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Stephen Gerard Krecik

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FODDER TREE ESTABLISHMENT AND PRODUCTION IN SEASONALLY DRY AREAS OF JAMAICA

By

Stephen Gerard Krecik

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ABSTRACT

FODDER TREE ESTABLISHMENT AND PRODUCTION IN SEASONALLY DRY AREAS OF JAMAICA

by

Stephen Gerard Krecik

Seven fodder tree species were established and grown at five planting sites in Green Park, Trelawny Parish, Jamaica. Five species, Cajanus cajan, Calliandra calothyrsus, Leucaena leucocephala, Sesbania sesban, and Gliricidia sepium, grew above pasture grasses and survived acceptably at some sites but require further study for possible use in local silvopastoral systems. Alternative establishment methods survived and grew better than direct-seeded Calliandra and Gliricidia. Survival and height growth was best at sites with deeper soils and protection from excessive wind and sun exposure.

In a second experiment located at Moneague, St. Ann Parish, previously established Leucaena was harvested at two cutting frequencies, and Calliandra and Gliricidia were harvested at two cutting frequencies and two heights. Cutting treatments affected only the Calliandra plantation. Calliandra production was approximately four times greater than either of the other tree species. The combination of tree fodder with grass production increased total fodder biomass production in the Leucaena and Gliricidia plantations over Calliandra, which had no grass production under its dense canopy.

ACKNOWLEDGMENTS

This thesis culminates nearly three years of education in the principles of forest research, in an international context. Without the mentoring and support of many individuals and organizations, this effort would not have been possible. In guiding the design and completion of this research, Dr. Douglas Lantagne and Dr. Michael Gold struck a finely honed balance between academic discipline and intellectual freedom. Their guidance has forged the unrefined energies of a freshly returned Peace Corps Volunteer into a novice scientist who possesses the skills to systematically investigate research questions, and for this I am very grateful.

Drs. Maureen McDonough and Michael Allen also served on my committee and their efforts also warrant sincere appreciation. Dr. McDonough helped refine the community development dimension of the project design, while Dr. Allen provided both advice and occasional sanctuary from the Natural Resources building. Drs. George Wilson, Lyndon MacLaren and the Jamaica Agricultural Research Programme staff are sent heartfelt thanks for their support and for the opportunity to conduct on-farm research. Through my years of Jamaican residence, I came to love this island, and am grateful for the opportunity to return some of what I gained there. Interaction with Green Park farmers has made the impact and meaning of this thesis much greater than could have been realized through traditional experiment station research. Special thanks is due to Mr. Rupert Brown, whose intuitive skills as both an agriculturist and a sociologist have propelled this project forward since its inception more than three years ago.

Ultimate credit must be given to my parents, whose ability to transform an infant into a responsible, caring citizen has been demonstrated sevenfold with my younger brothers and sisters. I carry on this circle of life with love for my wife Irwyna and our son James, whose presence and reciprocal love have reaffirmed my conviction for the reason we have all been placed on this earth.

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INTRODUCTION

This thesis concerns itself with the precept that Jamaican livestock production systems can be made more efficient and self-sustaining through the input of fodder trees. With a minimal capital input, fodder trees can be incorporated into pastures so that they utilize unexploited resources, provide high protein livestock feed especially during dry seasons, and enhance the overall productivity of a farming system. This research seeks to answer questions related to the needs of small-scale farmers within the context of their economic constraints, through on-farm research. On a wider scale, the overall efficiency of Jamaica's agricultural sector can potentially be increased by reducing foreign currency dependency on imported feed inputs.

The manuscript consists of two chapters. Chapter 1 examines the effect of cutting height and frequency treatments on biomass and fodder production on three fodder tree species established at Moneague, St. Ann Parish. Chapter 2 examines the establishment of seven different fodder tree species, and planting stock alternatives for two of those species in the Green Park project area.

Data for the research were collected from September 1991 to September 1992. This study is a continuation of a project jointly administered by Michigan State University and Jamaica Agricultural Research Programme. The project goal is to integrate fodder tree growth and management knowledge with current farming practices to develop alternative silvo-pastoral systems for small-scale farms in the Green Park area. The project has already compiled a survey of the project area's indigenous knowledge (Morrison 1991) and social and economic systems (Andreatta 1992), and gathered data on the impact of various establishment methods and the nutritive values of commonly used fodder trees (Roshetko 1991). Feeding trial and fodder tree management research will continue until September 1993.

EFFECT OF TWO CUTTING FREQUENCIES ON *LEUCAENA* FODDER PRODUCTION AND OF TWO CUTTING HEIGHTS AND FREQUENCIES ON *CALLIANDRA* AND *GLIRICIDIA* FODDER PRODUCTION IN A SEASONALLY DRY AREA OF JAMAICA.

Abstract. In 1990, plantations of *Calliandra*, *Gliricidia*, and *Leucaena* were established in an improved pasture in St. Ann Parish, Jamaica at a density of 4,444 trees/ha. Cutting height treatments of 75 and 150 cm and harvest interval treatments of 9, 12, and 18 weeks were evaluated over a 36 week period for *Calliandra* and *Gliricidia* fodder production. *Leucaena* fodder production of trees cut at 75 cm was evaluated at 8 and 12 week harvest interval treatments over a 24 week period. Co-incident grass production was also measured if present in the plantations.

Calliandra harvested at 150 cm produced 8.7 t/ha/yr, 19% more dry matter fodder than at 75 cm. Twelve week harvest intervals produced 9.1 t/ha/yr, 34% more dry matter fodder than at nine weeks. Grass production increased 6.5 t/ha/yr when *Leucaena* and grass were harvested after 8 weeks rather than 12 week intervals. *Gliricidia* fodder production was not influenced by cutting height or interval treatments.

Calliandra production was approximately four times greater than either of the other two tree species. The combination of tree fodder and co-incident grass production under *Gliricidia* and *Leucaena* increased total output 33% and 64%, respectively, over *Calliandra*. There was no grass production under the *Calliandra* canopy.

INTRODUCTION

Raising cattle for the production of meat and dairy products is a significant agricultural endeavor in Jamaica. Cattle rearing, the major economic activity for over twenty percent of agricultural lands, is a stabilizing force in the national economy and a consistent contributor to gross domestic product. Farms which engage in production range from large (>1000 ha) estates to small-scale (< 1 ha) farmers (SIOJ 1979). Domestic production of meat and dairy products is about 106 thousand metric tons/year (FAO 1988). However, the country still imports large quantities of beef. During the period of 1981-1985, nearly 12% of all domestic consumption was imported (GOJ 1987).

Under proper management, most of Jamaica's agricultural land area is suitable for pasture and livestock production (GOJ 1987). Attempts to increase domestic livestock production have been thwarted by high production costs, the long-term nature of livestock production, and inconsistent governmental policies (GOJ 1987, Bell 1989). Past research and extension activities have also concentrated on improving the production systems of larger (>10 ha) growers, which make up less than 2% of all Jamaican farmers (Blustain and Lefranc 1987, GOJ 1987).

In addition to economic and policy factors, there are biological restrictions on the growth potential of Jamaica's cattle industry. The most significant restriction is the effect of seasonal rainfall patterns on forage quality and its effect on ruminant nutrition (Paterson et al. 1987). Most Jamaican cattle subsist primarily on pasture grasses (Bell 1989, Rueggsegger 1992). During the biannual dry seasons in July-August and December-March (CRIES 1982), the availability and nutritive value of these grasses decrease as they become desiccated (Pound and Cairo 1983). In response, some farmers supplement the dietary requirements of their livestock with expensive imported feeds. Most resource-limited farmers, however, must resort to local forages including sugar cane tops and tree fodder when pasture grass is scarce and of poor quality and imported feed is too expensive (Morrison 1991). The well documented potential of the purposeful inclusion of fodder trees into agroecosystems (Von Carlowitz 1987) has not been extensively studied in Jamaica (JAGRIST 1992).

Examples of fodder tree cultivation abound in Nepal (Panday 1982), Australia (Torres 1983), Israel, Chile (NRC 1981), Indonesia (Devendra 1990) and the Dominican Republic (Pound and Cairo 1983), where trees are grown and employed as important components in ruminant nutrition. Some examples of silvopastoral systems, which include the incorporation and utilization in pastures of multipurpose trees for fodder, exist in Jamaica. Farmers in Moneague, St. Ann Parish, periodically supplement the diet of cattle with the foliage of <u>Gliricidia sepium</u> planted as living fence posts (Bell 1989). Dairy farmers near Black River, St. Elizabeth Parish, use <u>Leucaena</u> and <u>Gliricidia</u> fodder banks to supplement the diets of their animals (Rueggsegger 1992). In general, Jamaican farmers use naturally occurring trees for fodder (Morrison 1991), which have low nutrient values compared with planted exotic species used elsewhere in the world (Roshetko 1991).

The quality and quantity of locally produced cattle forage can be greatly improved during dry periods by incorporating tree forage. Freshly cut tree foliage generally has a higher crude protein content and digestibility when compared to dry pasture grasses (Paterson et al. 1987, Pound and Cairo 1983, Devendra 1990). Tree roots access soil water and nutrients unavailable to pasture grasses (Sanchez et al. 1985) and maintain green foliage during periods of drought (Pound and Cairo 1983). Nitrogen fixing trees may also enhance site conditions over time by raising soil nitrogen levels (Nair 1985, Pound and Cairo 1983).

Questions fundamental to tree fodder research include proper species-site selection, and tree species management (NFTA 1989a). Tree fodder management factors include: age at first cutting, height of cutting, amount of leaf material removed, harvest interval, plant density, and interactions of these and other possible factors (Horne et al. 1985). Site adaptability and management trials, coordinated and supported by various international research organizations, continue to identify promising species and appropriate management systems throughout the world. Particularly in Jamaica, the knowledge of fodder tree production, management, and utilization needs to increase if the potential of this resource is to be realized (Roshetko 1991).

The objectives of this study were 1) to determine the effect of cutting height and frequency on Calliandra and Gliricidia production, and cutting frequency on Leucaena production; and 2) to determine the effect of coppiced trees on grass production in St. Ann Parish, Jamaica.

LITERATURE REVIEW

Fodder production. Comparison of different tree fodder production trials presents difficulty because definitions of fodder vary among researchers (Horne et al. 1985). Several authors examining Leucaena (Guevarra et al. 1978, Evensen 1984) and other fodder tree species (Sumberg 1985, Ella et al. 1991) use dry matter (DM) leaf production as a benchmark for determining fodder yield. This method disregards the considerable amount of biomass in petioles and small stems that can be used for animal feed.

A variety of diverse factors influence the actual portion of fodder tree biomass which animals consume. These factors include growing interval between harvests, freshness (age since harvest in cut-and-carry systems), mixture with (in cut-and-carry) or availability of (in direct grazing systems) other forages, and animal adaptation (NFTA 1989b). The influence of these factors on consumption raises difficulties in making a strict determination of the edible portion of fodder plant biomass. Range inventories often employ proper-use factors to estimate the percent of a particular plant species' biomass utilized by animals (Stoddart et al. 1975). In fodder tree yield studies by Guevarra et al. (1978) and Akkasaeng et al. (1989), the authors attempt to define the palatable portion of tree yield by separating out branches greater than 5 mm in diameter. While it is probably inaccurate to make a standard proper-use estimate for several tree species, the authors attempt to make consistent and reasonable fodder tree proper-use estimates by imposing this criterion.

Cutting height. The study of cutting height influence on fodder tree production occurred as early as 1949 (Takahashi and Ripperton 1949). Most investigators examining Leucaena have found that taller cutting heights give greater yields. Krishnamurthy and Mune Gowda (1982) found that DM yield was optimized at the tallest height in a range of 60 to 150 cm, while Siregar (1983) found that DM yield was highest at 100 cm within a range of 90-120 cm. Evensen (1984) found no significant production differences when Leucaena cutting height was varied from 42 to 84 cm.

There is less data on cutting height effects for other tree fodder species. Siregar (1983) found both Flamengia congesta and Calliandra calothyrsus performed best at a 100 cm height when cut over a range of heights from 5 to 150 cm. Lazier (1981) found higher leaf and stem yield in taller cuttings of Codariocalyx gyroides, a leguminous tropical shrub, when cutting height was varied from 5 to 50 cm.

The positive effect of cutting height in most Leucaena fodder production trials is linked to the number of vegetative buds on residual stems. Alferez (1978) found that non-structural carbohydrates stored in Leucaena were not affected by cutting height and determined that new leaf production was primarily influenced by the number of buds arising from the stump. Perez and Melendez (1980) and Alferez (1978) both demonstrated that the number of buds emanating from Leucaena stumps was positively influenced by cutting height.

Cutting frequency. As with cutting height, there are highly variable results when different cutting frequencies are applied to fodder tree production trials. The majority of production studies which look at cutting frequency have examined Leucaena. Differences in results between studies can be related to the use of inconsistently-defined terminology regarding the type of yield measured (Horne et al. 1985). When studies that examine DM biomass are examined, there is a trend of maximum production achieved through less frequent cuttings. For total Leucaena DM yield, Ozman (1981) found a cutting period of 90 days best in a test of 30, 60, 90, and 120 day intervals, and Guevarra et al. (1978) determined the longest of three intervals (76, 100, 126 days) optimized production when harvested over a 16 month period. Ella et al. (1989) found that longer (12 vs. 6 week) intervals produced greater total DM yield in <u>Calliandra</u>, <u>Gliricidia</u>, and <u>Leucaena</u> when planting density averaged 18,750 trees/ha.

When considering fodder yields as expressed by leaf DM or proper-use estimate rather than total dry matter, the effect of cutting frequency is not as consistent. Pathak et al. (1980) found 40 day intervals gave higher <u>Leucaena</u> DM leaf production than longer periods. Conversely, Guevarra et al. (1978) found that longer intervals produced more <u>Leucaena</u> fodder DM. These experiments may have confounding influences, including genotypic variations, seasonality, and spacing, which modify or influence the results (Horne et al. 1985). A consistent relationship for the cases reported is the increase in the amount of woody material (and hence non-fodder) in collected biomass as time between harvests increased. In instances where wood for building and fuelwood, seeds for food, and other products are considerations for the management of fodder trees, the determination of the best cutting frequency will have to be weighed by considering the need for these other products.

Tree-grass interactions. In tree-grass mixtures, light is often the most limiting factor to plant growth (Santhirasegaram et al. 1966). While the yield of most grasses decline when shading is imposed, the response of individual species is variable. Panicum maximum yielded greater production than three other grass species when grown under shade (Ericksen and Whitney 1982). Under low moisture conditions, however, water availability may limit grass growth. In a tree-grass association with an average planting density of 18,750 trees/ha, Ella et al. (1991) found that Panicum grass production increased during dry season conditions under longer harvest regimes of Calliandra, Gliricidia, and Sesbania. They concluded that the shade from the fodder tree crop conserved soil moisture and enhanced grass output during the dry season, while it limited grass growth during the wet season when light was the limiting factor.

Other factors. Considering the wide array of management treatments, planting densities, tree species, and varieties reported in the literature, it is difficult to draw clear conclusions about many of the other factors that influence tree fodder production. Several physiological factors potentially influence tree fodder yield, including varietal differences, flowering and seed production, and response to competition (Horne et al. 1985).

Varietal differences are often expressed by varying growth responses to different site conditions. Rosecrance et al. (1989) found significant differences in fodder yield when testing 21 varieties of Cajanus and concluded these differences resulted from varietal reactions to site conditions. With the considerable and well documented genetic variation in tree fodder species such as Cajanus and Leucaena, it is possible to test and select varieties for particular site conditions and production systems (Ramanujam 1981)

Variations in flowering and seed production habits can explain some inter-varietal differences found in fodder production. Guevarra et al. (1978) observed a marked difference in the total and leaf DM yield of two varieties of Leucaena. He found that one variety, K341, flowered more readily within any of the three cutting intervals and this propensity to flower drew resources away from fodder biomass production.

Plant spacing and subsequent competition also influences fodder tree yield. Recommended planting densities for fodder tree banks range from 5,000 to 50,000 trees/ha (Paterson et al. 1987). Horne et al. (1985) report maximum production efficiency is attained when the canopy closes and before shading causes leaf loss. At high plant densities of Leucaena harvested over a 16 month period, shorter intervals maximized yield (Guevarra et al. 1978, Pathak et al. 1980). In low density plantings, potential fodder production was lost because Leucaena was unable to close its canopy and offset greater spacing by producing more stems (Guevarra et al. 1978).

In addition to physiological factors, a wide array of abiotic factors influence fodder tree growth. Soil factors which influence plant growth include soil texture and structure, excessive soil acidity or alkalinity, nutrient availability, drainage, water-holding capacity, and salt levels. Some fodder tree species such as Leucaena have been studied extensively for soil effects (NRC 1981), while complete information for others is lacking (Von Carlowitz 1987). Other abiotic factors, including seasonal rainfall variations, temperature changes, altitude differences, and the presence of frequent wind and fire events may also affect fodder tree productivity (Von Carlowitz 1987). Guevarra et al. (1978) found a relationship between temperature, solar radiation and fodder production in irrigated Leucaena. Others have demonstrated that as rainfall increases so too can cutting frequency in Leucaena, Calliandra, Gliricidia, and Sesbania grandiflora (Ella et al. 1991, Evensen 1984).

Summary. The management of fodder trees can greatly influence the amount and quality of their total yield (Horne et al. 1985). Cutting height (Takahashi and Ripperton 1949, Krishnamurthy and Mune Gowda 1982, Siregar 1983, Evensen 1984) and cutting frequency (Ozman 1981, Guevarra et al. 1978, Ella et al. 1991) are two important factors in defining optimum management methods for fodder trees. By determining optimum cutting heights and intervals for fodder tree species in Jamaica, a clearer understanding of factors related to fodder tree production can be realized for this country.

METHODS AND MATERIALS

Site. The study site was located in Unity Valley near Moneague, St. Ann, Jamaica. Unity Valley is 500 m above sea level and surrounded on three sides by steep, wooded limestone hills. The soil, classified as a St. Ann clay loam, is a well drained, medium deep red clay over limestone with significant deposits of bauxite (Baker 1968). The soil has a pH of 7.48 and available phosphorous and potassium levels of 7 and 95 ppm (Roshetko 1991). Average annual rainfall is 2000 mm, and daily temperatures typically range from 15 - 25° C (Baker 1968).

Plant Species. Three nitrogen-fixing fodder tree species, Calliandra calothyrsus, Gliricidia sepium, and Leucaena leucocephala were used in the fodder yield trials. They were previously established as part of another study to investigate the effects of different planting techniques on survival and growth (Roshetko 1991). These species were originally selected because they are good sources of high protein fodder (Panday 1982, Pound and Cairo 1983, NRC 1981). The predominant grass species growing at the site was para grass (_Brachiaria mutica_) with some guinea grass (_Panicum maximum_) also present. These grasses are classified as "improved" grass species for Jamaican pastures (JLA 1983).

Establishment. _Calliandra_, _Leucaena_, and _Gliricidia_ were established in May 1990, in three blocks of 17 by 17 trees in a single pasture. An exterior border row and shared interior border rows were used to separate sixteen measurement plots in each block, to minimize edge effects (NFTA 1989a). The establishment sites did not differ significantly in slope, soils or vegetation at the time of establishment. _Gliricidia_ was directly sown into cultivated planting pits during May 1990, at 1.5 m^2 spacing. _Calliandra_ and _Leucaena_ were planted at the same spacing with containerized seedlings in September 1990 after direct seeding failed. Tree density averaged 4,444 trees/ha, which is considered low for fodder bank plantings (Paterson et al. 1987). Monthly removal of grass competition occurred during the first six months after planting to ensure establishment. Grass continues to grow in the _Leucaena_ and _Gliricidia_ plantations but is no longer present in the Calliandra plantation due to canopy closure.

Treatments. Cutting heights of 75 and 150 cm were used to simulate the effects of a cut-and-carry management system and a direct grazing management system, respectively, in the Gliricidia and Calliandra plantations. During the previous establishment trials, poor Leucaena survival resulted in a stocking level inadequate for the implementation of cutting experiments. As a result, Leucaena was only tested at the 75 cm height. To provide uniform stands for the measurement of harvested regrowth, all Calliandra and Gliricidia were cut at the designated heights in November 1991 and all Leucaena were cut in February 1992.

Two harvest frequencies, as determined by regrowth height, were originally planned to compare the effect of short and long cutting interval extremes on fodder production. The first interval was to be initiated when branch regrowth had reached between 30 and 50 cm, and the second when crown closure started to cause shade-induced leaf fall. Rapid Calliandra regrowth permitted harvest intervals to be applied to this species as planned. Gliricidia and Leucaena regrowth, however, did not achieve crown closure by the midway point of their respective study periods. It was decided to implement the second harvest interval at this time so that comparisons could be made with

the first harvest interval. Table 1 summarizes the cutting heights and intervals by species.

Table 1: Cutting height and frequency treatments used in fodder production trials in St. Ann Parish, Jamaica.

Treatment	Calliandra		Gliricidia		Leucaena
Height (cm)	75	150	75	150	75
Interval A (weeks)	9	9	12	12	8
Interval B (weeks)	12	12	18	18	12
Total time of study	36	36	36	36	24

Experimental Design. Four treatments were applied to both a Calliandra and a Gliricidia plantation. Two cutting frequency treatments were nested within each of two cutting heights (Table 1). To avoid confounding treatment impacts on fodder production from establishment treatments, the cutting height and frequency treatments were distributed systematically (Appendix A) across the original treatment plots (Roshetko 1991).

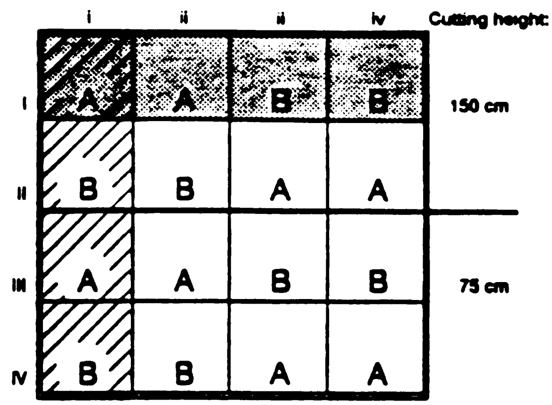
Cutting height treatments were applied across half of each Calliandra and Gliricidia plantation. Homogeneity within plantations and throughout the site, and the use of non-parametric analysis allowed for appropriate statistical comparisons. Within each cutting height unit, cutting frequency treatments were applied as two sets of paired plots. Blocks for non-parametric analysis were designated as shown in Figure 1. A total of four blocks were used for the analysis of cutting height and frequency on each plantation. Plots within a given block with the same cutting height or frequency treatments were summarized to determine treatment means used for analysis.

Paired plots of two cutting frequencies were replicated four times in the Leucaena plantation in a completely randomized design (Figure 2). All trees were cut at a height of 75 cm.

Measurements. Nine interior trees per plot were used for all measurements and sampling. Border trees separating plots were harvested but not included in the data collection. Survival data was noted and biomass samples collected to calculate fresh weight (FW) biomass production and dry matter (DM) fodder production. Biomass sampling removed all growth that had occurred since the previous harvest. Leaves, petioles, and stems were weighed using a hanging radial dial spring scale to determine FW biomass production.

Fodder Production. To determine the percentage of fodder production in the harvested biomass, complete branch samples were collected for each cutting frequency within

FIGURE 1: Experimental design layout used to test for the effects of cutting height and frequency on fodder production of Calliandra and Gliricidia.



KEY: A) Calliandra: 9 week interval.
Gliricidia: 12 week interval.

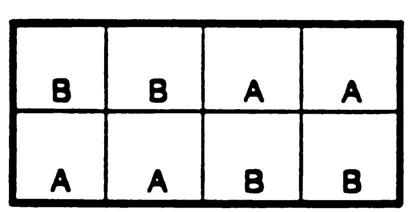
B) Calliandra: 12 week interval.
Gliricidia: 18 week interval.

BLOCKING:

1) Shaded row (I) represents one of four blocks used for comparisons of cutting frequency.

2) Cross-hatched column(i) represents one of four blocks used for analysis of cutting height.

FIGURE 2: Randomized complete block experimental design layout used to test the effect of cutting frequency on Leucaena cut at a 75 cm height.



KEY: A) 8 week interval
B) 12 week interval

each species. Sampled branches were drawn from a composite pile of harvested material. A total of four to eight branches, comprising 250 to 450 g of FW material were processed to determine DM content for the two cutting intervals of each species. Samples were chopped to a maximum length of 5 cm and oven-dried at 105° C for 24 to 48 hours to a constant weight. Measurement for the ratio of "fodder" to "wood" biomass production was determined by separating the dried samples into leaves and branches less than 5 mm and branches greater than 5 mm and re-weighing. Total DM fodder production in tons/ha/year was calculated from the DM and FW biomass information.

Estimates of grass production in the Gliricidia and Leucaena plots were determined by randomly locating three 1 m^2 sample areas in each plot. Grass was concurrently harvested with tree biomass. Grass was cut to a 5 cm. height, and subsamples of the harvested material were weighed, dried, and re-weighed. All grass remaining in the harvested tree plot was subsequently cut.

Data Analyses. Non-parametric statistical analyses were conducted on FW biomass and DM fodder production of trees and grass, and DM content data. The impact of treatments from the previous fodder tree establishment study was also evaluated. Analysis of Calliandra and Gliricidia production data was made using Friedman's test for related

samples. All other analyses used the Kruskall-Wallis test for independent samples. Assumptions for the independence of samples (Kruskall-Wallis) and of blocks (Friedman) were achieved with the use of border tree rows (Conover 1971, NFTA 1989a). Non-parametric statistical methods were used to overcome study design deficiencies related to the lack of full treatment randomization.

RESULTS

Treatments significantly ($P<.05$) influenced fodder production in Calliandra and Leucaena plantations. All three species responded well to management, as evidenced by the 100% survival of trees included in the study. Dry matter tree fodder production varied widely between species, ranging from 1.5 t/ha/yr for Gliricidia harvested at 150 cm to 9.1 t/ha/yr for Calliandra harvested at the same height. Average Calliandra DM tree fodder production of 8.0 t/ha/yr was approximately four times greater than that of Gliricidia and Leucaena at 1.8 and 2.3 t/ha/yr, respectively. However, when grass yield from the Gliricidia and Leucaena plantations was added to tree fodder production, these plantations had a greater total yield of 10.7 and 13.1 t/ha/yr, respectively (Table 2).

Fresh weight and dry weight biomass production of Calliandra was affected by both cutting height and frequency

(Tables 2 and 3). The 150 cm cutting height and the twelve week cutting interval produced significantly more usable material than the alternative treatments. As would be expected from a twelve week cutting interval, the percentage of woody material (branch diameter > 5 mm) within harvested biomass increased significantly when compared to the nine week cutting intervals (Table 4).

Fresh weight and dry matter tree fodder production of _Gliricidia_ and _Leucaena_ were not affected by cutting height or frequency (Tables 2, 5 and 6). As with _Calliandra_, shorter cutting intervals produced a higher percentage of fodder and a lower percentage of woody material in the harvested biomass (Table 4).

Grass production was unaffected by cutting height or frequency under _Gliricidia_, but was significantly greater under _Leucaena_ with an eight week interval (Tables 2, 5 and 6). Although differences were not statistically significant for grass production under _Gliricidia_, they were substantial. Dry matter grass production was 10.1 t/ha/yr under a 12 week harvest interval, 2.4 t/ha/yr greater than the 7.7 t/ha/yr average for the 18 week harvest interval.

Height x interval interactions could not be tested for _Calliandra_ and _Gliricidia_ within the experimental design. Graphs of height x cutting interval for these species showed

TABLE 2: Fresh weight biomass and dry matter fodder yields for Calliandra, Gliricidia and grass at two cutting heights and frequencies, and Leucaena and grass at two cutting frequencies.

Species	Treatment		Fresh weight biomass(1)		Dry weight fodder(2)			Average fodder production(3)		
	Cutting interval -weeks-	Cutting height -cm-	tree t/ha/yr	grass t/ha/yr	tree t/ha/yr	grass t/ha/yr	total t/ha/yr	tree t/ha/yr	grass t/ha/yr	total t/ha/yr
Calliandra	9		28.7*	n/a	7.3*	n/a	7.3*			
	12		39.2	n/a	8.7	n/a	8.7			
		75	29.1*	n/a	6.8*	n/a	6.8*			
		150	38.8	n/a	9.1	n/a	9.1	8.0	n/a	8.0
Gliricidia	12		10.1	50.4	2.0	10.1	12.1			
	18		7.8	38.6	1.5	7.7	9.2			
		75	10.2	47.5	2.0	9.5	11.5			
		150	7.7	41.1	1.5	8.3	9.8	1.8	8.9	10.7
Leucaena	8	75	9.5	70.8*	2.6	14.2*	16.7*			
	12	75	7.2	38.3	1.9	7.7	9.5	2.3	11.0	13.3

1. Biomass produced since the previous harvest.
2. Dry matter production of tree leaves and branches < 5 mm diameter.
3. Average across the cutting height and frequency treatments.

n/a Grass production was not present due to dense tree canopy.

* Significant differences were present between treatments at P< .05.

TABLE 3: Friedman two-way rank test for differences in Calliandra dry matter fodder production (1) from two cutting height and frequency treatments.
(Chi-square approximation with 1 df)

Cutting interval -weeks-	Cutting height -cm-	Rank Sum	Friedman Test Statistic
9		4	4 *
12		8	
	75	4	4 *
	150	8	

1. Dry matter production of leaves and branches <5 mm diameter.

* Significant differences were present between treatments at P<.05.

TABLE 4: Percent dry matter, usable fodder, and woody material har-harvested at two cutting frequencies from Calliandra, Gliricidia, and Leucaena.

Species	Cutting interval (weeks)	Percent dry matter (DM)	Usable fodder portion(1) of DM	Woody material portion(2) of DM
Calliandra	9	32.3	78.7*	21.3*
	12	31.4	72.3	27.7
Gliricidia	12	25.4	79.1*	20.9*
	18	25.3	74.3	25.7
Leucaena	8	31.3	86.9	13.1
	12	31.4	82.2	17.8

1. Proportion of harvested biomass which consisted of leaves and branches < 5 mm diameter.
2. Proportion of harvested biomass which consisted of branches > 5 mm diameter.

* Significant differences were present between treatments at $P<.05$.

TABLE 5: Friedman two-way rank test for differences in Gliricidia and grass dry matter fodder production from two cutting height and frequency treatments.
(Chi-square approximation with 1 df)

Type of fodder:	Cutting interval -weeks-	Cutting height -cm-	Rank Sum	Friedman Test Statistic
Gliricidia(1)	12		6	0 n.s.
	18		6	
		75	6	0 n.s.
		150	6	
grass (2)	12		7	1 n.s.
	18		5	
		75	7	1 n.s.
		150	5	

1. Dry matter production of leaves and branches <5 mm diameter.
2. Dry matter grass production under tree canopy, harvested concurrently with tree fodder.

n.s. No significant differences were present between treatments at P<.05.

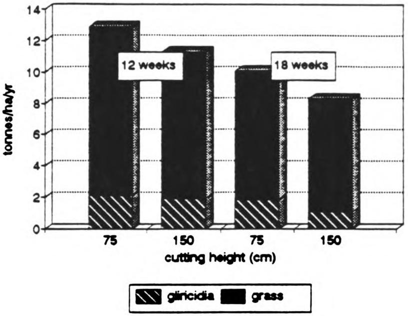
TABLE 6: Kruskall-Wallis one-way rank test for differences in Leucaena and grass dry matter fodder (1) production from two cutting frequency treatments.
(Chi-square approximation with 1 df)

Type of fodder:	Cutting interval -weeks-	Rank Sum	Kruskall-Wallis Test Statistic
Leucaena(2)	8	21	11
	12	15	
grass(3)	8	26	16*
	12	10	

1. Dry matter production of tree leaves and branches <5 mm diameter.
2. Cutting height was 75 cm.
3. Grass production under tree canopy, harvested concurrently with tree fodder.

* Significant differences were present between treatments at $P<.05$.

FIGURE 3: Gliricidia and grass dry matter fodder production (1) at 75 and 150 cm cutting heights within 12 and 18 week intervals.



1. Dry matter production of leaves and branches < 5mm diameter.

no evidence of interaction as illustrated using Gliricidia in Figure 3.

DISCUSSION

Species comparisons. Below-normal precipitation levels, less than 50% of the normal average, were recorded over the study period. Low rainfall may have limited Gliricidia and Leucaena from occupying sites quickly after harvest. Under normal rainfall conditions, higher production of tree fodder would be expected as has been demonstrated in other studies (Ella et al. 1991, Horne et al. 1985).

While statistical comparisons between species are not possible due to the experimental design, average Calliandra production yielded four times more DM tree fodder (8.0 tons/ha/yr) than the other two species on this site. This quantity is comparable to yields of DM leaf material reported by Ella et al. (1989), for Calliandra harvested at nearly the same age, planting density, cutting interval, and height. Even when planted at the comparatively low density of 4,444 trees/ha, Calliandra produced superior fodder yields compared to Gliricidia and Leucaena. Calliandra shaded out pasture grasses at the tested cutting heights and intervals. This species fully closed its canopy within twelve weeks of harvest, and allowed virtually no grass and broadleaf weed growth even within the nine week harvest interval. In contrast, the canopies of *Leucaena* and *Gliricidia* plantations did not completely shade out grasses after establishment periods of 14 and 18 months, and did not reach crown closure between harvests. Based on the results of this trial, it appears that these species cannot form pure fodder tree banks at the tested planting density and harvest intervals.

The average of 1.8 t/ha/yr for *Gliricidia* production was the lowest of the three tested species. In other Jamaican production trials under drier conditions, this species yielded similar results (Rueggsegger 1992). Under similar rainfall patterns in Indonesia, *Gliricidia* DM leaf production yielded more than three times the output reported in this study (Ella et al. 1989). Tree fertilization, better soils, and higher planting densities in the Indonesian trial may have contributed to the higher yields. Higher yields of tree leaf material are potentially attainable at higher planting densities. Increasing *Gliricidia* density in Indonesia (Ella et al. 1991) and in the Ivory Coast (Budelman 1987) from 1,200 to 40,000 trees/ha increased DM leaf production by as much as 44% on a 12 week harvest schedule. Grass production was not significantly affected by *Gliricidia* planting density except du

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during the dry season, when grass production increased at higher densities (Ella et al. 1991).

Differences noted in the Gliricidia fodder production results of this study and those in the literature may be due to tree management. In other Gliricidia production trials, it has been shown that the initiation of harvesting 4 to 6 months before the onset of the dry season results in increased fodder production (Ella et al. 1987, NFTA 1989b). In Jamaica, unmanaged trees drop their leaves and flower during the dry season. This study, which discarded the initially harvested material, was initiated 2 to 3 months before the onset of the dry season. The Gliricidia biomass yield data for the second and third measured harvests showed six-fold increases in yield over the first measured harvest despite the below-average rainfall which occurred over the study period. Excluding the first measured harvest, Gliricidia production yield was closer to production levels cited by other authors (Ella et. al 1991, Budelman 1987).

Leucaena DM fodder production averaged 2.3 t/ha/yr. This level compares favorably with fodder bank production reported for Jamaica (Rueggsegger 1992), but considerably less than the production level reported for other countries. Horne et al. (1985) surveyed seven studies and found DM leaf yields ranging from 4.0 to 15.2 t/ha/yr, with the lowest still producing nearly twice that of the Leucaena in this study. In four of these trials, however, planting densities ranged from 15,000 to 60,000 trees/ha compared to 4,444 trees/ha in this study. Higher planting density would be expected to increase DM tree leaf yields. Ella et al. (1989) found that increasing Leucaena density from 5,000 to 40,000 trees/ha increased yields by nearly 200%. In addition to density, other Leucaena varieties should be evaluated. Differences in growth and DM leaf yield have been noted between Leucaena varieties both in Jamaica and Hawaii (Thompson 1985, Guevarra et al. 1978). Despite low fodder tree production levels, the quality of fodder produced by the Leucaena plantation is greater than grass pastures alone. This plantation, when properly managed, could support more than twice the livestock number as nearby grass pastures (JLA 1983).

Grass constituted approximately 80% of DM fodder yield in Gliricidia and Leucaena plantations. Combining grass yields with tree production increased DM fodder yield in those plantations by 2.7 and 5.1 t/ha/yr, respectively, over Calliandra. The high nutritive quality of Calliandra when compared to grasses, however, gives pure fodder tree plantations greater value for dry season feed than mixed grass and fodder tree plantations. During the dry season, tropical grass crude protein levels often decrease below critical levels while those of Calliandra, Gliricidia, and

Leucaena remain constant. Under dry season conditions, protein levels in fodder tree species can often exceed grasses by 500 percent or greater (Paterson et al. 1987).

Besides protein content, other considerations important in tropical dry season fodder quality include digestibility, palatability and antinutrient levels (Akkasaeng et al. 1989). Fiber content, as measured by acid detergent fiber (ADF), is a negative index of feed quality. High ADF levels in feed can cause reduced digestibility and voluntary intake (Owen et al. 1989). The tested fodder tree species often have low fiber levels when compared to many grass species. In one trial, ADF levels in Gliricidia and Leucaena were lower when compared to two grass species and three agricultural by-products (cassava tops, and corn, banana, and papaya leaves) commonly used for feed (Cheeke and Roharjo 1987). Some fodder tree species, including Gliricidia, are often initially rejected by livestock because they find the taste unpalatable. These feeding patterns can be changed by mixing tree fodder with grass until cattle become acquainted with its taste (NFTA 1989b). Antinutrient compounds, such as mimosine, tannins, and saponins occur in some tree fodder species and can limit their effectiveness as feed sources (NRC 1981). Their effects, however, can be lessened through proper management. Deleterious mimosine effects have been eliminated through the metabolic activity of rumen microbes which occur in cattle where Leucaena is native, and these organisms can be introduced into other livestock populations (NRC 1981). Negative effects of other antinutrient compounds can be reduced by limiting tree fodder intake to safe levels (Panday 1982, NRC 1981). When managed properly in animal production systems, species tested in this trial have performed well elsewhere in the world for supplementing the protein needs of livestock (Panday 1982, Torres 1983, NRC 1981, Devendra 1990).

Cutting interval. Manipulating cutting interval is an effective management tool for some of the fodder tree plantations tested in this trial. Longer harvest intervals produced proportionately more wood and less fodder within harvested biomass. After removing the woody portion, however, Calliandra DM fodder production increased from 7.3 to 8.7 t/ha/year when cutting interval was increased from nine to twelve weeks. Similar increases were made in another trial when harvest intervals were increased from six to twelve weeks (Ella et al. 1989). Conversely, grass production under Leucaena decreased from 14.2 to 7.7 t/ha/yr when cutting interval was increased from eight to twelve weeks. It is suspected that competition with Leucaena for light limited grass yield when longer cutting intervals were used.

Cutting interval treatments did not significantly impact other fodder tree and grass production levels. Production increases from 7.7 to 10.1 t/ha/yr for grass production in Gliricidia plantations, however, were substantial. In other mixed tree/grass Gliricidia and Leucaena plantations, twelve week cutting intervals have produced significantly more DM tree fodder and less grass when compared to six week intervals (Ella et al. 1991). These results, however, were highly influenced by precipitation variations during the different harvest periods. Results of this study may become similar as additional harvests are conducted in higher rainfall periods and continuing management stabilizes production.

Cutting height. Calliandra DM fodder production was significantly greater at the 150 cm cutting height when compared to the 75 cm height, increasing from 6.8 to 9.1 t/ha/yr. Similarly, Siregar (1983) found that this species produced the greatest biomass at 100 cm when cutting heights were varied from 5 to 150 cm. Increased DM leaf yields for Leucaena have been shown to result chiefly from an increased number of buds in taller residual stems, and it is speculated this may also be true for Calliandra (Alferez 1978).

Differences in cutting height had no effect on Gliricidia tree fodder production, and were not tested on

Leucaena. Although the effect of cutting height was not tested on _Leucaena_, other research has shown that increased height leads to greater biomass and fodder production. For this reason, cutting height treatments should be considered in future _Leucaena_ trials (Alferez 1978, Perez and Melendez 1980). Other studies concerning the effect of cutting height on _Gliricidia_ are lacking. The use of this species as a living fencepost, where cutting height does not vary greatly, may be partly responsible for the lack of research data. The author speculates that morphological differences between _Gliricidia_ and _Calliandra_ may be partly responsible for the lack of yield differences in the tested cutting height treatments. Individual _Gliricidia_ trees have fewer and larger branches, petioles, and leaves than similar sized _Calliandra_, and may differ in its ability to respond to differences in the tested cutting height treatments

Dry matter grass production increased from 8.3 to 9.5 t/ha/yr in _Gliricidia_ plantations cut at 75 and 150 cm, respectively. Other cutting height studies on mixed _Gliricidia_ and grass production are lacking, however, numerous tree/crop interface studies have indicated increased cutting height increases shade and reduces interplanted crop production (Attah-Krah and Sumberg 1987, Ella et.al. 1991).

Grass did not grow in the Calliandra plantation. The author speculates that the dense shade of the Calliandra canopy was responsible for limiting the growth of grass and other vegetation. Harvested plantations regrew quickly and were able to create heavy shade within twelve weeks of harvest.

In tree and grass associations, the relative growth rates of component species are affected by a variety of factors, including temperature, precipitation, shading, root competition, allelopathy, and soil moisture and nutrient levels (Ella et al. 1991, Ludlow et al. 1974). Regulation of planting density, cutting interval, and height can alter solar radiation and soil moisture levels in the plantation and influence the relative growth rates of grass to trees. During dry season conditions, grass grown under twelve week cutting intervals have produced greater yields than six week intervals, and it was suspected that soil moisture level, rather than light, was the most limiting factor (Ella et al. 1991). Conversely, when soil moisture and nutrients were adequate for good grass growth, competition for light has been shown to be the limiting growth factor (Ericksen and Whitney 1982). If precipitation levels remain low, cutting intervals could be increased so that shading from fodder trees conserves soil moisture and increases grass yield. The implementation of longer cutting intervals must be viewed with caution, as the feed quality of grasses has been shown to diminish with longer harvest intervals (Stoddart et al. 1975).

Applications. Fodder tree banks, similar to the ones employed in this experiment, can increase livestock carrying capacity by providing high protein dry season fodder. According to Paterson et al. (1987), between 24 and 32 percent of the diet of adult cattle (450 kg. live weight) should consist of legumes to satisfy dietary protein requirements when grass protein content is severely limited because of low rainfall. This translates into an adult animal consuming about 3 kg/day of tree fodder. Based on this trial's production, the highest producing Calliandra stand could provide the protein needs of approximately ten 450 kg animals/ha/year. Further efficiency could be realized by providing tree fodder supplements only when grass no longer provides adequate protein, drying and storing leaf meal for future use, and targeting animals in most need (Paterson et al. 1987).

Grass production in fodder tree plantations. Eight week cutting intervals increased grass production in Leucaena from 7.7 to 14.2 t/ha/yr when compared to the twelve week interval. This result differs from other Leucaena studies using interplanted Guinea grass, which found greater grass production in twelve week cutting

intervals when compared to six week intervals (Ella et al. 1991). Some of the production variation could be related to difference in grass species physiology. Para grass, the dominant graminous species in this trial, has been shown to be less shade-tolerant than Guinea grass (Ericksen and Whitney 1982).

In applying the results of these experiments to Jamaican animal production systems, the types of animal management systems must be defined. Management system considerations include the fodder tree planting configuration, harvest method, and the season and frequency required of tree fodder inputs. Once these parameters are defined, appropriate fodder tree species, planting densities, and harvest heights and intervals may be recommended. When tree fodder is used in conjunction with well managed grass pastures, about ten percent of farm land area should be planted in fodder trees (Paterson et al. 1987).

There are a variety of configurations in which fodder trees can be placed, including fencelines, as scattered trees in pastures, and as banks of either pure fodder trees or mixed trees and grass. If pure <u>Gliricidia</u> and <u>Leucaena</u> fodder banks are to be established, closer tree spacing than 1.5 m^2/tree will be required. Conversely, mixed grass and <u>Calliandra</u> stands will require wider spacings than those

tested. Fodder tree banks should be fenced to control animal access and situated where several paddocks meet. By centrally placing tree fodder banks to grass paddocks, labor needed for either cutting and carrying tree fodder to animals or moving animals to browse tree fodder is minimized.

In mixed tree and grass fodder banks, the relative need for either product could be used to determine the cutting interval. Prior to the dry season, tree harvest would be delayed until regrowth produced higher proportions of tree fodder relative to grass. Closer spacings can also be used to influence the balance of tree fodder production in mixed tree and grass plantations (Ella et al. 1991).

Fodder trees can be harvested by either direct grazing or by cutting and carrying to livestock. Cutting and carrying tree fodder has been shown to require a greater labor input than direct grazing (Paterson et al. 1987). Cut material, however, can be dried and stored for later use, thereby allowing farmers to harvest tree fodder when time is available (NRC 1981, Paterson 1987). Cutting makes more efficient use of tree fodder than direct grazing, since less is lost from trampling and wastage (Paterson et al. 1987). In direct grazing systems, livestock tend to ride down fodder tree stems and bite off the tops and small branches, leaving a tall residual stem (NRC 1981, Paterson et al.

1987). In directly-grazed fodder banks, tree management is limited to regulating tree height to within the reach of grazing animals.

A balance between the production of planted fodder trees and livestock tree fodder requirements must be maintained, as would grass production in a properly managed pasture grass system. Animal browsing and cutting activities must be regulated so that a constant supply of tree fodder is available. Directly browsed fodder banks need to be fenced into sections so that previously browsed trees can adequately grow back before being used again. An alternate method of regulating fodder bank grazing pressure for resource limited farmers is to tie animals in fodder banks and move them periodically, thus reducing fencing costs.

CONCLUSIONS

This research has demonstrated that the production of fodder trees and fodder tree/grass associations can be managed by manipulating cutting heights and cutting intervals. The incorporation and proper management of fodder trees is vital if the limitations imposed on feed quality by dry season conditions are to be overcome in Jamaican livestock systems. This technology can be incorporated with less capital and labor investment when compared to other feed alternatives, making it especially applicable to small producers.

Tree forage represents only part of the solution to dry season pressures on Jamaican cattle. Herd size has to be matched to the pasture carrying capacity, and supplemental feeding in the form of concentrates, sugar cane tops and urea/molasses blocks may be necessary when grass and tree fodder is limited in supply.

ACKNOWLEDGEMENTS

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BIBLIOGRAPHY

Alferez, A.C. 1978. Management of ipil-ipil for forage. pp. 51-56. In: International Consultation on Ipil-Ipil Research: Papers and Proceedings. Philippines Council for Agriculture and Resources Research, Los Banos, Philippines.

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

Attah-Krah, A.N. and J.E. Sumberg. 1987. Studies with Gliricidia sepium for crop/livestock production systems in West Africa. pp. 31-43. In: Withington, D, N. Glover and J.L. Brewbaker (eds.) Gliricidia sepium management and improvement: Proceedings of a workshop sponsored by the Nitrogen Fixing Tree Association, June 21-27, Turrialba, Costa Rica. 255 p.

Baker, G.H. 1968. Soil and Land Use Survey No. 24: Jamaica, Parish of St. Ann. Regional Research Centre (RRC), Department of Soil Science, University of the West Indies, Trinidad and Tobago.

Bell, E. 1989. Moneague District Forester, Jamaica Department of Forestry and Soil Conservation. Personal communication.

Blustain. H and E. Lefranc. 1987. Strategies for Organization of Small Farm Agriculture in Jamaica. University of the West Indies Centre for Economic and Social Research, Kingston.

Budelman, A. 1987. Gliricidia sepium in the Southern Ivory Coast: Production, composition and decomposition of the leaf biomass. pp. 74-81. In: Withington, D, N. Glover and J.L. Brewbaker (eds.) Gliricidia sepium management and improvement: Proceedings of a workshop sponsored by the Nitrogen Fixing Tree Association, June 21-27, Turrialba, Costa Rica. 255 p.

Cheeke, P.R. and Y.C. Raharjo. 1987. Evaluation of Gliricidia sepium forage and leaf meal as foodstuffs for rabbits and chickens. pp. 193-198. In: Withington, D, N. Glover and J.L. Brewbaker (eds.) Gliricidia sepium management and improvement: Proceedings of a workshop sponsored by the Nitrogen Fixing Tree Association, June 21-27, Turrialba, Costa Rica. 255 p.

Conover, W.J. 1971. Practical Nonparametric Statistics. John Wiley and Sons Inc. New York. 462 p.

CRIES. 1982. Jamaica Resource Assessment. Comprehensive Resource Inventory and Evaluation System Project (CRIES). Michigan State University, Ohio State University, U.S. Department of Agriculture. 75 p.

Devendra, C. (ed). 1990. Shrubs and tree fodders for farm animals. Proceedings of a workshop in Denpasar, Indonesia, 24-29 July 1989. International Development Research Centre, Ottawa, Canada. 349p.

Ella, A., W.W. Stur, G.J. Blair and C.N. Jacobsen. 1989. Effect of plant density and cutting frequency on the yield of four tree legumes. Tropical Grasslands 23:28-34.

Ella, A., W.W. Stur, G.J. Blair and C.N. Jacobsen. 1991. Effect of plant density and cutting frequency on the yield of four tree legumes and interplanted <u>Panicum</u> <u>maximum</u> cv. Riversdale. Tropical Grasslands 25:281-286.

Evensen, C.L.I. 1984. Seasonal yield variation, green leaf manuring and eradication of <u>Leucaena</u> <u>leucocephala</u>. Master's Thesis. University of Hawaii, Manoa, Hawaii.

Ericksen, F.I., and A.S. Whitney. 1982. Growth and N fixation of some tropical forage legumes as influenced by solar radiation regimes. Agronomy Journal 74:703-709.

FAO. 1988. Production Yearbook 1987 vol. 41. FAO. Rome.

GOJ (Government of Jamaica). 1987. Jamaica: Country Environmental Profile. Government of Jamaica, Kingston. 362 p.

Guevarra, A.B., Whitney, A.S. and Thompson, J.R. 1978. Influence of intra-row spacing and cutting regimes on the growth and yield of <u>Leucaena</u>. Agronomy Journal 70:1033-1037.

Horne, P.M., D.W. Catchpoole and A. Ella. 1985. Cutting management of tree and shrub legumes. pp. 164-169. In: Blair, G.J., D.A. Ivory and T.R. Evans (eds.) Forages in Southeast Asian and South Pacific Agriculture. Australian Center for International Agricultural Research (ICIAR), Proceedings No. 12. ACIAR: Canberra.

JAGRIST. 1992. An Annotated Bibliography Relating to Agriculture in Jamaica. Jamaica Society for Agricultural Sciences (JSAS), Kingston, Jamaica. 275 p.

JLA. 1983. Livestock Manual for the Tropics. The Jamaica Livestock Association. Kingston, Jamaica. 406 p.
Krishnamurthy, K. and M.K. Munegowda. 1982. Effect of cutting frequency regimes on the herbage yield of Leucaena. Leucaena Research Reports 3:31-32.

Lazier, J.R. 1981. Effect of cutting height and interval on dry matter production of Codariocalyx gyroides (syn. Desmodium gyroides) in Belize, Central America. Tropical Grasslands 15:10-16.

Little, T.E. and F. J. Hills. 1978. Agriculture Experimentation: Design and Analysis. John Wiley and Sons Inc. New York. 350 p.

Ludlow, M., G.L. Wilson and M.R. Heselhurst. 1974. Studies on the productivity of tropical pasture plants. Effect of shading on growth, photosynthesis and respiration of two grasses and two legumes. Australian Journal of Agricultural Research 25:198-201.

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

NRC (National Research Council). 1981. Leucaena: Promising Forage and Tree Crop for the Tropics (2nd ed.). National Academy Press. Washington D.C. 115 p.

Nair, P.K.R. 1985. Classifications of agroforestry systems. Agroforestry Systems 2:97-128.

NFTA. 1989a. Cooperative Planting Program: Establishment Guide. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 36 p.

NFTA. 1989b. Gliricidia Production and Use. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 44 p.

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

Ozman, A.M. 1981. Effects of cutting interval on the relative dry matter of four cultivars of Leucaena. Leucaena Research Reports 2:33-34.

Panday, K.K. 1982. Fodder Trees and Tree Fodder. Swiss Development Cooperation. Berne, Switzerland. 107 p.

Pathak, P.S., P. Rai, and Roy R.D. 1980. Forage production from koo babool (Leucaena leucocephala (Lam.) de Wit): (1) effect of plant density cutting intensity and interval. Forage Research 6(1):83-90.

Paterson, R.T., G.A. Proverbs and J.M. Keoghan. 1987. The Management and Use of Fodder Banks. Caribbean Agricultural Research and Development Institute (CARDI), St. Augustine, Trinidad. 21 p.

Perez, P. and P. Melendez. 1980. The effect of height and frequency of defoliation on formation of bud of Leucaena leucocephala in the state of Tabasco, Mexico. Tropical Animal Production 5(3):280.

Pound, B. and L.M. Cairo. 1983. Leucaena: its Cultivation and Uses. Overseas Development Administration, London. 287p.

Ramanujam, S. 1981. Varietal adaption to production systems. In: Proceeding of the International Workshop on Pigeonpeas, Vol 2. ICRISAT, India.

Rosecrance, R., W. Dominick and B. Macklin. 1989. Cajanus cajan accession evaluation for green leaf manure production and coppicing ability. Nitrogen Fixing Tree Research Report 7:81-83.

Roshetko, J.M. 1991. Establishment and Nutritive Value of Native and Exotic Fodder Tree Species in Jamaican Pasture Systems. Master's Thesis. Department of Forestry, Michigan State University, E. Lansing, MI. 90 p.

Rueggsegger, G. 1992. University of Florida. Personal communication.

Sanchez, P.A., C.A. Palm, C.B. Davey, L.T. Scott and C.E. Russell. 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. Institute of Terrestrial Ecology. Natural Environment Research Council. 592 p.

Santhirasegaram, K., J.E. Coaldrake and M.H.M. Salih. 1966. Yields of a mixed subtropical pasture in relation to frequency and height of cutting and leaf area index. pp. 125-129. In: Proceedings of the X International Grassland Congress. Helsinki.

SIOJ. 1979. Census of Agriculture 1978-1979: Preliminary Report. Statistical Institute of Jamaica.

Siregar, M.E. 1983. Effect of cutting management on the yield and quality of tropical forage species. pp. 613-614. In: Proceedings, 5th World Animal Production Conference, Tokyo, Japan.

Stoddart, L.A., A.D. Smith and T.W. Box. 1975. Range Management (3rd ed.) McGraw-Hill, New York. 532 p.

Sumberg, J.E. 1985. Note on estimating the foliage yield of two tropical browse species. Tropical Agriculture (Trinidad) 62(1):15-16.

Thompson, D.A. 1986. Leucaena leucocephala trials in Jamaica. Leucaena Research Reports 6:60-62.

Takahishi, M. and J.C. Ripperton. 1949. Koa haole (Leucaena glauca): its establishment, culture and utilization as a forage crop. p. 56. In: Bulletin 100, Hawaii Agricultural Experiment Station.

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

Von Carlowitz, P.G. 1987. Multipurpose tree yield data: their relevance to agroforestry research and development and the current state of knowledge. Agroforestry Systems 4:29-314.

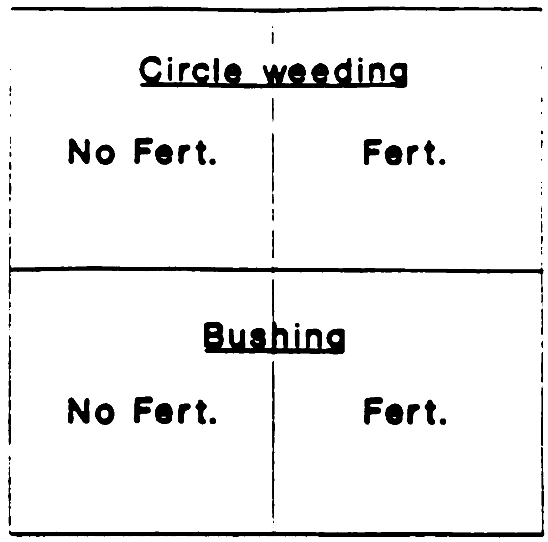

Figure 1a. Main block layout of fertilizer and weed control levels.

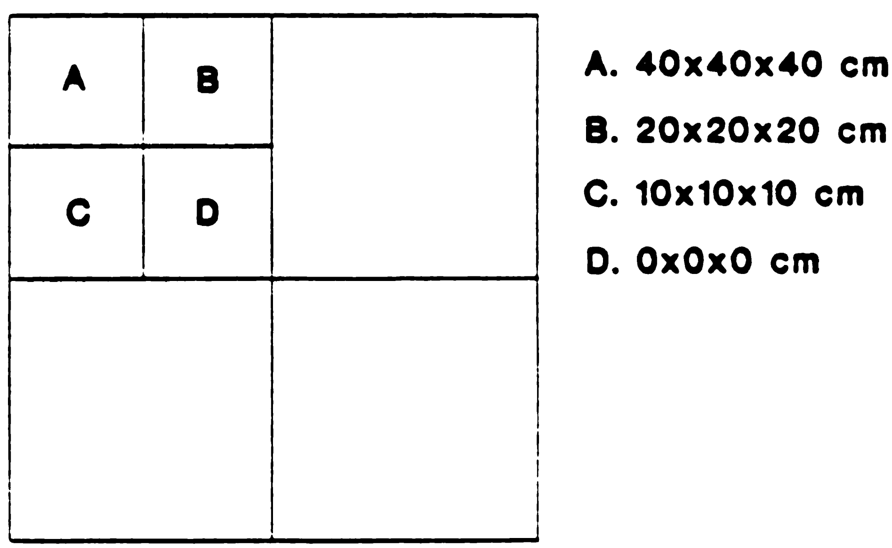

Figure 1b. Main block layout of planting pit size levels.

APPENDIX A: Experimental design used in Moneague establishment method trials (Roshetko 1991).

FODDER TREE ESTABLISHMENT IN A SEASONALLY DRY AREA OF JAMAICA

ABSTRACT. Seven fodder tree species were established and grown at five planting sites in Green Park, Jamaica. Six species, Leucaena leucocephala, Gliricidia sepium, Calliandra calothyrsus, Erythrina poepiggiana, Cajanus cajan, and Sesbania sesban, were established by direct seeding and one species, Brosimum alicastrum, by seedlings. Additional Calliandra and Gliricidia plots were established with seedlings and vegetative cuttings. Trees were planted at 1 m^2 spacing in 25 (5 x 5) tree plots.

Data were taken over a six month period. Survival of Gliricidia cuttings and Cajanus was similar at 84 and 82 percent, respectively. The two next highest survival rates were 66 and 56 percent for Calliandra seedlings and directly sown Gliricidia, respectively. Total height growth of Cajanus averaged 113 cm, more than twice that of any other tested species. Directly sown Gliricidia, Leucaena, and Sesbania reached a total height of approximately 45 cm. Survival and height growth ranged widely between planting sites.

INTRODUCTION

Raising cattle for the production of meat and dairy products is a significant agricultural endeavor in Jamaica. Cattle rearing, the major economic activity for over twenty percent of agricultural lands, is a stabilizing force in the national economy and a consistent contributor to gross domestic product. Farms which engage in production range from large estates to small-scale farmers (SIOJ 1979). Domestic production of meat and dairy products is about 106 thousand metric tons/year, however, the country still imports large quantities of beef. During the period

1981-1985, nearly 12% of all domestic consumption was imported (GOJ 1987).

Under proper management, most of Jamaica's agricultural land area is suitable for pasture and livestock production (GOJ 1987). Attempts to increase domestic livestock production have been thwarted by high production costs, the long-term nature of livestock production, and inconsistent governmental policies (GOJ 1987, Bell 1989). Past research and extension activities have also concentrated on improving the production systems of larger (>10 ha) growers, which make up less than 2% of all Jamaican farmers (Blustain and Lefranc 1987, GOJ 1987).

In addition to economic and policy factors, there are biological restrictions on the growth potential of Jamaica's cattle industry. The most significant restriction is the effect of seasonal rainfall patterns on forage quality and its effect on ruminant nutrition (Paterson et al. 1987). Most Jamaican cattle subsist primarily on pasture grasses (Bell 1989, Rueggsegger 1992). During the biannual dry seasons in July-August and December-March (CRIES 1982), the availability and nutritive value of these grasses decrease as they become desiccated (Pound and Cairo 1983). In response, some farmers supplement the dietary requirements of their livestock with expensive imported feeds. Most resource-limited farmers, however, must resort to local forages including sugar cane tops and tree fodder when pasture grass is scarce and of poor quality and imported feed is too expensive (Morrison 1991). The well documented potential of the purposeful inclusion of fodder trees into agroecosystems (Von Carlowitz 1989) has not been studied extensively in Jamaica (JAGRIST 1992).

Examples of fodder tree cultivation abound in Nepal (Panday 1982), Australia (Torres 1983), Israel, Chile (NRC 1981), Indonesia (Davendra 1990), and the Dominican Republic (Pound and Cairo 1983), where trees are grown and employed as important components in ruminant nutrition. Some examples of silvopastoral systems, the planting and utilization of multipurpose trees for fodder, exist in Jamaica. Farmers in Moneague, St. Ann Parish periodically supplement the diet of cattle with the foliage of Gliricidia sepium planted as living fence posts (Bell 1989). Dairy farmers near Black River, St. Elizabeth Parish, use Leucaena and Gliricidia fodder banks to supplement the diets of their animals (Rueggsegger 1992). In general, Jamaican farmers chiefly use naturally occurring trees for fodder (Morrison 1991), which have low nutrient values compared with planted exotic species used elsewhere in the world (Roshetko 1991).

The quality and quantity of locally produced cattle forage can be greatly improved during dry periods by incorporating tree forage. Freshly cut tree foliage generally has a higher crude protein content and digestibility when compared to dry pasture grasses (Paterson et al. 1987, Pound and Cairo 1983, Davendra 1990). In addition, tree root systems access soil water and nutrients unavailable to pasture grasses (Sanchez et al. 1985) and maintain green foliage during periods of drought (Pound and Cairo 1983). Nitrogen fixing trees may also enhance site conditions over time by recycling nitrogen and raising soil nitrogen levels (Nair 1985, Pound and Cairo 1983).

Questions fundamental to tree fodder research include species-site selection, and tree species management (NFTA 1989a). Tree fodder management factors include: age at first cutting, height of cutting, amount of leaf material removed, interval between harvests, plant density, and interactions of these and other possible factors (Horne et al. 1985). Site adaptability and management trials, coordinated and supported by various international research organizations, continue to identify promising species and appropriate management systems throughout the world. Particularly in Jamaica, the knowledge of fodder tree production, management, and utilization needs to increase if the potential of this resource is to be realized (Roshetko 1991).

The study objectives were to 1) demonstrate the biological feasibility of establishing six selected exotic fodder tree species by direct seeding in the seasonally dry area of Green Park, Jamaica, 2) demonstrate alternative establishment methods for two of those species, and 3) demonstrate establishment of an indigenous fodder tree species by seedlings.

LITERATURE REVIEW

Fodder tree species. Small-scale farmers in seasonally dry areas of Jamaica traditionally use tree fodder for dry season livestock feed (Rueggsegger 1992, Bell 1989, Morrison 1991). In Green Park, 85% of cattle farmers harvest tree fodder during some time of the year, and nearly 30% spend four or more hours per day to harvest tree and grass fodder during the biannual dry seasons (Morrison 1991). Tree species commonly harvested include Breadnut (*Brosimum alicastrum*), *Gliricidia sepium*, and *Leucaena leucocephala*. Species naturalized to Jamaica (Adams 1972) and used successfully in other seasonally dry areas include *Calliandra calothyrsus*, *Erythrina poepiggiana*, *Cajanus cajan*, and *Sesbania sesban* (Panday 1982, Little and Wadsworth 1989).

Breadnut is a large tree of the Moraceae family, growing to 30 m or greater. It is found from Mexico to

Ecuador, as well as in Cuba and Jamaica (Adams 1972), and is used throughout its range for dry season livestock feed (NAS 1975). In Jamaica, it is preferred for charcoal-making and its seeds are eaten by both people and livestock (NAS 1975, Morrison 1991). Research concerning this species has centered on its role in forest ecosystems (Peters 1987, Bongers and Popma 1990) and use in ruminant nutrition (Roshetko 1991). It produces highly palatable fodder that is classified as a good dairy feed, based on crude protein levels of 13% and acid detergent fiber levels of 31% (Roshetko 1991).

Gliricidia sepium is a small (maximum 10 m) tree of the Papilionaceae family native to Central America. It has infrequently produced seeds in Jamaica (Rueggsegger 1992), and has been propagated throughout its range using large stem cuttings (NFTA 1989b). Cuttings develop shallow fibrous root systems, in contrast to the central taproot of seedlings. There is concern that a shallow, fibrous root system may limit the long-term viability of cutting-established Gliricidia by limiting access to soil nutrients and moisture, and by increasing susceptibility to windthrow (NFTA 1989b). Gliricidia cuttings are used in Jamaica to establish living fences (Adams 1972, Little and Wadsworth 1989), and to provide dry season fodder (Bell 1989, Morrison 1991). Direct-seeded Gliricidia have averaged 151 cm of height growth over ten months in an establishment trial in Jamaica (Roshetko 1991). Classified as an excellent feed source with low initial palatability, its average crude protein level ranges between 22% and 27% and digestibility between 50% to 75% (NFTA 1989b). When mixed with grass and molasses, animals become used to its taste and readily accept it (NFTA 1989b).

Leucaena leucocephala (Mimosaceae) is a tree genus native to Central America and the West Indies. In Jamaica it grows in pastures and along roadsides into a shrub or small tree to a maximum height of 6 m (Adams 1972). Other previously described Leucaena varieties are morphologically different and may have greater growth rates than those found in Jamaica (NRC 1981). Leucaena is an acceptable fodder tree species in Jamaica because of its high average crude protein levels (25%), digestibility (55% to 70%) and palatability (NFTA 1990a, Morrison 1991). Mimosine, a toxic amino acid present in Leucaena, causes hair loss and thyroid injury in livestock when consumed in large quantities. A rumen bacterium found in many cattle populations can break down mimosine and eliminate the toxic side effects associated with its consumption. The lack of reported mimosine toxicity in Jamaican livestock probably indicates that this bacterium is already present in Jamaica (NRC 1981, Rueggsegger 1992). Jamaican establishment trials using direct-seeded trees have produced ten-month growth averaging 183 cm (Roshetko 1991).

Calliandra calothyrsus (Mimosaceae) is a shrub or small tree (maximum 10 m) native to northern South America. Originally introduced to Jamaica as an ornamental species, it has been planted extensively for erosion control and rehabilitation of degraded sites (Adams 1972, Bell 1989). Optimal annual rainfall for this species is reported to be between 2000 and 4000 mm. Its natural range, however, includes areas with only 700 mm (NFTA 1989c). Jamaican establishment trials have reached an average six-month height of 233 cm in an area that receives 2000 mm average annual precipitation (Roshetko 1991). The fodder potential of Calliandra is reported to be limited by foliage tannin levels that limit digestibility to around 40 percent (NFTA 1989c).

Erythrina poepiggiana (Papilionaceae) is a large tree (maximum 30 m) native to Central and South America. In its natural range, annual precipitation ranges between 1500-4000 mm and can include dry seasons as long as 6 months (Adams 1972, NFTA 1986). In Jamaica and elsewhere, it has long been employed to shade coffee and as living fenceposts (Little and Wadsworth 1989). Cattle also will consume Erythrina foliage, which averages 25% crude protein and a 50% to 80% level of digestibility (NFTA 1986).

Cajanus cajan (Papilionaceae) is a short-lived leguminous shrub (maximum 5 m) that has been grown throughout the tropics for human food and livestock fodder (Adams 1972). Wide genetic variability exists within this species, and research has concentrated on identifying and developing higher yielding, disease-resistant perennial varieties (Daniel and Ong 1990). Its relatively high crude protein content (15% to 24%), palatability, digestibility and non-toxicity (NFTA 1988), coupled with rapid growth in Jamaica and elsewhere have shown this shrub to be a good short-term fodder source while longer-lived species become established (Roshetko 1991, Daniel and Ong 1990). In Green Park, Jamaica, it has been grown for food and windbreaks, but has not regularly been used for fodder (Morrison 1991).

Sesbania sesban (Papilionaceae) is a shrub or small tree (maximum 6 m) native to Africa and Asia, and sparingly found in Jamaica (Adams 1972). Establishment trials in Jamaica have averaged height growth of 468 cm in ten months (Roshetko 1991). It has been widely used for fodder, and has produced crude protein levels ranging from 17% to 30% and digestibility exceeding 60% (NFTA 1990b). Tannins and saponins present in Sesbania may affect ruminant utilization, but have not been fully studied (NFTA 1990b).

Direct-seeding. All the previously discussed species, except Breadnut, are suitable for direct seeding establishment into pastures (NRC 1979, Paterson et al. 1987). Establishment trials in Moneague, Jamaica, have shown Leucaena, Calliandra, Gliricidia, and Sesbania to be highly productive when established by direct seeding in improved grass pastures at 500 m elevation above sea level and 2000 mm average annual precipitation (Roshetko 1991). Direct seeding has been shown to be inherently less expensive than seedling or cutting establishment methods because less labor and equipment are used per established tree (Smith 1986). Other advantages of direct seeding when compared to seedling or cutting establishment include: large areas planted with minimum preparation time, natural root system development, elimination of transplanting mortality, reduction of windthrow and root rot, and potentially dense stocking rates (Smith 1986, NFTA 1989).

Site condition variations hold greater influence over direct-seeding than seedling or cutting establishment methods. When fodder trees are sown directly into pastures, rainfall patterns, sowing depth, exposure of mineral soil, and seed pretreatment all heavily influence germination. The greatest limiting factor to direct seeding, however, is the need for frequent rain after sowing (Smith 1986). Uniform germination in Leucaena, Calliandra, and Sesbania can be enhanced by pretreatment to increase seed coat permeability but such seed is more susceptible to drought

(NFTA 1989a). The species tested in this trial (except Breadnut) are nitrogen-fixing and require inoculation with appropriate Rhizobium species to successfully establish in many areas (NFTA 1989a). When direct-seeded trees begin to establish strong taproots, the influence of rainfall variation diminishes and the influence of grass and broadleaf weed competition increases. Grass and weed competition become less important as seedlings establish dominance over pasture vegetation (Smith 1986). The rapid growth of competing vegetation, especially tropical pasture grasses, has made frequent early weeding treatments necessary for successful establishment of direct-seeded fodder trees (Roshetko 1991).

Seedlings. The most effective and guaranteed way to establish trees is to plant viable, sturdy seedlings (Smith 1986). Seedling establishment methods have a less restricted planting season and efficiently use limited quantities of genetically superior seed. They also require less weeding when compared to direct seeding establishment methods (Smith 1986). Seedlings and cuttings also require more labor and capital than direct seeding, due to the cost of nursery operations and transportation (Evans 1982).

When wild seedlings are used for fodder tree establishment, they can eliminate nursery establishment costs. Such seedlings, however, particularly from species with strong taproots, often cannot be reliably transplanted (Smith 1986). Both Calliandra and Breadnut produce large numbers of seedlings in their understory, and can supply planting stock for fodder tree establishment (Bell 1989).

Vegetative cuttings. Cuttings, like seedlings, are a more reliable way to establish individual trees when compared to direct seeding. Vegetative cuttings also produce plants that are genetically identical, increasing stand productivity when superior planting stock is used (NFTA 1989b). Lack of genetic variation, however, may predispose entire plant populations to biotic and abiotic problems (Evans 1982). Nursery establishment costs can be reduced by using cuttings, but trees from which sufficient numbers of cuttings can be produced take much longer to establish than nursery seedlings (NFTA 1989).

Gliricidia, Erythrina, and Breadnut have been grown from cuttings under field conditions (NFTA 1989b, NFTA 1986, NAS 1975). Trials conducted to establish treated and untreated Breadnut cuttings were unsuccessful in this trial. Gliricidia and Erythrina cuttings 1 to 2 m long, 2 to 6 cm in basal diameter and planted 20 to 50 cm deep are typically used to establish fence line plantings (NFTA 1989b, NFTA 1986). Erythrina poepiggiana, however, is not found in Green Park and only Gliricidia was available to use for vegetative establishment (Morrison 1991).

METHODS AND MATERIALS

Site. Green Park is located in the Trelawny Parish, Jamaica, 8 km south of the coastal town of Falmouth. Green Park is a former sugar estate purchased in 1959 by Kaiser Jamaica Bauxite Company Ltd. for the relocation of landowners displaced by bauxite mining in St. Ann parish near Alexandria (Andreatta 1992).

Green Park is a seasonally dry area, with 8 months of the year receiving less than 100 mm of rain. Rainfall averages 1140 mm/yr and is bimodally distributed. A long wet season lasts from September to December and a shorter one occurs from May through June. Mean daily temperatures range from 24^{0} C to 28^{0} C, with minimum and maximum temperatures of 18^{0} C and 33^{0} C. Most of Green Park lands (95%) are dominated by two slightly acid to alkaline clay loams, Lucky Hill and Bonnygate (RRC/UWI 1970). Bonnygate soils are generally found on hillsides greater than 10 degrees and are shallow, highly erodible, and excessively well drained with poor nutrient- and moisture-holding capacity. Lucky Hill soils are generally found on valley bottom sites with slopes less than 10 degrees. Their average soil depth is 12 cm greater than the Bonnygate soil type, and they are slightly erodible, with poor nutrient- but moderate water-holding capacity (CRIES 1982). Bonnygate soils are the most common Green Park soil, representing 70 percent while Lucky Hill soils comprise most of the remaining 30 percent of agricultural lands.

Five establishment trial sites were located on farms in the Green Park area. Each site was previously used for pasture. Seymour grass (*Andropogon pertusus*) dominated four sites while Guinea grass (*Panicum maximum*) was the main grass species at one site. Guinea grass is considered to be an improved pasture grass in Jamaica, and with another improved grass, Star grass (*Cynodon plechtostachyus*), is favored by Green Park farmers (Morrison 1991, JLA 1983). Seymour grass is typically found on degraded, overgrazed pastures and is the dominant grass on most Green Park pastures (JLA 1983, Morrison 1991). Planting sites varied considerably in soil depth, slope, aspect, and represented a wide range of potential places in which silvopastoral management can be introduced into Green Park.

Species and planting stock. Based on previous Jamaican establishment trials (Roshetko 1991), a report of indigenous Jamaican knowledge relating to tree fodder which listed preferred fodder tree species (Morrison 1991), a search of the literature, and communications with the Nitrogen Fixing Tree Association (NFTA)[1], the Oxford Forestry Institute (OFI)[2], and the International Crops Research Institute for

[1] Nitrogen Fixing Tree Association, 1010 Holomua Rd., Paia, Hawaii.

[2] Oxford Forestry Institute, South Parks Rd., Oxford, U.K.

the Semi-Arid Tropics (ICRISAT)[3], six exotic leguminous, nitrogen-fixing fodder tree species likely to perform well under direct-seeding and frequent fodder harvesting in the Green Park environment were selected. The selected fodder tree species were: Cajanus cajan, Calliandra calothyrsus, Erythrina poepiggiana, Gliricidia sepium, Leucaena leucocephala, and Sesbania sesban. A seventh indigenous, non-nitrogen fixing species, Breadnut (Brosimum alicastrum, family Moraceae), was chosen because it is a preferred dry season fodder in Green Park (Morrison 1991).

There were seven species, with planting method combinations used in the study (Table 1). All species, with the exception of Breadnut were established by direct seeding. Breadnut and Calliandra were established with seedlings, and Gliricidia were established with cuttings. These establishment methods were employed based on indigenous planting practices, the species' biological potential, and planting stock availability.

Tree seed was secured from the Nitrogen Fixing Tree Association, Oxford Forestry Institute, and the

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[3] International Crops Research Institute for the Semi-Arid Tropics, P.O. Patancheru 502 324, Andhra Pradesh, India.

Table 1: Species, varieties, and establishment methods used in Green Park, Jamaica.

SPECIES	VARIETY	Establishment Method[1]	Number of plots established[2]
Leucaena	NFTA[3] K636	direct seeding	24
Sesbania	NFTA 874	direct seeding	19
Cajanus	ICP[4] 88040	direct seeding	18
Erythrina	BLSF[5] 2510	direct seeding	11
Brosimum	local[6]	seedling	7
Calliandra	NFTA 896	direct seeding	9
Calliandra	local	seedling	14
Gliricidia	NFTA 1	direct seeding	23
Gliricidia	local	cutting	7

1) All establishment methods planted in 20 cm^3 cultivated planting pits and weeded three times at six week intervals.
2) Number planted over five sites.
3) Nitrogen Fixing Tree Association.
4) ICRISAT (International Crops Research Institute for the Semi-Arid Topics) Cajanus Provenance.
5) Banco Latino Americano de Semillas Forestales (obtained through NFTA).
6) Planting stock obtained in the Green Park area.

International Crops Research Institute for the Semi-Arid Tropics. The balance of planting materials were acquired through local sources. *Gliricidia* cuttings were selected from Green Park trees. *Calliandra* and Breadnut seedlings were transplanted from a nearby plantation and woodlands, respectively.

Establishment. Plots of 25 trees, planted at a 1 by 1 m spacing (10,000 trees/ha), were established on five farms in October 1990. Planting sites were chosen by the participant farmers. Prior to planting, on-farm sites were fenced, sprayed with paraquat (750 g concentrate/ha) to reduce grass competition, and 20 cm^3 planting holes were excavated and refilled as planting sites. *Calliandra*, *Leucaena* and *Sesbania* seed were pretreated with hot water (approximately 76^0 C) at 5 times seed volume, and allowed to cool to room temperature (NFTA 1989a). All seed was inoculated with *Rhizobium* and planted 1 to 2 cm deep (NFTA 1989a). Multiple seeds were sown in each planting pit at 2 to 3 times the expected germination rate. Both Breadnut and *Calliandra* seedlings were graded to a 20 mm root collar diameter and 10 cm taproot minimum, and transplanted under a grass mulch with foliage intact. *Gliricidia* cuttings between 75 and 120 cm long, and 3 to 6 cm diameter were planted between 20 and 30 cm deep, after foliage was removed. Both seedlings and cuttings were planted at one stem per planting pit.

Weeding treatments were conducted three times following establishment, at approximately 6 week intervals. Weeding removed grass and broad-leaved weeds within a 30 cm radius circle around each seedling. Pasture vegetation was undisturbed outside the circle weeded area.

Planting Design. Locations of planting plots for species and planting stock combinations were selected randomly at each site. The number of replications per species was based on the amount of planting material available. Three species, *Cajanus*, *Gliricidia*, and *Calliandra* were replicated at all five sites. Although sites differed greatly in soils, aspect and other features, individual sites were homogeneous.

Measurements. Tree height (cm) and survival (planting pit occupancy) were recorded at six week intervals over 24 weeks. The nine interior trees of each 25 tree plot were measured. Border rows acted as a safeguard against edge effects (NFTA 1989a). Height growth of vegetatively-propagated *Gliricidia* was recorded as the length of the longest shoot on each cutting. The height above ground of emergent shoots on *Gliricidia* cuttings was observed but not recorded. Height of undisturbed pasture vegetation was measured and recorded at each site.

In addition to collecting tree growth data, man-hours required for the establishment and maintenance of each site were noted. Labor activities included herbicide application, plot and planting pit location, pit establishment, seed pretreatment and sowing, and the acquisition, movement, and planting of seedlings and cuttings.

Table 2:. Analysis of variance for survival of six direct-seeded fodder tree species at the Jones farm, Green Park, Jamaica.

Source	Degrees of freedom[1]	Mean square for error	F
species	5	1684.03	7.90**
error	16	213.18	

1. Other sites had fewer species, resulting in fewer species degrees of freedom. The number of replications for each species varied at different sites.
** Survival of species were significantly different at $P < 0.01$.

Analysis. Analysis of variance for a completely randomized design was used to test for differences among the direct-seeded species at each site (e.g. Table 2). Height growth data was normally distributed and conformed to the assumptions of analysis of variance. Arcsine transformation of survival percentages was completed before the analysis of variance (Little and Hills 1978). Tukey's multiple range test was used to compare survival and height growth means of direct-seeded species at each site. Survival and growth of

Calliandra and Gliricidia planting stock alternatives were analyzed at two sites using T tests.

RESULTS

Survival. Significant survival differences were found for direct-seeded species at all sites but the Brown farm (Table 3). Erythrina and transplanted Breadnut did not survive on any study plot and were omitted from all analyses. Direct-seeded Calliandra did not grow after germination at the Henry farm, and was not included in the analysis at that site.

Direct-seeded Cajanus survival was consistently higher than other direct-seeded species at each site. Direct-seeded Gliricidia was the next best species, with a survival level of 81 percent at the Sterling farm and a range of 44 to 53 percent survival at the other four sites. At three sites where four or more direct-seeded species were tested, Gliricidia was significantly better than other species at only one location. Leucaena germinated and survived poorly at three of the four sites tested, averaging 53 percent survival at the Sterling farm and 36 percent across the other sites. Sesbania survived well at the Sterling farm, averaging 72 percent, but averaged only 6 and 20 percent at two other sites where it was tested.

Height growth. Direct-seeded species differed significantly in six-month height growth at all sites (Table 4). During the six to ten months following planting, trees were damaged by animal trespass in approximately 50 percent of *Leucaena* plots and 10 percent of *Gliricidia* plots. Comprehensive height measurements were not taken in these plots because of animal damage, but growth of undamaged trees was observed to ten months.

Cajanus height growth averaged 113 cm and was significantly greater than other direct-seeded species at four of five sites. Direct-seeded *Gliricidia* and *Leucaena* were the next tallest species at sites where they were planted. *Gliricidia* grew 63 and 78 cm at the Sterling and Brown farms, but only ranged from 20 to 39 cm in height at three other sites. Average *Leucaena* height growth ranged from 30 to 65 cm across the four sites where it was planted. Average *Sesbania* height varied widely, ranging from 11 to 92 cm at three sites. *Sesbania* grew as tall as *Cajanus* at the Sterling farm but grew the least at the Jones farm. Guinea grass height averaged 110 cm, and Seymour grass height averaged 40 cm after six months.

Planting stock differences. Survival of *Calliandra* seedlings was greater than those established by direct-seeding at the two sites where both planting stocks were established. Height growth differences were

TABLE 3: Average six month survival[1] for five direct-seeded fodder tree species established at five farms in Green Park, Jamaica.

Species	Percent survival					
	Brown[2]	Henry	Jones	Scott	Sterling	MEAN
Cajanus cajan	67	94 a[3]	78 a	73 a	96 a	82
Calliandra calothyrsis			22 bc			9
Gliricidia sepium	52	44 b	49 ab	53 b	81 ab	66
Leucaena leucocephala	44		31 bc	25 c	53 c	38
Sesbania sesban			6 c	20 c	72 bc	33

1. Survival = planting pit occupancy; seed was sown at 2 to 3 times expected germination.
2. There were no significant differences in survival between species at the Brown farm.
3. Treatment averages followed by the same letter did not differ significantly at $P < 0.05$ using Tukey's multiple range test.

TABLE 4: Average six month height growth for five direct-seeded fodder tree species established at five farms in Green Park, Jamaica.

	Height growth (cm)					
Tree species	Brown	Henry	Jones	Scott	Sterling	MEAN
Cajanus cajan	129 a[1]	111 a	100 a	76 a	151 a	113
Calliandra calothyrsis			19 bc			9
Gliricidia sepium	78 b	39 b	25 bc	20 b	63 b	45
Leucaena leucocephala	65 b		45 b	30 b	36 b	44
Sesbania sesban			11 c	30 b	92 ab	44
Grass species						
Panicum maximum	110					110
Andropogon pertusus		39	41	29	51	40

1. Treatment averages followed by the same letter did not differ significantly at $P<0.05$, using Tukey's multiple range test.

TABLE 5: Average six month survival[1] and height growth[2] of two alternative establishment methods for Calliandra and Gliricidia at two farms in Green Park, Jamaica.

		Henry		Jones	
Species	Establishment method	Survival -%-	Height -cm-	Survival -%-	Height -cm-
Calliandra calothyrsis	direct seed	0 **	0 +	22 *	19 n.s.
Calliandra calothyrsis	seedlings	72	43	50	41
Gliricidia sepium	direct seed	44 +	39 **	49 **	25 +
Gliricidia sepium	cuttings	78	14	91	14

1. Survival = planting pit occupancy. Seed was sown at 2 to 3 times expected germination. Seedlings and cuttings were planted one per pit
2. Height growth of Gliricidia cuttings was recorded as the length of the longest shoot.

** Significant differences in establishment treatments at $P < 0.01$, using T test.
* Significant differences in establishment treatments at $P < 0.05$, using T test.
+ Significant differences in establishment treatments at $P < 0.10$, using T test.
n.s. Establishment treatments did not significantly differ at $P < 0.10$, using T test.

substantial at only one site. Gliricidia cuttings had a higher level of survival as compared to direct-seeded Gliricidia (Table 5). Dominant emergent shoots from Gliricidia cuttings averaged 14 cm as compared to 32 cm for direct seeded trees. The emergent shoots, however, originated 45 to 100 cm above the ground line. Seedlings and cuttings required .67 and .70 man-days, respectively, to establish a single 25 tree plot. Direct-seeding to establish these same species required only .24 man-days per 25 tree plot.

DISCUSSION

Demonstrating the biological as well as the economic feasibility of fodder tree establishment is important for the long-term viability and success of fodder tree introduction in Green Park farming systems (Morrison 1991). Limited labor and capital resources constrain farmer's ability to establish and cultivate fodder trees, to move cumbersome planting stock or harvested fodder, or to provide barriers necessary for protecting young plants from livestock (Morrison 1991, Andreatta 1992). These restrictions dictate that suitable fodder tree species must be able to establish and grow quickly. Besides survival and growth, factors including site conditions and planting stock differences are important to consider when selecting fodder tree species for Green Park farms.

Site differences. Growth and survival varied considerably between planting sites. Only one species, *Cajanus*, survived and dominated the sites at all five planting locations. Planting site differences in soil depth, and sun and wind exposure appeared to influence growth differences between sites. Overall tree growth was greatest at the Sterling and Brown sites where Lucky Hill soils, with a 30 to 45 cm clay loam layer which increased in stoniness with depth, were found. The Sterling site is exposed to prevailing area winds. The Brown site is protected from wind and excessive solar radiation by a fencerow and a coconut plantation. The poorest overall growth was found at the Jones farm. This site was located in the middle of a large pasture were fodder trees were exposed to winds and direct, full day solar radiation. In addition, the Bonnygate soils at this site are heavily eroded and are only 20 to 30 cm over solid limestone.

Because Bonnygate soils comprise the majority of Green Park land, low moisture and nutrient levels will limit plantings of fodder trees at most sites. Planting sites that afford some protection from wind and direct sunlight appear to be favored for enhanced establishment results.

Survival and Height Growth. Survival and height growth in this trial was less than reported for two other Jamaican establishment trials. When planted in an area receiving nearly twice the average annual precipitation of Green Park, Gliricidia, Leucaena, Sesbania, and Calliandra grew 2 to 7 times taller in six months (Roshetko 1991). Leucaena growing under similar rainfall conditions as found in Green Park averaged only 20 cm taller after six months of growth (Thompson 1985).

Cajanus grew aggressively in both Guinea and Seymour grass pastures, and generally formed closed canopies after six month's growth. Unfortunately, Cajanus suffers from a variety of insect and disease problems that limit its long-term viability (Daniel and Ong 1990, Roshetko 1991). Seed borer (Helicoverpa armigera) was observed through all plots four months after establishment. Mortality of 20 percent from an unidentified stem wilt was noted ten months following establishment at one site. Although short-lived, Cajanus's aggressive establishment, human and animal food value, and fast growth make it a useful multiple purpose tree for short-term fodder production while long-lived species become established (Morrison 1991).

Direct-seeded Gliricidia were free to grow above Seymour grass pastures 6 months after planting at all but the two poorest sites. In another Jamaican study, direct-seeded Gliricidia grew above Para grass (Brachiaria mutica) within six months of planting (Roshetko 1991). At some planting sites, direct-seeded Gliricidia may require additional weeding treatments to establish when planted in Guinea grass. Gliricidia produces seed sporadically in Jamaica, and without locally produced seed, it will be difficult to find seed for direct-seeded establishment.

Gliricidia cuttings established above pasture grasses at all sites because shoots emerged 45 to 100 cm above ground level. Although sources report vegetatively-propagated Gliricidia to have limited long-term viability (NFTA 1989b), established Gliricidia cuttings in Green Park are vigorous and healthy 5 to 7 years after planting. The use of Gliricidia cuttings to establish living fenceposts is an increasingly accepted practice in Green Park (Morrison 1991). For these reasons, vegetatively-propagated Gliricidia is recommended for continued planting as living fenceposts and for further study as a fodder tree in Green Park pastures.

Despite seed pretreatment and planting depth regulation, poor germination of Leucaena occurred. Seed lot tests indicated an expected germination rate of 88 percent germination but field trials registered much lower rates of germination. The author speculates that seed pretreatment made this species more susceptible to dehydration during a post-planting drought. Survival of sown seed planted without pretreatment was 27 percent greater than pretreated seed, even when sown during a period of lower precipitation.

Leucaena height growth matched or outgrew pasture grasses at two sites in 6 months. Trees which escaped animal damage grew from 75 to 200 cm tall at all farms but Scott, ten months following planting. Thompson (1985) also noted slow initial height growth for *Leucaena* when planted on dry, limestone-derived soils in Jamaica. Other authors have reported that *Leucaena* shoot growth accelerates after root systems become established (NAS 1981).

Previous research and suggestions from some Green Park farmers indicate that fodder trees could be integrated with present pasture improvement activities (Morrison 1991, Brown 1992). The introduction of *Leucaena* to pasture improvement practice is particularly suitable because many Green Park farmers presently maintain the naturally-seeded local variety of *Leucaena* in their pastures (Adams 1972). Further testing of the K636 variety and other arboreal varieties are recommended because of their high fodder yields and long growth interval prior to seeding compared to spreading varieties (Guevarra et al. 1978). Future direct-seed plantings should include both non-treated and pretreated *Leucaena* seed.

Introducing *Calliandra* seedlings into Green Park silvopastoral systems is constrained by the lack of local planting stock sources, and Green Park farmers' unfamiliarity with this species (Morrison 1991, Andreatta 1992). Although *Calliandra* seedlings grew well at three of the five sites, additional weeding treatments were necessary to establish it in the Guinea grass pasture. Seedlings grew vigorously for the ten months following establishment, but approximately 25 percent had foliage die-back on at least one branch by the tenth month. In addition, direct-seeded *Calliandra* performed poorly in Green Park pastures. Further planting trials and continued observation of established trees are advised before this species can be recommended for Green Park.

Sesbania grew and survived well on one site with deep soils and limited wind exposure, and poorly on two other exposed sites with poor soil. The potential of this species on selected sites should be studied. However, a lack of local seed sources and unfamiliarity of farmers with the species will limit its immediate use in Green Park.

Direct-seeded *Erythrina* and Breadnut were omitted from the analysis because they failed to survive in Green Park pastures. Direct-seeding does not appear to be a viable strategy for establishing *Erythrina* under the low rainfall conditions found in Green Park. A single attempt to transplant wild Breadnut seedlings into the study sites was also unsuccessful. Breadnut is widely used in Green Park as a fodder tree. Further attempts to establish Breadnut are warranted based on the importance given this species by local farmers (Morrison 1991), and are currently underway (Morikawa 1993).

Establishment method. Three different establishment methods (direct seeding, cuttings, and seedlings) were tested for two species in this trial. Two establishment methods for Calliandra and Gliricidia were tested at each of two planting sites. Marked differences in survival, growth and labor inputs required for each method were noted.

Direct-seeding required approximately 1/3 of the labor input of seedlings and cuttings. The larger labor investment for seedling establishment has been noted by forest managers throughout the world (Smith 1986). Other advantages of direct seeding include the ability to rapidly plant large areas of land and establish extensive fodder tree plantings. Commonly discussed disadvantages include the need for larger seed quantities, more weeding treatments than needed for seedlings or cuttings, (Smith 1986) and seasonally related activities that constrain farm labor (Andreatta 1992). The selection of species to directly seed will probably depend on growth habit and seeding frequency. Leucaena and Cajanus are particularly suitable for direct seeding because they are currently found in Green Park and produce large quantities of easily-collected seed.

Cutting and seedling survival exceeded direct-seeded trees by 30 to 42 percent in trials where direct-seeded plants survived. Because of increased survival, seedling establishment is recommended over direct seeding when high value germplasm is to be established or when low density plantings are desired. Fewer weeding inputs are required for seedlings and cuttings when compared to direct-seeding (Evans 1982). For this reason, cuttings and seedlings are a good choice for fodder tree establishment, especially in tall, fast-growing tropical grasses such as Guinea grass, when labor for weeding is unavailable at later periods (Andreatta 1992).

Fodder tree establishment has potential to be integrated into current farming practices. One such example is the practice of establishing short-term crops with Star grass (Morrison 1991). Crops and grass could be planted with fodder trees, and resources used to weed and protect plants from livestock could be combined to establish a tree/grass pasture. The combination of these activities could possibly make more efficient use of resources when compared to planting the components separately (Morrison 1991), and should be investigated.

CONCLUSIONS

From this study, it appears that Cajanus, Calliandra seedlings, vegetatively-propagated Gliricidia, Leucaena, and Sesbania require further study for possible use in Green Park pasture systems. Observations made after establishment indicate that Cajanus should be used for short-term fodder production while slower-growing but longer-lived species become established. Future plantings should be concentrated on sites with deeper soils and protection from excessive sun and wind exposure.

Direct-seeded Erythrina and Calliandra were unsuccessful due to low survival or slow, inconsistent growth. Direct-seeding of Gliricidia is not practical without locally produced seed. These species might have application for fodder tree use elsewhere in Jamaica, but are not recommended for further study in Green Park. Breadnut seedlings were not successful, but further study of alternative establishment methods is recommended because of the popularity of this species for dry season fodder (Morrison 1992).

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BIBLIOGRAPHY

Adams, C.D. 1972. Flowering Plants of Jamaica. MacLehose and Co., The University Press. Glasglow, Scotland. 848p.

Andreatta, S. 1992. People, crops, trees and livestock: an agro-silvopastoral system in Jamaica (1990-1991) (an anthropological and ecological perspective). Ph.D. dissertation draft. Michigan State University, Department of Anthropology. 247p.

Bell, E. 1989. Moneague District Forester, Jamaica Department of Forestry and Soil Conservation. Personal communication.

Blustain. H and E. Lefranc. 1987. Strategies for Organization of Small Farm Agriculture in Jamaica. University of the West Indies Centre for Economic and Social Research, Kingston.

Bongers, F. and J. Popma. 1990. Leaf dynamics of rain forest species in relation to canopy gaps. Oecologia 82:122-127.

Brown, R. 1992. Farmer, Green Park, Jamaica. Personal communication.

CRIES. 1982. Jamaica Resource Assessment. Comprehensive Resource Inventory and Evaluation System Project (CRIES). Michigan State University, The Ohio State University, U.S. Department of Agriculture. 75p.

Davendra. C. (ed). 1990. Shrubs and tree fodders for farm animals. Proceedings of a workshop in Denpasar, Indonesia, 24-29 July 1989. International Development Research Centre, Ottawa, Canada 349p.

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

Ella, A. W.W. Stur, G.J. Blair and C.N. Jacobsen. 1989. Effect of plant density and cutting frequency on the yield of four tree legumes. Tropical Grasslands 23:28-34.

Evans, J. 1982. Plantation Forestry in the Tropics. Oxford Press. Oxford, U.K. 472p.

FAO (Food and Agriculture Organization of the United Nations). 1988. Production Yearbook 1987 vol. 41. FAO. Rome.

GOJ (Government of Jamaica). 1987. Jamaica: Country Environmental Profile. Government of Jamaica, Kingston. 362p.

Horne, P.M., D.W. Catchpoole and A. Ella. 1985. Cutting management of tree and shrub legumes. pp. 164-169 In: Blair, G.J., D.A. Ivory and T.R. Evans (eds.) Forages in Southeast Asian and South Pacific Agriculture. Australian Center for International Agricultural Research (ICIAR), Proceedings No. 12. ACIAR: Canberra.

JAGRIST. 1992. An Annotated Bibliography Relating to Agriculture in Jamaica. Jamaica Society for Agricultural Sciences (JSAS), Kingston, Jamaica. 275p.

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

Little, T.E. and F. J. Hills. 1978. Agriculture Experimentation: Design and Analysis. John Wiley and Sons Inc. New York. 350p.

Little, E.L. and F.H. Wadsworth. 1989. Common Trees of Puerto Rico and the Virgin Islands (2nd ed.). Agriculture Handbook No. 249. USDA Forest Service. Washington, D.C. 556p.

Morikawa, R. 1993. Department of Forestry, Michigan State University, E. Lansing, Michigan. Personal communication.

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

Nair, P.K.R. 1985. Classifications of agroforestry systems. Agroforestry Systems 2:97-128.

NAS (National Academy of Science). 1975. Under-exploited Tropical Plants with Promising Economic Value (2nd ed). National Academy Press, Washington, D.C. 189p.

NAS. 1981. Leucaena: Promising Forage and Tree Crop for the Tropics (2nd ed.). National Academy Press, Washington D.C. 100p.

NFTA. 1986. Nitrogen Fixing Tree Highlights: Erythrinas provide beauty and more. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 2p.
NFTA. 1988. Nitrogen Fixing Tree Highlights: Cajanus cajan: it's more than just a pulse crop. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 2p.

NFTA. 1989a. Cooperative Planting Program: Establishment Guide. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 36p.

NFTA. 1989b. Gliricidia Production and Use. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 44p.

NFTA. 1989c. Nitrogen Fixing Tree Highlights: Calliandra calothyrsus: an Indonesian favorite goes pan-tropic. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 2p.

NFTA. 1990a. Nitrogen Fixing Tree Highlights: Leucaena: an important multipurpose tree. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 2p.

NFTA. 1990b. Nitrogen Fixing Tree Highlights: Sesbanias: a treasure of diversity. Nitrogen Fixing Tree Association, Waimanolo, Hawaii. 2p.

NRC (National Research Council). 1979. Tropical Legumes: Resources for the future. National Academy Press, Washington D.C. 332p.

NRC (National Research Council). 1981. Leucaena: Promising Forage and Tree Crop for the Tropics (2nd ed.). National Academy Press, Washington D.C. 115p.

Paterson, R.T., G.A. Proverbs and J.M. Keoghan. 1987. The Management and Use of Fodder Banks. Caribbean Agricultural Research and Development Institute (CARDI), St. Augustine, Trinidad. 21p.

Panday, K.K. 1982. Fodder Trees and Tree Fodder. Swiss Development Cooperation. Berne, Switzerland. 107p.

Peters, C.M. 1987. Regeneration and growth strategies of Brosimum alicastrum Sw. in the moist tropical forests of Mexico. pp. 31-34 In: A.E. Lugo (ed.) People and the Tropical Forest: a Research Report from the United States Man and the Biosphere Program. U.S. Department of State, Washington D.C.

Pound, B. and L.M. Cairo. 1983. Leucaena: Its Cultivation and Uses. Overseas Development Administration, London. 287p.

Roshetko, J.M. 1991. Establishment and Nutritive Value of Native and Exotic Fodder Tree Species in Jamaican Pasture Systems. Master's Thesis. Department of Forestry, Michigan State University, E. Lansing, MI. 90p.

RRC/UWI-Regional Research Centre. 1970. Soil and Land Use Survey No. 25, Jamaica, Parish of Trelawny. University of the West Indies, Trinidad, West Indies.

Rueggsegger, G. 1992. University of Florida. Personal communication.

Sanchez, P.A., C.A. Palm, C.B. Davey, L.T. Scott and C.E. Russell. 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. Institute of Terrestrial Ecology. Natural Environment Research Council. 592p.

SIOJ. 1979. Census of Agriculture 1978-1979: Preliminary Report. Statistical Institute of Jamaica.

Smith, D.M. 1986. The Practice of Silviculture. John Wiley and Sons. New York. 527p.

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

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

Von Carlowitz, P.G. 1987. Multipurpose tree yield data: their relevance to agroforestry research and development and the current state of knowledge. Agroforestry Systems 4:29-314.

SUMMARY

This research has shown that fodder trees and fodder tree/grass associations can be managed by manipulating cutting intervals and heights. Calliandra produced approximately four times more tree fodder than the Gliricidia and Leucaena plantations. The combination of tree fodder and grass production under the Gliricidia and Leucaena increased total fodder production over the Calliandra plantation.

The incorporation and proper management of tree fodder is vital if dry season conditions are to be overcome in small-scale Jamaican livestock systems. Tree forage is intended to compliment pasture grass, and grass should continue to provide the larger volume of feed. Tree forage represents only part of the solution to dry season pressures, however. Herd size has to be matched to pasture carrying capacity, and other supplemental feeds may still be necessary when grass and tree fodder supply is limited.

From establishment trials in Green Park, it appears that Cajanus, Calliandra, Leucaena, Sesbania, and vegetatively-propagated Gliricidia show promise for inclusion in Green Park farming systems. Observations made to ten months after establishment indicate Cajanus should be used for short-term fodder production while slower-growing

species become established. Further study is needed to determine the long-term growth habits of all these species. Fodder tree survival and growth were highly variable at different planting locations, and future plantings should be concentrated on sites with deeper soils and protection from excessive sun and wind exposure.

DIRECTION OF FUTURE RESEARCH

This study has produced many useful results that may be used to guide the future establishment and management of fodder trees in Jamaican farming systems. If the project goal to integrate fodder tree establishment and management data with current farming systems is to be realized, however, more research questions need to be addressed. This study examined the establishment of seven different fodder tree species in Green Park, but observations were limited to the ten months following establishment. The growth habits of established trees need to be further noted so the long-term suitability of these species can be established.

Past development experience has demonstrated that tree planting arrangements which conform to current agricultural land uses and labor constraints are more likely to be adopted into a given farming system. Fodder trees in this study were established in fenced forage banks which were placed in the corners of pasture paddocks. The suitability of this and alternative planting arrangements with current agricultural practices needs to be examined. Continued exchange of ideas with Green Park farmers should be used to aid in the design of future establishment experiments.

Fodder tree management studies were carried out in Moneague over nine months, and should be continued to determine the long-term effects of repeated harvest and rainfall variations. Management studies of established trees in Green Park should be implemented to determine harvest strategies specific to the environmental conditions which occur there. Feeding trials should also be initiated in Green Park both to determine the effect of tree fodder on animal performance and to demonstrate the use of this technology to Green Park farmers.

Finally, economic analyses should be performed to compare the viability of silvo-pastoral alternatives to traditional livestock management systems. Care should be taken so that fair values are assigned to all inputs and outputs, especially those which are not normally assigned market values.

Integrating and expanding the role of tree fodder into Jamaican livestock production systems has great potential, repeatedly demonstrated in other tropical countries, to increase overall productivity. The knowledge of appropriate species and management regimes should continue to be expanded in Jamaica. If the potential of this resource is to be realized, however, research needs to be accompanied by the participation of Jamaican producers so that the technology can be extended into and refined by the audience it is aimed at benefiting.