter growth of study species at ten months.

Species	Seed lot	Germination[1] -%-	Survival[2] -%-	Height -cm-	Diameter Basal	Diameter DBH[3]
Albizia lebbeck	NFTA 802	14	4	118	14	--
Albizia procera	NFTA 865	31	18	109	30	--
Albizia saman	NFTA 825	61	33	105	22	--
Albizia saman	local	--	--	--	--	--
Bauhinia variegata[4]	local	97	96	345	45	--
Cajanus cajan	NFTA 826	61	--	--	--	--
Chamaecytisus palmensis	NFTA 489	--	--	--	--	--
Desmodium gyroides	NFTA 730	5	20	124	21	--
Desmodium nicaraguense	NFTA 731	60	0.4	179+	26+	--
Flemingia macrophylla	NFTA 897	6	4	204	20	--
Leucaena hybrid[4]	KX3	61	59	377	35	23
Sesbania grandiflora[4]	NFTA 835	75	70	567	55	42
Sesbania grandiflora[4]	NFTA 872	55	66	384	63	36
Sesbania sesban[4]	NFTA 812	83	79	531	65	40
Sesbania sesban	NFTA 873	77	79	405	54	31

Note: Albizia saman is synonymous with Samanea saman.

1 Germination at three weeks, based on total number of seeds sown.
2 Survival % represents seedlings remaining in pits at 10 months.
3 DBH is Diameter at breast height (1.5 meters)
4 Species that have performed satisfactory through 10 months.
\+ Only one specimen of Desmodium nicaraguense survived.

species, with the exception of Leucaena, were in codominate or dominate positions compared to the pasture vegetation. Although weed control was continued for six months, it was not necessary after four months. After six months, Sesbania species established a closed canopy which suppressed grass growth.

Cajanus cajan performed very well for six months, height growth was 292 cm - greater then all species except S. grandiflora NFTA 835 and S. sesban NFTA 812, and survival was 67 percent (Roshetko et al. 1991). By ten months all the Cajanus trees were infected with a root rot and most were dead. Field identification of the pathogen indicated Macrophomina phaseolina (Sinclair et al. 1987), a common disease of Cajanus (Daniel and Ong 1990).

The other six species have performed poorly under direct seeding in pastures. The Albizia species, F. macrophylla, and the Desmodium species are all recommended for direct seeding, if weed control is practiced through establishment (NRC 1979, 1980, NFTA 1987, 1988a, 1989a, Jackson 1987, Paterson 1988). In this study monthly weed control for six months was inadequate to furnish these species with a competitive advantage over the pasture grasses. After ten months, pasture grasses continue to dominant and suppress all of these tree species except F. macrophylla, which is in a codominant position. All six of these species also displayed low germination and survival rates.

In Indonesia, A. saman survived poorly when planted in a grass ecosystem. In the same study, A. procera survived satisfactorily, but grew slowly for three years. In the fourth year growth improved greatly, and fodder production equalled that of Leucaena and Gliricidia (Blair et al. 1988). For the species that performed poorly in this study, more intensive weed control for a longer period of time may lead to acceptable establishment. This represents an increase expense of time and money. In view of the superior growth of B. variegata, Leucaena, and the Sesbania species under the original weed control conditions, this increased expense would not be justified.

CONCLUSION

From this study it appears that Bauhinia variegata, Leucaena hybrid KX3, Sesbania grandiflora 835 and 872, and Sesbania sesban 812 and 873 can be established in improved pastures by direct seeding. All of these species are valued fodder resources (Pandy 1982, NRC 1984, NFTA 1990), and have potential to supplement Jamaican livestock production. Follow up studies to determine nutritive value of these species are reported in the following chapter.

Of the species that performed poorly in this study one deserves special mention. Cajanus cajan is a common pea crop in Jamaica, but it is unknown as a fodder crop. Under proper management this species can produce both pods and fodder.

Although it had died out by the end of the study, C. cajan did establish successfully by direct seeding. It may hold great potential as a fodder crop in Jamaica.

The other species that performed poorly in the study may have a useful role as fodder resources in Jamaica, but because of their low survival and relatively slow growth are not recommended for direct seeding into improved grass pastures for this site. Improved weed control, fertilization, and use of seedling or stump sprouts (Jackson 1987) may be useful in establishing these species in grass pasture ecosystems. Species that demonstrated low germination should be retested to determine if failure was due to poor seed quality.

ACKNOWLEDGEMENTS

The author would like to thank the Jamaica Agricultural Development Foundation and the United States Agency for International Development for financial support, Alcan Jamaica Co., Agricultural Division, for logistical and technical support and the use of the research site, and the Nitrogen Fixing Tree Association for the seeds.

BIBLIOGRAPHY

Adams, C.D. 1972. Flowering plants of Jamaica. MacLehose & Co., The University Press Glasgow, Scotland. 848 p.

Ahmed, B. 1986. Growing forage legumes. CARDI Factsheet No. AP-F/21.86. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad. West Indies. 4 p.

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

Allen, O.N. and E.K. Allen. 1981. The Leguminosae: A source book of characteristics, uses and nodulation. Wisconsin Press. Madison, Wisconsin. 812 p.

Baker, G.H. 1968. Soil and landuse survey No. 24 Jamaica, Parish of St. Ann. Regional Research Centre, Department of Soil Science, University of the West Indies, Trinidad.

Blair, G.J., M. Panjaitan, D. Ivory, B. Palmer, and M. Sudjadi. 1988. An evaluation of tree legumes on an acid ultisol in South Sumatra, Indonesia. Journal of Agricultural Science (Cambridge) 111:435-441.

CRIES. (1982). Jamaican resource assessment. Comprehensive resource inventory and evaluation system project (CRIES). Michigan State University - U.S. Department of Agriculture - The Ohio State University. Department of Resource Development, Michigan State University, East Lansing, Michigan.

Daly, J.J. 1984. Importance of trees for cattle. Tropical Grasslands 18:154-156.

Daniel, J.N., and C.K. Ong. 1990. Perennial pigeonpea: a multi-purpose species for agroforestry systems. Agroforestry Systems 10:113-129.

FAO. (1988). Some guidelines for designing integrated farming systems. FAO Regional Office for Latin America and the Caribbean. Santiago, Chile. 50 p.

Halliday J., and P. Nakao. 1984. Technical notes on the germination of leguminous tree seeds. pp. 231-234. In: Simposio Sobre Fixacao de Nitrogenio em Arvores Tropicais. Brazilian Journal of Agricultual Research Volume 19 (Special Issue).

Hewitt, C.W. 1964. Soil technical sheets. Agric. Chem. Div., Ministry of Agriculture, Jamaica. 144 p.

Holdridge, L.R. 1967. Life zone ecology. Tropical Science Center. San Jose, Costa Rica.

IDRC. 1990. Shrubs and tree fodders for farm anaimals. International Development Research Centre. Ottawa, Ontario, Canada. 349 p.

Jackson, J.K. 1987. Manual of afforestation in Nepal. Nepal-United Kingdom Forestry Project. Department of Forestry. Kathmandu, Nepal. 402 p.

JADF. 1988. Jamaica Agriculture Research Program Annual Report 1988. Jamaica Agriculture Development Foundation. Kingston, Jamaica.

JLA. 1983. Livestock manual for the tropics. The Jamaica Livestock Association. Kingston, Jamaica. 406 p.

Kaplan, I., H.I. Blustein, K.T. Johnston, and D.S. McMorris. 1976. Area handbook for Jamaica. Foreign Area Studies of the American University. Washington D.C. 332 p.

Koul, V.K., S.D. Bhardwaj, and A.N. Kaushal. 1989. Bauhinia variegata does not nodulate. Nitrogen Fixing Tree Research Report 7:75.

Le Houeron , N.H. (Editor) 1980. Browse in Africa: The current state of knowledge. ILCA Addis Ababa. 491 p.

Little, E.L., and F.H. Wadesworth. 1964. Common trees of Puerto Rico and the Virgin Islands. Agriculture Handbook No. 249. USDA Forest Service. Washington D.C. 556 p.

Little, E.L., R.O. Woodbury, and F.H. Wadesworth. 1974. Commons trees of Puerto Rico and the Virgin Islands, Second Volume. Agriculture Handbook No. 449. USDA Forest Service. Washington D.C. 1024 p.

Logan, I.A., and J.E. Radcliffe (Eds.). 1985. Fodder trees - A summary of current research in New Zealand. Crop Research Division - Department of Scientific and Industrial Research. Christchurch, New Zealand. 49 p.

Lowery J.B. 1989. Agronomy and forage quality of Albizia lebbeck in the semi-arid tropics. Tropical Grasslands 23:84-91.

Lowery J.B., J.B.C. Lowery, and R. Jones. 1988. Enhanced grass growth below the canopy of Albizia lebbeck. Nitrogen Fixing Tree Research Report 6:45-46.

Malla, Y.B. 1988. The case for placing more emphasis on privatet tree planting programmes. Forestry Research Paper Series No. 13. HMG-USAID-GTZ-FORD-WINROCK Project. Kathmandu, Nepal. 46 p.

Minson, D.J. 1980. Nutritional differences between tropical and temperate pastures. pp. 143-157. In: F.H.W. Morley (ed.) Grazing animals. Elsevier Publishing Company, Amsterdam.

Nair, P.K.R. 1983. Tree integration on farmlands for sustained productivity of smallholdings. pp. 333-350. In: W. Lockeretz (ed) Environmentally sound agriculture. Praeger, New York.

NFTA. 1987. Nitrogen Fixing Tree Highlights: The multipurpose rain tree, Samana saman. Nitrogen Fixing Tree Association, Waimanalo, Hawaii. 2 p.

NFTA. 1988a. Nitrogen Fixing Tree Highlights: Albizia lebbeck - A promising fodder tree for semi-arid regions. Nitrogen Fixing Tree Association, Waimanalo, Hawaii. 2 p.

NFTA. 1988b. Nitrogen Fixing Tree Highlights: Cajanus cajan - It's more than just a pulse crop. Nitrogen Fixing Tree Association, Waimanalo, Hawaii. 2 p.

NFTA. 1989a. Nitrogen Fixing Tree Highlights: Flemingia macrophylla - A valuable species in soil conservation. Nitrogen Fixing Tree Association, Waimanalo, Hawaii. 2 p.

NFTA. 1989b. NFTA cooperative planting program - Establishment guidelines. Nitrogen Fixing Tree Association, Waimanalo, Hawaii. 36 p.

NFTA. 1990. Perennial Sesbania production and use. Nitrogen Fixing Tree Association. Waimanalo, Hawaii. 41 p.

NRC (NATIONAL RESEARCH COUNCIL). 1979. Tropical legumes: Resources for the future. National Academy Press, Washington, D.C. 332 p.

NRC (NATIONAL RESEARCH COUNCIL). 1980. Firewood crops: Shrub and tree species for energy production. National Academy Press, Washington, D.C. 236 p.

NRC (NATIONAL RESEARCH COUNCIL). 1984. Leucaena: Promising forage and tree crop for the tropics. Second Edition. National Academy Press, Washington, D.C. 100 p.

Pandey, K. K. 1982. Fodder trees and tree fodder in Nepal. Swiss Development Cooperation. Berne, Switzerland. 107 p.

Paterson, R.T. 1988. The introduction of legumes into degraded tropical pastures. Ph. D. Thesis. University of Reading. Reading, England.

Paterson, R.T., G.A. Proverbs, and J.M. Keoghan. 1987. The management and use of forage banks. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad, West Indies. 21 p.

Paterson, R.T., J.M. Keoghan, and G.A. Proverbs. 1988. Forage-based grazing systems for the drier parts of the caribbean region. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad. West Indies. 23 p.

Postgate, J. 1987. Nitrogen fixation. Edward Arnold LTD. London, Great Britain. 73 p.

Reynolds, L., and S.A.O. Adeoye. 1986. Planted leguminous browse and livestock production. Paper presented at: International workshop on alley farming for humid and sub-humid regions of tropical Africa. Ibadan, Nigeria. March 10-14, 1986.

Robinson, P.J. 1985. Trees as fodder crops. pp. 281-300. In: M.G.R. Cannell, and J.E. Jackson (eds.) Attributes of trees as crop plants. 592 p. Institute of Terrestrial Ecology. Natural Environment Research Council. Huntingdon, England.

Roshetko, J.M., D.O. Lantagne, M.A. Gold. 1991. Direct seeding of fodder tree species in Jamaican pastures. Nitrogen Fixing Tree Research Reports 9:68-70.

Ruegsegger, G. 1990. On-farm evaluation of Leucaena, Gliricidia and legume/grass conserved fodder as high protein forages in dairy cattle rations. Paper presented at the Second Annual Seminar for presentation of progress reports on Jamaican Agricultural Research Projects. The Jamaican Agricultural Development Foundation. Kingston, Jamaica. September 18-20, 1990.

Rusten, E. 1989. An investigation of an indigenous knowledge system and management practices of tree fodder resources in the middle hills of central Nepal. Ph.D. Dissertation. Department of Forestry, Michigan State University. 282 p.

Sanchez, P.A., C.A. Palm, C.B. Davey, L.T. Scott, and C.E. Rusell. 1985. Tree crops as soil improvers in the humid tropics. pp. 327-358. In: M.G.R. Cannell, and J.E. Jackson (eds.) Attributes of trees as crop plants. 592 p. Institute of Terrestrial Ecology. Natural Environment Research Council. Huntingdon, England.

Sinclair, W.A., H.H. Lyon, and W.T. Johnson. 1987. Disease of trees and shrubs. Comstock Publishing Associates, Cornell University Press. Ithaca, New York. 574 p.

Singh, R.V. 1982. Fodder trees of India. Oxford and IBH Publishing Co. New Delhi, India. 663 p.

Torres, F. 1983. Role of woody perennials in animal agroforestry. Agroforestry Systems 1:131-163.

Vohnout, K., and C. Jimenez. 1975. Supplemental by-product feeds in pasture-livestock feeding systems in the tropics. pp. 71-82. In: E.C. Doll, and G.O. Mott (eds.) Tropical Forage in Livestock Production Systems. American Society of Agronomy - Special Publication No. 24. Madison, Wisconsin. 104 p.

Wellington, K.E. 1989. Agricultural Director, Alcan Jamaica Company LTD. Manderville, Jamaica. Personal communication.

ESTIMATED NUTRITIVE VALUE OF NATIVE AND EXOTIC FODDER TREE SPECIES IN JAMAICA AND THEIR COMPARISON TO COMMON PASTURE GRASS SPECIES

Abstract. The estimated nutritive value of eight native and six exotic Jamaican tree fodder species are presented. Exotic species generally have superior crude protein and phosphorus levels, and lower fiber contents. Native species have greater dry matter content. Ash, calcium, and magnesium percentages are about equal between the two groups. The exotic species appear to have greater potential as livestock feed resources. Samples were collected and analyzed in January and April of 1991, respectively.

Compared to common pasture grasses in Jamaica, tree fodder species are inferior in digestibility and mineral content, but superior in crude protein. This characteristic makes tree fodders excellent feeds for the dry season when grass crude protein levels fall below animal maintenance requirements. During seasonal dry periods crude protein levels in tree species do not decrease because of their deep perennial root systems. In Jamaica, tree fodder serves a supplementary role in livestock production, it is not meant to replace grass as the major dietary input.

INTRODUCTION

Trees can be extremely valuable animal fodder resources. Torres (1983) has described the widespread reliance on tree fodder as a dry season emergency feed in various parts of Australia. Le Houerou (1980) has edited a thorough compilation on the importance of tree browse to animal production in Africa. In other countries tree fodder is currently receiving attention as a means of increasing livestock production on small farms (Logan and Radcliffe 1985, IDRC 1990).

In Nepal, over fifty percent of fodder needs are supplied from trees (Pandy 1982). Surveys have shown that up to 93 percent of Nepalese farmers cultivate fodder trees (Malla 1988), and that trees and woody vines are the single most important fodder source on some farms (Rusten 1989). In many parts of the world, fodder trees are deliberately incorporated on to small farms to expand fodder resources, particularly for dry season use (Von Carlowitz 1989). These trees are planted on contour lines to stabilize soil (Fonzen and Oberholzer 1984), on boundaries to serve as living fences (Budowski 1987), with forage grasses or shrubs to form fodder banks (Nitis et al. 1987), or scattered around the farm where site characteristics are too poor to support agronomic crops (Ivory 1990).

In Jamaica, the use of tree fodder as a livestock feed has been documented for over 200 years (Browne 1789, Lunar 1814, Hooper 1886, Swaby 1941). More recently, in a study of small cattle farmers in northwest Jamaica, Morrison (1991) found that 95% of farmers utilized tree species as dry season feed.

Although the use of tree fodder is known in Jamaica, it is not a widespread practice and is mainly limited to small farmers. Tree fodder is under utilized, and given only passing mention in the Jamaican Livestock Association's management manual (JLA 1983). Generally, large livestock producers ignore tree fodders, and concentrate on the use of grass and pastures. Most Jamaican grass species contain ample amounts of protein, energy, and minerals when grown under proper conditions (JLA 1983). Animals raised on these grasses maintain high levels of productivity during the wet season.

This situation changes drastically in the dry season, when livestock production begins to suffer from a paucity of nutritious feed. Typically, Jamaica experiences two dry seasons per year; a short period from July to August and a long period from December to March (CRIES 1982). During these periods precipitation is insufficient to sustain vigorous grass production, and livestock must survive on dry pasture grasses (Kaplan et al. 1976). The nutritional quality of this forage is low.

Tropical grass nutritive values decline during the dry season. Crude protein contents, which may be as high as 14% under normal conditions, diminish to 5 or 6%. This level is below the 7% maintenance requirement reported for mature cattle in the Caribbean (Ahmed 1986, Paterson et al. 1987). Furthermore, low protein and dry forage diets are low in digestibility and remain longer in the stomach (Minson 1980, Paterson et al. 1988). This results in reduced feed intake and may cause corresponding deficiencies of minerals, vitamins, and energy. Restricted to a dry forage diet, livestock often suffer a decline in health and in the extreme may even die (Vohnout and Jimenez 1975, FAO 1988).

For a variety of reasons, incorporation of fodder trees on pastureland can be helpful in overcoming this dearth of quality dry season feed (Robinson 1985). Trees have extensive root systems that tap subsoil water throughout the year (Sanchez et al. 1985). This enables trees to retain foliage in the dry season, providing a timely supply of fresh succulent fodder when grass resources are dry. The deep roots also capture and recycle soil nutrients which have leached beyond the grass rhizophere (Sanchez et al. 1985). Besides remaining fresh, the foliage of many fodder trees are also nutritious. Most tree fodders contain crude protein levels of 10-20%, some species having levels as high as 25-30% (IDRC 1990).

If spaced too closely, trees can decrease grass production by competing for light and moisture. Conversely, at appropriate spacing trees also ameliorate environmental conditions which indirectly increase pasture and animal production (Torres 1983). Tree roots enhance soil aeration and water permeability, and tree shade helps decrease soil temperature and desiccation. These factors improve the microsite of the pasture plants (Nair 1983). If nitrogen fixing trees are used, the soil enriching ability of the tree litter may lead to increases in grass production (Lowry et al 1988, Lowry 1989). Trees also provide animals with wind and sun protection. In the tropics, such stress reduction increases animal efficiency and productivity (Daly 1984).

Considering the important role tree fodder plays in other countries, there is reason to believe that its potential in Jamaica is not being fully realized. The purpose of this paper is twofold; 1) to present the estimated nutritive values of fourteen Jamaican fodder tree species recently collected and analyzed, and 2) to compare the nutritive values of these tree species with those of the common grass species used in Jamaican livestock production.

MATERIALS AND METHODS

Species: The fodder tree species analyzed in this study can be assigned to one of two groups:

Native	Exotic
Brosimum alicastrum	Bauhinia variegata
Bursera simaruba	Leucaena hybrid
Cecropia peltata	Sesbania grandiflora (NFTA 835)
Citharexylum fruticosum	Sesbania grandiflora (NFTA 872)
Guazuma ulmifolia	Sesbania sesban (NFTA 812)
Haemaloxylum campechianum	Sesbania sesban (NFTA 873)
Ipomoea tiliacea	
Piscidia piscipula	

Native Fodder Species. The native species are either indigenous to or naturalized in Jamaica and occur frequently in forests, pastures, or bushlands (Little and Wadesworth 1964, Adams 1972, Little et al. 1974). Seven of the plants are trees, Ipomoea tiliacea is a herbaceous vine. The term "tree fodder" will be used to include I. tiliacea in future discussion. Each of the species is used to a different extent by Jamaican farmers. Brosimum alicastrum, Bursera simaruba, Guazuma ulmifolia, and I. tiliacea are considered excellent feeds that are readily accepted by livestock. Cecropia peltata, Haemaloxylum campechianum, and Piscidia piscipula are regarded as good feeds, but inferior to the others in quality and acceptability. Citharexylum fruticosum is a dry season emergency feed that is only used when other resources are lacking. Seven of the native tree fodders are used as goat and cattle feed, I. tiliacea is fed to goats and pigs. The use of H. campechianum is limited because of the presence of sharp thorns on its branches.

Leaf samples of the native species were collected from forests and pastures in Green Park, Trelawny Parish. Elevation in the area is 150 meters. Annual precipitation averages 100 cm, annual temperatures vary between 20-30°C (Baker 1970). Ecologically, this area is classified a subtropical dry forest life zone by Holdridge (1967). The land in the area varies from flat pasture and cropland to steep wooded hillsides. Suggested land use is pasture/livestock production and natural forest cover (Baker 1970).

The soil in the area is Bonny Gate stony loam, a thin brown or reddish soil over hard limestone (Baker 1970). It is generally considered to be infertile and slightly alkaline. Available nitrogen, phosphorus, and potassium are all low (Hewitt 1964).

Exotic Fodder Species. The exotic species are all fast growing, highly valued fodder trees of the Leguminosae family (NRC 1984, Jackson 1987, NFTA 1990). In Asia and Africa they are often established on private land specifically as livestock feed resources (NRC 1984, Jackson 1987, NFTA 1990). Their crude protein values vary from 19 to 29 percent (IDRC

1990). All of these species except Bauhinia variegata are nitrogen fixing trees (Allen and Allen 1981). These species are currently found in Jamaica, and although not presently utilized as fodder, have potential as protein rich feed supplements for livestock production. Leucaena leucocephala is native to Jamaica (Adams 1972). The Leucaena hybrid in the study is a cross of L. leucocephala K636 and L. diversifolia K156 (Moore 1991).

All of these exotic species were established in a trial planting near Moneague, St. Ann Parish in May of 1990 (Roshetko et al., in press). Elevation of the site is 500 meters. Annual temperatures vary from 15-25^{o}C, and average annual precipitation is 200 cm (Baker 1968). Holdridge (1967) classifies this area as a subtropical moist forest life zone. The study site is located on a flat grass pasture. The surrounding area is comprised of rolling pastures and steep forested hillsides. Suggested land use for the area is pasture/livestock production and natural forest cover (Baker 1968).

The soil is classified as a St. Ann clay loam, a medium deep red clay over white limestone which contains rich deposits of bauxite (Baker 1968). The soil is generally considered to be infertile and slightly alkaline (Hewitt 1964, Weir 1980).

Collection Procedure: Foliage samples for nutritive analysis were collected from each tree species. With the exception of C. peltata, samples were collected from three to five specimens. For C. peltata only two specimens were sampled. Only leaves (i.e. leaves, leaflets and petioles) on the outside of the tree crown were included in the samples. Foliage samples of exotic species were grown in full sun, but foliage collected from native species were not necessarily grown under full sun, due to shading from competing vegetation. Native trees sampled were mature and of varying age. Exotic trees were seven months old when sampled. All specimens were healthy. Collection was conducted in mid-January, which corresponds to the beginning of the winter dry season, a period of considerable tree fodder use.

Processing Procedure: Fresh weight of samples were recorded at collection. Samples were air dried for 24 hours and then oven dried at 61°C for 48 hours. After cooling, samples were ground using a Wiley Mill with a 1x1 mm screen. Approximate analysis values for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), ash, phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) content were determined for each sample. These values are only estimates of each species' nutritive worth to livestock, but are good as initial information and for comparative purposes.

Laboratory Procedure: Sample analysis was begun at the Sugar Industry Research Institute (SIRI) Laboratory in Mandeville, Jamaica and completed at the Forage Laboratory, Department of Crops and Soil Science, Michigan State University. All analyses were replicated twice. In Jamaica, samples were analyzed for phosphorus, and potassium content on a Technicon AutoAnalyzer II. This system uses colormetric determination by segmented flow analysis. Standard procedures as outlined by Technicon (1978, 1981) were followed.

At Michigan State University, samples were analyzed for crude protein, calcium, and magnesium on a HACH plant tissue analysis system. This system uses colormetric determination by continuous flow analysis. Standard procedures as outlined by HACH were followed for these analyses (1988). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) content were determined according to Goering and Van Soest (1979). Ash content was determined by incinerating samples at 495^{o}C for six hours.

RESULTS AND DISCUSSION

Approximate analysis nutritive values for all fourteen tree species are reported in Table 1. Crude protein and phosphorus levels are higher in the exotic species. Dry matter, ADF, NDF, and potassium values are higher in native species. Ash, calcium, and magnesium contents are about equal between the two groups. The following discussion compares analysis values of these fodder tree species with approximate

Table 1. Composition of Tree Fodder Species (as percent of dry matter).

Species (NFTA No.)	DM	CP	ADF	NDF	Ash	Ca	P	K	Mg
Group I: Exotic									
Bauhinia variegata	28.1	22.2	33.6	53.4	8.0	.37	.36	.93	.64
Leucaena hybrid	24.4	28.2	31.7	49.8	7.0	.27	.26	1.16	1.41
S. grandiflora* (835)	19.1	30.0	19.6	28.9	12.2	.49	.33	.93	.67
S. grandiflora* (872)	17.8	25.1	24.7	36.4	11.8	.49	.31	1.16	.66
S. sesban* (812)	17.6	23.7	20.6	31.1	17.9	.44	.31	1.16	.26
S. sesban* (873)	15.6	25.3	22.2	33.2	16.1	.45	.33	1.46	.43
Mean for exotics	20.4	25.8	25.4	38.8	12.2	.42	.32	1.13	.68

Species	DM	CP	ADF	NDF	Ash	Ca	P	K	Mg
Group II: Native									
Brosimum alicastrum	34.7	12.6	31.4	41.8	11.9	.51	.17	1.45	.77
Bursera simaruba	24.1	14.5	22.5	57.3	9.0	.48	.17	1.70	1.14
Cecropia peltata	22.6	22.2	33.8	47.2	12.6	.53	.21	1.66	1.30
C. fruticosum**	26.3	15.0	47.5	50.8	5.9	.23	.20	1.29	.38
Guazuma ulmifolia	33.9	20.0	28.0	58.9	10.5	.37	.21	1.88	.66
H. campechianum***	38.7	14.9	28.7	46.0	12.1	.59	.17	.71	.44
Ipomoea tiliacea	15.3	18.5	36.3	46.3	12.1	.43	.51	3.28	.00
Piscidia piscipula	35.7	14.6	28.7	46.0	14.9	.69	.14	1.00	.88
Mean for natives	28.9	16.5	32.1	49.3	11.1	.48	.28	1.62	.70

Note: DM = Dry Matter, CP = Crude protein, ADF = Acid detergent fiber, NDF = Neutral detergent fiber, * - S. = Sesbania, ** - C. = Citharexylum *** - H. = Haemaloxylum values for tropical grass species published by the Jamaican Livestock Association (JLA 1983). The values presented here may vary from those determined for different sites, climates, and stages of vegetative growth.

Crude Protein: Protein is vital for animal maintenance, growth, production and reproduction. Protein deficiency is often the most limiting factor to livestock production (FAO 1988). All fourteen tree species in the study have crude protein values greater than those of the main grass species used in Jamaica (Table 1 and 2). In a one to one comparison of all species, only guinea grass (Panicum maximum) has a crude protein value greater than a tree species, B. alicastrum. The crude protein value of most tree species are twice that of the grass species. This difference becomes even greater during the dry season when tropical grass crude protein levels decrease to 5 or 6% (Ahmed 1986, Paterson et al. 1987), a level below the minimum requirement for mature cattle maintenance in Jamaica (Table 3). Without feed supplements, cattle can not remain productive on diets of dry season grasses.

Tree fodder is an ideal high protein feed supplement for dry season livestock production. Crude protein levels in fodder trees do not decline in the dry season (Reynolds and Adeoye 1986). Akkasaeng et al. (1989) reported that while crude protein levels in tree fodders can fluctuate slightly over the year, there is no seasonal pattern to the

Table 2. Composition of Jamaican grass species (as percent of dry matter)

Species (Common Name)	DM	CP	CF	Ca	P
Brachiaria mutica (Para)	28.0	7.0	33.9	.42	.34
Cynodon plectostachus (Star)	27.6	8.5	35.4	.61	.16
Panicum maximum (Guinea)	18.0	13.7	33.2	.53	.32
Pennisetum purpureum (Napier)	21.0	9.2	33.9	.44	.35
Mean	23.6	9.6	34.1	.50	.29

Source: Jamaica Livestock Association 1983
Note: DM = Dry matter, CP = Crude protein CF = Crude fiber

Table 3. Daily Nutrient Requirements of Dairy Cattle (as % of dry matter)

Body weight	sex	age(weeks)	DM (lbs)	CP	Ca	P
100 LBS	Female	10	2.8	12.9	.71	.46
100 LBS	Male	10	2.8	14.3	.78	.50
400 LBS	Female	52	10.5	11.6	.41	.28
400 LBS	Male	44	10.5	13.0	.45	.30
800 LBS	Female	109	17.6	9.9	.31	.22
800 LBS	Male	85	18.7	10.6	.32	.24
1200 LBS	Female	---	21.6	9.3	.28	.20
1200 LBS	Male	129	23.0	9.3	.29	.22
1600 LBS	Male	---	25.5	8.7	.26	.20
2000 LBS	Male	---	26.9	8.4	.26	.20
2400 LBS	Male	---	30.8	8.3	.27	.20
2800 LBS	Male	---	34.6	8.2	.27	.20
Lactating Diary Cows						
800 LBS			----	12.2	.48	.39
1200 LBS			----	11.5	.49	.39
1600 LBS			----	11.2	.49	.40
1800 LBS			----	11.1	.49	.40

Source: Jamaican Livestock Association (1983).
Note: DM = Dry matter CP = Crude protein
Daily requirements for beef cattle are below those for diary cattle.

variation. Crude protein values may be higher in either the dry or wet season. Because of their stable and high crude protein contents, small portions of tree fodder in dry season diets can fulfill animal protein requirements.

Among the tree species analyzed, crude protein levels of exotic species were higher than those of native species. This indicates that exotic species are potentially more valuable feeds, particularly for dry season livestock production when low crude protein values in pasture grasses must be augmented with supplemental feedings. As mentioned, all exotics, except B. variegata, are nitrogen fixing species (Allen and Allen 1981). This may be one reason for their greater crude protein values.

The crude protein values listed for the exotic species in Table 1 correspond favorably with other data published for these species (Pandy 1982, NRC 1984, NFTA 1990), and are similar to those for Gliricidia sepium and Calliandra calothyrsus, two highly valued nitrogen fixing fodder trees (NRC 1983, NFTA 1989). While the crude protein values of the native species are lower than those of the exotic species, they correspond well with values published for other non-nitrogen fixing trees (IDRC 1990). Barnett (1936), Vargas et al. (1987), and Hunt (unpublished) also found the crude protein values of native species to be below those of nitrogen fixing fodder trees. Little additional information is available on crude protein values of the native species.

Fiber: Fiber is a negative index of feed quality. Generally, the higher the fiber content, the lower the feed quality (Van Soest 1982). High fiber feeds have been correlated with reduced voluntary intake by animals (Wilson et al. 1966, Blair et al. 1988) and decreased digestibility (Blair et al. 1988, Akkasaeng et al. 1989). Owen et al. (1989) suggested feed quality classes based on the ADF and NDF values of alfalfa cultivars (Table 4). Working with tropical tree fodders, Wanapat (1990) classifies NDF values of 29.5-44.2% as low, i.e. good feed quality. These values correspond to Class I & II feeds in Table 4. Although Table 4 represents work from a single temperate species, it will be used as a comparative gauge for the species considered here.

Species that rank in Class I, II, or III are considered prime dairy, good dairy, and good beef feeds, respectively. These classes of feed are nutritious enough to support livestock productivity. Class IV feeds are less nutritious and will only maintain a mature animal's current condition. Class V feeds are nutritionally inadequate and provide poor quality livestock diets.

Both ADF and NDF values are lower in the exotic tree species when compared to the native tree species. Using Table 4 as a gauge of feed quality, all exotic species are considered potentially nutritious feeds capable of supporting productive livestock (i.e. Classes I to III). Of the native species, only half are classified as nutritious feeds. The

Table 4. Relationship between fiber parameter and alfalfa feed quality

Uses		ADF (% of DM)	NDF (% of DM)
Class I	(Prime dairy feed)	< 31	< 40
Class II	(Good dairy feed)	31-35	40-46
Class III	(Good beef feed)	36-40	47-53
Class IV	(Maintenance feed)	41-42	54-60
Class V	(Poor quality feed)*	43-45	61-65

Note: ADF = Acid detergent fiber, NDF = Neutral detergent fiber, DM = Dry matter
* Requires supplementation with higher quality (energy) feeds as well as possibly other nutrients for most animals.

Source: Adapted from Owen et al. (1989)

rest are considered maintenance or poor quality feeds (Classes IV or V). As with crude protein content, fiber analysis indicates that the exotic tree species are better feeds. This inter-group ranking supports current thoughts: that exotic species are highly nutritious feeds that are readily consumed by livestock (Pandy 1982, NRC 1984, NFTA 1990), and that native species are mainly considered dry season maintenance feeds.

Of the native species, Jamaican farmers consider B. alicastrum, Bursera simaruba, G. ulmifolia, and I. tiliacea excellent feeds, that produce good weight gain, and are readily consumed by livestock. Although mainly used as dry season feed, these species are considered sufficiently nutritious to be used year round. The remaining native species are considered inferior in feed quality and animal acceptability. Yet, if fiber content were used to rank the group, B. simaruba and G. ulmifolia would be classified below all but one (C. fruticosum) of these less useful species. Obviously, fiber content alone is not an adequate indicator when rating tree fodder quality. Evidence from other sources support this premise. Working with tree fodder in Thailand, Akkasaeng et al. (1989) reported moderately high NDF values and low *in vitro* dry matter digestibility for Calliandra calothyrsus. According to Blair et al. (1988), high NDF values result in not only low feed digestibility but also low voluntary intake. However, Calliandra is a highly preferred and productive feed in Indonesia (NRC 1983), and in Jamaica is readily consumed during the wet season, sometimes in preference to pasture grasses. Other plant compounds may be involved in improving feed utilization. Jones (1979) reports that moderate levels of tannins in Leucaena fodder improve ruminant nutrition by protecting protein from degradation in the rumen and making it more available in the small intestine.

Fiber content for the grass species are reported as crude fiber (Table 2). For comparison purposes, crude fiber is basically equivalent to ADF. Van Soest (1982) states that this useful relationship is not based on any solid theory, but on statistical association. According to Van Soest (1982), the limitation of this relationship should be recognized when comparing these different fiber parameters.

Based solely on crude fiber (i.e. ADF) values, all four grass species are nutritious feeds (Classes I to III). This compares favorably with the tree fodders, of which eleven are classified as nutritious feeds and three are only maintenance or poor quality feeds. Caution must be exercised when comparing these species without the benefit of NDF values for the grasses. NDF is the "truly indigestible component of feed" and is the more limiting fiber parameter (Van Soest 1982). From our own data the importance of this statement is evident. If NDF values were excluded from the above evaluation, all tree species would be considered nutritious feeds. If NDF values were available for the grass species, their relative feed quality may decrease. However, it should be restated that all four grass species are preferred feed resources for both dairy and beef production in Jamaica (JLA 1983). Furthermore, small farmers prefer grass over tree fodder if it is fresh and available. This suggests that these grass species are good livestock feed resources.

Minerals: Phosphorus (P) levels in the grass species and the exotic tree fodders are roughly equivalent and sufficient to meet the dietary requirements of all but the youngest cattle (Table 3). Exceptions are Leucaena and Cynodon plectostachus, both having low P levels. Phosphorus levels in the native tree species are comparatively lower and insufficient to meet even the maintenance requirements of adult cattle. I. tiliacea is the exception in this group, with a P level high enough to satisfy the minimum requirements of all cattle classes.

Calcium (Ca) levels in grass and most tree fodder species are between 40 and 60 percent. This level of Ca is adequate to meet minimum requirements for all but the youngest cattle (Table 3). Some tree fodders have Ca levels below those of grasses, but still sufficient to meet the requirements of most cattle classes. Animal mineral requirements unsatisfied by grass or tree fodder feeds must be met by dietary supplements.

Dry Matter: Dry matter is an inverse measure of the amount of water in a feed. High dry matter values indicate that nutrients compose more of the feed's mass. If two species have equal nutrient values but different dry matter percents, the species with the higher dry matter percent will contain more nutrients per equal weight of fresh forage (FAO 1988).

Dry matter contents of the grass species were slightly greater then those of the exotic tree species. With the exception of I. tiliacea, dry matter content in the native tree species are considerably greater to those of either the grass or exotic tree species. The lower nutritive values in the native tree fodder species are somewhat compensated for in this manner.

Possible Inhibition of Nutrient Digestibility: All of the nutrients present in a fodder resources may not be available to animal digestion. Although Leucaena leucocephala, Robinia pseudoacacia, and alfalfa have comparatively equal crude nutrient contents, animal performance is much better on alfalfa than the other two feeds (Jones 1979, Cheeke 1991). In L. leucocephala the toxic amino acid mimosine interferes with nutrient absorption, decreasing dry matter, protein, fiber, and mineral digestibility (Jones 1979). In R. pseudoacacia tannins impair animal utilization of dry matter, protein, fiber, and minerals (Horton and Christensen 1981, Cheeke 1991). Tannins also bind plant nitrogen in cassava, inhibiting protein absorption by livestock (Reed et al. 1982). Only at high levels do tannins obstruct digestion, as mentioned earlier, at moderate levels tannins improve ruminant nutrition (Jones 1979, Shelton 1991).

The tree fodder species included in this study were not analyzed for nutrient digestibility nor the presences of tannins or other antinutrient compounds. Mimosine and tannins have already been identified in Leucaena (Jones 1979). Tannins and saponins are thought to occur in some Sesbania species (NFTA 1990). The possible presence of antinutrient compounds in the other tree fodder species are not yet known. Before the more promising species in this study (B. variegata, B. simaruba, B. alicastrum, G. ulmifolia, and I. tiliacea) can be promoted as excellent fodder resources, nutrient digestibility studies, feeding trials and the possible presence of antinutrient compounds should be investigated.

CONCLUSION

This study has demonstrated that tree fodder can be a suitable feed for animal production in Jamaica. While some tree fodders are inferior to grasses in mineral and fiber content, tree fodders in general are superior to grasses in crude protein content. This characteristic is very important for dry season livestock production when grass crude protein levels are below animal maintenance requirements.

Among the fodder trees analyzed, the native species are generally inferior to exotic species in crude protein, phosphorus, and digestibility. Exotic species have potential as high protein feed supplements to increase year round animal performance (Van Eyes et al. 1986, Ruegsegger 1990). The main use of native fodder species is as dry season feeds when grass resources are low in nutritive values. In either case, tree fodder is a complimentary resource to grasses, not a competitive one. As in humid Africa (Atta-Krah and Reynolds 1987), tree fodder in Jamaica is used to improve animal production, not to replace the use of grass. Grasses still provide most of the bulk in the diet.

Based on their estimated nutritive values, species characteristics, and/or uses in Jamaica B. variegata, B. alicastrum, B. simaruba, G. ulmifolia, I. tiliacea, Leucaena and the Sesbania species can all be classified as excellent animal feeds; C. peltata, and P. piscipula as good feeds; H. campechianum as a fair feed; and C. fruticosum as a poor feed.

ACKNOWLEDGEMENT

The authors would like to thank the Jamaican Agricultural Development Foundation and the United States Agency for International Development for financial support, and Dr. W.J. Moline and Mr. Rusty Plumber of the Department of Crop and Soil Sciences, Michigan State University for instruction and assistance with laboratory work.

BIBLIOGRAPHY

Adams, C.D. 1972. Flowering plants of Jamaica. MacLehose & Co., The University Press Glasgow, Scotland. 848 p.

Ahmed, B. 1986. Growing forage legumes. CARDI Factsheet No. AP-F/21.86. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad. West Indies. 4 p.

Allen, O.N. and E.K. Allen. 1981. The Leguminosae: A source book of characteristics, uses and nodulation. Wisconsin Press. Madison, Wisconsin. 812 p.

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

Atta-Krah, A.N., and L. Reynolds. 1987. Utilization of pasture and fodder shrubs in the nutrition of sheep and goats in the humid tropics of West Africa. Paper presented at: FAO seminar on sheep and goat meat production in the humid tropics of West Africa, Yamoussoukro, Cote D'Ivorie. September 21-25, 1987.

Baker, G.H. 1968. Soil and landuse survey No. 24 Jamaica, Parish of St. Ann. Regional Research Centre, Department of Soil Science, University of the West Indies, Trinidad.

Baker, G.H. 1970. Soil and landuse survey No. 25 Jamaica, Parish of Trelawny. Regional Research Centre, Department of Soil Science, University of the West Indies, Trinidad.

Barnett, W.L. 1936. Grasses and forage crops in Jamaica. Department of Agriculture Miscellaneous Circular No. 2. Ministry of Agriculture, Jamaica. 17 p.

Blair, G.J., M. Panjaitan, D. Ivory, B. Palmer, and M. Sudjadi. 1988. An evaluation of tree legumes on an acid ultisol in South Sumatra, Indonesia. Journal of Agricultural Science (Cambridge) 111:435-441.

Browne, P. 1789. Civil and Natural History of Jamaica. B. White and Sons, at Horace's Head Fleet Street, London, England.

Budowski, G. 1987. Living fences in tropical America, a widespread agroforestry practice. pp 169-178. In: H.L. Gholz (Ed.) Agroforestry: realities, possibilities and potentials. Martinus Nijhoff. Dordrecht, Netherlands.

Cheeke P.R. 1991. Black locust forage as an animal feedstuff. Paper presented at the International Conference on Black Locust: Biology, culture, and utilization. Michigan State University. East Lansing, Michigan. June 17-21, 1991.

CRIES. 1982. Jamaican Resource Assessment. Comprehensive Resource Inventory and Evaluation System Project (CRIES). Michigan State University - U.S. Department of Agriculture - The Ohio State University.

Daly, J.J. 1984. Importance of trees for cattle. Tropical Grasslands 18:154-156.

FAO. 1988. Some Guidelines for Designing Integrated Farming Systems. FAO Regional Office for Latin America and the Caribbean. Santiago, Chile. 50 p.

Fonzen P.F., and E. Oberholzer. 1984. Use of multipurpose trees in hill farming systems in Western Nepal. Agroforestry Systems 2:187-197.

Goering, H.K., and P.J. Van Soest. 1979. Forage Fiber Analysis. Agriculture Handbook No. 379. United States Department of Agriculture. Washington D.C.

HACH. 1988. Plant tissue and sap analysis manual. HACH Company, Loveland, Colorado. U.S.A.

Hewitt, C.W. 1964. Soil Technical Sheets. Agric. Chem. Div., Ministry of Agriculture, Jamaica. 144 p.

Holdridge, L.R. 1967. Life zone ecology. Tropical Science Center. San Jose, Costa Rica.

Horton G.M.J., and D.A. Christensen. 1981. Nutritional value of black locust tree leaf meal (Robinia pseudoacacia) and alfalfa meal. Canandian Journal of Animal Science 61:503-506

Hooper, E.D.M. 1886. Report upon the forests of Jamaica. Indian Forest Department. Waterlow & Sons Limited Printers, London.

Hunt, A. 1987-88. Miscellaneous data on nutritive values of some Jamaican livestock feeds (Unpublished). Bodles Agricultural Research Centre, Department of Agriculture, Old Harbour, St. Catherine, Jamaica.

IDRC. 1990. Shrubs and Tree Fodders for Farm Animals. International Development Research Centre. Ottawa, Ontario, Canada. 349 p.

Ivory, D.A. 1990. Major characteristics, agronomic features, and nutritional values of shrubs and tree fodders. pp 22-38 In: C. Devendra (ed.) Shrubs and Tree Fodders for Farm Animals. International Development Research Centre. Ottawa, Ontario, Canada. 349 p.

Jackson, J.K. 1987. Manual of afforestation in Nepal. Nepal-United Kingdom Forestry Project. Department of Forestry. Kathmandu, Nepal. 402 p.

JLA. 1983. Livestock Manual for the Tropics. The Jamaica Livestock Association. Kingston, Jamaica. 406 p.

Jones, R.J. 1979. The value of Leucaena leucocephala as a feed for ruminants in the tropics. World Animal Review 31:13-23.

Kaplan, I., H.I. Blustein, K.T. Johnston, and D.S. McMorris. 1976. Area Handbook for Jamaica. Foreign Area Studies of the American University. Washington D.C. 332 p.

Le Houerou , N.H. (editor) 1980. Browse in Africa: The current state of knowledge. ILCA Addis Ababa. 491 p.

Little, E.L., and F.H. Wadesworth. 1964. Common trees of Puerto Rico and the Virgin Islands. Agriculture Handbook No. 249. USDA Forest Service. Washington D.C. 556 p.

Little, E.L., R.O. Woodbury, and F.H. Wadesworth. 1974. Commons trees of Puerto Rico and the Virgin Islands, Second Volume. Agriculture Handbook No. 449. USDA Forest Service. Washington D.C. 1024 p.

Logan, I.A., and J.E. Radcliffe (eds.). 1985. Fodder Trees - A Summary of Current Research in New Zealand. Crop Research Division - Department of Scientific and Industrial Research.

Lowry, J.B. 1989. Agronomy and Forage Quality of Albizia lebbeck in the Semi-arid Tropics. Tropical Grasslands 23:84-91.

Lowry, J.B., J.B.C. Lowry, and R. Jones. 1988. Enhanced grass growth below the canopy of Albizia lebbeck. Nitrogen Fixing Tree Research Report 6:45-46.

Lunar, J. 1814. Hortus Jamaicensis - or a botanical description (according to the Linnear system) and an account of the vitae of its indigenous plants hertherto known, also of the most useful exotic. Two volumes. St. Jago de en Veja Gazette, Jamaica.

Malla, Y.B. 1988. The Case for Placing more Emphasis on Private Tree Planting Programmes. Forestry Research Paper Series No. 13. HMG-USAID-GTZ-FORD-WINROCK Project. Kathmandu, Nepal. 46 p.

Minson, D.J. 1980. Nutritional differences between tropical and temperate pastures. 143-157 pp. In: F.H.W. Morley (ed.) Grazing Animals. Elsevier Publishing Company, Amsterdam.

Moore, E. 1991. Nitrogen Fixing Tree Association. Personal communication.

Morrison, B.J. 1991. Indigenous knowledge relating to fodder trees and silvo-pastoral management systems of small-scale farmers in Jamaica. Master's Thesis. Department of Forestry, Michigan State University (In Press).

Nair, P.K.R. 1983. Tree integration on farmlands for sustained productivity of smallholdings. pp 333-350 In: W. Lockeretz (ed) Environmentally Sound Agriculture. Praeger, New York.

NFTA. 1989. Gliricidia production and use. Nitrogen Fixing Tree Association. Waimanalo, Hawaii. 44 p.

NFTA. 1990. Perennial Sesbania production and use. Nitrogen Fixing Tree Association. Waimanalo, Hawaii. 41 p.

Nitis, I.M., K. Lana, M. Suarna, W. Sukanten, and S. Putra. 1987. Growth and yield of Gliricidia sepium in association with grasws, ground legumesand trees. pp 205-216. In: D. Withington, N. Glover, and J. Brewbaker (eds.) Gliricidia sepium (JACQ) Walp.: Management and Improvement. Proceedings of a workshop held at CATIE, Turrialba, Costa Rica, June 1987. Nitrogen Fixing Tree Association Special Publication 87-01. 225 p.

NRC (National Research Council). 1983 Calliandra: A versatile small tree for the humid tropics. National Academy Press, Washington, D.C. 52 p.

NRC (National Research Council). 1984. Leucaena: Promising forage and tree crop for the tropics. Second Edition. National Academy Press, Washington, D.C. 100 p.

Owen, F.G., B. Anderson, R. Rasby, and T. Madder. 1989. Testing livestock feeds for beef cattle, diary cattle, sheep and horses. NebGuide G89-915. Cooperative Extension Institute of Agriculture and Natural Resources, University of Nebraska. 4 p.

Pandy, K. 1982. Fodder Trees and Tree Fodder in Nepal. Swiss Development Cooperation. Berne, Switzerland. 107 p.

Paterson, R.T., G.A. Proverbs, and J.M. Keoghan. 1987. The management and use of forage banks. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad, West Indies. 21 p.

Paterson, R.T., J.M. Keoghan, and G.A. Proverbs. 1988. Forage-based grazing systems for the drier parts of the caribbean region. Caribbean Agricultural Research and Development Institute. St. Augustine, Trinidad. West Indies. 23 p.

Reed, J.D., R.E. McDowell, P.J. Van Soest, and P.J. Horvath. 1982. Condensed tannins: A factor limiting the use of cassava forage. J. Sci. Food Agric. 33:213-220.

Reynolds, L., and S.A.O. Adeoye. 1986. Planted leguminous browse and livestock production. Paper presented at: International workshop on Alley Farming for humid and sub-humid regions of tropical Africa. March 10-14, 1986.

Robinson, P.J. 1985. Trees as Fodder Crops. 281-300 pp. In: M.G.R. Cannell, and J.E. Jackson (Eds.) Attributes of Trees as Crop Plants. Institute of Terrestrial Ecology. Natural Environment Research Council.

Roshetko, J.M., D.O. Lantagne, and M.A. Gold. 1991. Direct seeding of fodder tree species in Jamaican pastures. Nitrogen Fixing Tree Research Reports 9:68-70.

Rueggsegger, G. 1990. On-farm evaluation of Leucaena, Gliricidia and legume/grass conserved fodder as high protein forages in dairy cattle rations. Paper presented at the Second Annual Seminar for presentation of progress reports on Jamaican Agricultural Research Projects. The Jamaican Agricultural Development Foundation. Kingston, Jamaica. September 18-20, 1990.

Rusten, E. 1989. An Investigation of an Indigenous Knowledge System and Management Practices of Tree Fodder Resources in the Middle Hills of Central Nepal. Ph.D. Dissertation. Department of Forestry, Michigan State University. 282 p.

Sanchez, P.A., C.A. Palm, C.B. Davey, L.T. Scott, and C.E. Rusell. 1985. Tree Crops as Soil Improvers in the Humid Tropics. 327-358 pp. In: M.G.R. Cannell, and J.E. Jackson (eds.) Attributes of Trees as Crop Plants. Institute of Terrestrial Ecology. Natural Environment Research Council.

Swabey, C. 1941. The principle timbers of Jamaica. Department of Science and Agriculture, Bulletin No. 29 (new series). The Government of Jamaica, Government Printer, Duke Street, Kingston.

Technicon. 1978. Analytical procedures for nitrogen and phosphorus. Industrial Methods No. 329-74W/B. Technicon Industrial Systems. Tarrytown, New York.

Technicon. 1981. Analytical procedures for potassium. Industrial Methods No. 637-81A (GT). Technicon Industrial Systems. Tarrytown, New York.

Torres, F. 1983. Role of Woody Perennials in Animal Agroforestry. Agroforestry Systems 1:131-163.

Van Eyes, J.E., I.W. Mathius, P. Pongspan, and W.L. Johnson. 1986. Foliage of the legumes Gliricidia, Leucaena, and Sesbania as supplement to napier grass diets for growing goats. Journal of Agricultural Science (Cambridge) 107:227-233.

Van Soest, P.J. 1982. Nutritional Ecology of the ruminant. O&B Books , Inc. Corvallis, Oregon. 374 p.

Vargas, B., E. Hugo, G. Pablo, and S. Elvira. 1987. Chemical composition, digestibility and intake of Leucaena leucocephala, Gliricidia sepium and Guazuma ulmifolia. pp 217-222 In: D. Withington, N. Glover, and J. Brewbaker (eds.) Gliricidia sepium (JACQ) Walp.: Management and Improvement. Proceedings of a workshop held at CATIE, Turrialba, Costa Rica, June 1987. Nitrogen Fixing Tree Association Special Publication 87-01. 225 p.

Vohnout, K., and C. Jimenez. 1975. Supplemental By-Product Feeds in Pasture-Livestock Feeding Systems in the Tropics. pp 71-82 In: E.C. Doll, and G.O. Mott (eds.) Tropical Forage in Livestock Production Systems. American Society of Agronomy - Special Publication No. 24. Madison, Wisconsin.

Von Carlowitz, P.G. 1989. Agroforestry technologies and fodder production - concepts and examples. Agroforesty Systems 9:1-16.

Wanapat, M. 1990. Availability and use of shrubs and tree fodders in Thailand. pp 244-254 In: C. Devendra (ed.) Shrubs and Tree Fodders for Farm Animals. International Development Research Centre. Ottawa, Ontario, Canada. 349 p.

Weir, C.C. 1980. A Trace Element Survey of the Major Soil Types in Jamaica. Tropical Agriculture 57:21-28.

Wilson, R.K., T.A. Spillane, and M.J. Clancy. 1966. The influence of fibre content on herbage intake by ruminants. Irish Journal of Agricultural Research 5:142-143.

SUMMARY

Leucaena and *Gliricidia* can be established in improved grass pastures by direct seeding, if proper seed scarification, inoculation, sowing and weed control procedures are followed. Although direct seeding of *Calliandra* was not thoroughly tested, initial results and review of the literature indicate it is also possible.

Adequate weed control leads to improved survival and growth of *Leucaena*, *Gliricidia*, and *Calliandra* in grass ecosystems. Circle weeding greatly enhanced survival and growth over bushing alone. Ancillary data suggests that bush weeding significantly improves tree survival and growth over no weed control at all. The preparation of larger planting pits and the use of fertilizers had little positive affect on tree survival or growth. The use of these treatments was not warranted.

Bauhinia variegata, *Leucaena* hybrid KX3, *Sesbania grandiflora*, and *Sesbania sesban* are other fodder tree species that can be established in improved grass pastures by direct seeding. These species could be incorporated into the forage component of the Jamaican livestock production system. *Albizia* species, *Desmodium* species, *Cajanus cajan*, *Chamaecytisus palmensis*, and *Flemingia macrophylla* all performed poorly under direct seeding in improved grass

pastures. These fodder species may hold promise for Jamaican livestock production, but further studies are necessary.

The nutritive values of the native and exotic fodder tree species examined compare well with the nutritive values of the main pasture grass species used in Jamaica. The exotic species are superior to the native species in nutritive value. All fodder tree species are a suitable feed for livestock production. In Jamaica, tree fodder is a complimentary resource to grasses, not a competitive one. Tree fodder should be used to improve animal performance during the dry season and other periods of need. Grass should still provide most of the bulk in the diet.

DIRECTION OF FUTURE RESEARCH

Although this study has provided useful information, more questions need to be answered. This study used tree height and diameter growth as experimental parameters. This information is not directly useful when studying tree fodder production. Forage biomass studies are needed to determine management techniques that will maximize fodder production under Jamaican conditions. Optimal tree arrangement, planting density, row spacing, cutting height, and cutting frequency all need to be determined for a variety of Jamaican farm situations. Also, on-farm studies comparing direct seeding, seedling transplants, and vegetative cuttings should be conducted to determined the best establishment techniques for various farm conditions.

Now that crude nutritive values for Jamaican fodder tree species have been determined, nutrient digestibility studies and feeding trials are needed to determine the livestock production potential of these species. Both grazing and stall feeding trials should be initiated to determine the persistence of the fodder tree species under intensive management.

The results of this study and the studies on indigenous knowledge, socio-economic conditions and farming systems of small-scale farmers need to be combined to devise the best method of incorporating silvo-pastoral management into the present systems. This also needs to done for larger scale livestock producers in Jamaica. Economic analysis of these potential systems must also be completed to determine if tree fodder production and silvo-pastoral management is a viable solution to Jamaica's livestock feed shortage.

The incorporation of tree fodder into the Jamaican livestock production systems seems to hold great promise for the future. Unfortunately, at present the depth of knowledge concerning fodder tree production, management, and utilization in Jamaica is minimal. If the potential of this valuable resource is to be realized the research mentioned here and more will need to be completed.