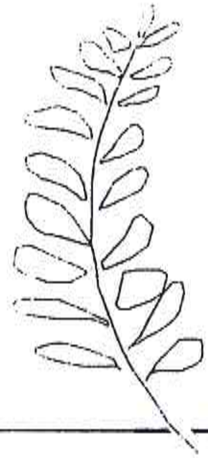

PROCEEDINGS OF THE
1ST INTERNATIONAL CONFERENCE ON LEUCAENA
WITH THE THEME:

LEUCAENA IN AGRICULTURAL DEVELOPMENT

Sponsored by

The Organization of American States (OAS) Caribbean Leucaena Project

in association with

- **The University of the West Indies**
- **Sugarcane Feeds Centre**
- **The National Institute of Higher Education (Research, Science and Technology) (NIHERST)**
- **The Caribbean Agricultural Research and Development Institute (CARDI)**
- **The Ministry of Food Production, Marine Exploitation, Forestry and the Environment of the Republic of Trinidad & Tobago**

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Editors' Note

The editors wish to express their joy in having had the opportunity to organize (as Chairman and Secretary of the Organizing Committee), edit and supervise the publication of this proceedings—The "**First International Conference on Leucaena—with the theme: Leucaena in Agricultural Development**." It was a very pleasurable experience in editing 30 papers submitted by participants from 16 countries; Australia, Barbados, Grenada, Guyana, Haiti, India, Indonesia, Jamaica, Malawi, Mexico, Saint Lucia, Suriname, Sri Lanka, Trinidad and Tobago, the United Kingdom and the United States of America. The presenters from Indonesia, Sri Lanka and the United Kingdom, however, were unable to attend. There were two papers with an engineering theme, five with the major them on forestry, six on farming systems, three on soils, three on research coordination, seven on animal nutrition, and five on Germplasm evaluation. In the latter we were able to get the opinions of one of the present Leucaena breeding groups of the USA, Mr. C. Sorensson (a colleague of Professor James Brewbaker of The University of Hawaii) and also of one of the principal workers from Europe (Dr. Hughes).

The presence of Dr. Mark Hutton from Australia who has been working on Leucaena breeding and selection since 1954, was indeed a privileged opportunity for us all. Mexico's contribution provided a description of their breeding infrastructure and the Germplasm evaluation work of the Caribbean was presented by one of the editors, Dr. T.U. Ferguson. However, it was unfortunate that the audio in the tape used to capture the presentation of Dr Miguel Laufer, Director of the Department of Scientific and Technological Affairs of the OAS was damaged and was not reproduced. His focal points were the compliments paid to the management of the Caribbean OAS Leucaena Project in which success was achieved through periodic contact, the sharing of information and the willingness to minimise the duplication of efforts. The contents of this document reflects the depth and breadth of the work done on Leucaena, a crop which is a problematic unexploited weed in some countries, while in others it is a source of food for animals and man, a source of fuel, a source of organic fertilizer and a soil erosion inhibitor. Extensive knowledge on the use of this nitrogen fixing tree has been obtained. The work done and knowledge generated on this crop can serve as a model which could be used to guide us in the future in evaluating and using the hundreds of other unexploited Nitrogen Fixing Trees (NFTs) available to man.

It would not be honourable of us if we did not acknowledge and thank the sponsors of the conference; the Organization of American States. They not only sponsored this conference but their support of the Caribbean Leucaena workers in facilitating annual meetings from 1981 to 1988 through the "OAS Caribbean Leucaena Project" was the foundation which made this document a reality. We would also like to further acknowledge all the OAS officials who facilitated the cumulative efforts in particular Professor Antonio Quesada. Special acknowledgements must be given to Dr. K.A.E. Archibald (the first regional co-ordinator of the "OAS Caribbean Leucaena Project," and Mr. R. Quintyre (the last co-ordinator). We must also acknowledge those collaborating organizations, The ministries of Agriculture of Food production of Barbados, Grenada, St. Lucia, Haiti, Jamaica, and Trinidad and Tobago; The University of the West Indies, The University of Suriname, and the Sugarcane Feeds Centre, in Trinidad and Tobago. Finally, we wish to thank Miss Charmine Clovis who assisted in the correcting of the first draft and the helpful staff of Gloria V. Ferguson's Printery.

T.U. Ferguson and G.W. Garcia
1992 August

Opening Address

Mr. Frank Rampersad
President of the National Institute of Higer Education Research, Science and Technology (NIHERST)

Ladies and Gentlemen,

I congratulate the University of the West Indies and the Organization of American States on their convening this the First International Conference on "Leucaena" at which the results of the research which regional scientists have undertaken over the last several years will be presented for examination. The work on "Leucaena" was a collaborative effort; the scientists from the University directed the scientific aspects of the research programme; national Research and Development institutions in the region participated in the field trials and in data collection; the OAS financed a part of the cost; NIHERST played a role in the management.

This conference carries us one step forward towards the eventual goal which we set ourselves - that of developing a commercially viable technology; and in this regard the Conference represents one form of response which scientists, technologists and policy advisers must make to the imperatives of adjustment and transformation in developing countries - that is, accumulating necessary intelligence and disseminating it to people who will put it to productive use.

Those of us who form part of the scientific and technological infrastructure in countries such as Trinidad and Tobago often find it difficult to meet the challenges which confront us as we seek to make a meaningful contribution to the process of strengthening the domestic economy. Perhaps the biggest difficulty we face is the pervasive dependency syndrome, a feeling that "foreign" is best. The scientific infrastructure cannot extirpate this syndrome by preaching or indeed only by publishing. It has to make it obvious to the population that the infrastructure is capable, relevant and useful. I want to suggest three ways by which we can approach that task.

First, we need to address the question of information relevant to the needs of the community which we serve. In this regard, it is necessary to recognise that countries like ourselves will always be extensively dependent on technology developed abroad. It is therefore necessary to develop a dynamic information system which will enable us, and the producers, to monitor technological changes taking place in the world and to facilitate planning for any adverse or favourable fall out which these developments may have on the national production system. But paralleling this database on foreign technology must also be a database on local technology and on national exploitable resources. This Conference addresses this need for information and in particular for disseminating information.

Second, we have to advance the technologies and ideas which our scientists develop up to the point where they can be put to work by producing enterprises. This is of particular relevance to countries such as Trinidad and Tobago. The scientists here and in the region have undertaken a great deal of high quality research which has passed the test of peer review; but, for the most part, these efforts have been driven by the search for scientific knowledge, not by the quest for solutions to the practical problems which enterprises confront on the factory floor. What we have to do is to take a few of these scientific ideas and carry them forward to the point of implementation in commercial production.

Third, while I do not wish to underplay the value of pure scientific research, I believe that, in our case, it is necessary to change the mix in the scientific inquiry which the country and the region undertake. In particular, I suggest that the predominant proportion of the research and development activity on which our scientists and technologists embark must derive directly from, and respond to, the needs of the production system; it must be uniquely concerned with removing as many as possible of the constraints which prevent producers from optimising the value added from the natural and human resources which the country and the region are fortunate to own. On the whole, I would suggest that the on-going scientific and technological effort does not pass this test.

In brief, it is my submission that the scientists of the country and the region will enhance their position and acceptability in the world of production and investment, and indeed of politics, only if they involve themselves, more than they have done in the past, with the direct needs of the production system. It is in their own self interest to do so. I say this not only because there is psychological income to be earned from seeing one's ideas converted into tangible form. I say it also because of the reality that it is becoming increasingly clear that the Governments of the region, even with the help of international organisations like the OAS, are not going to be able to provide the quantum of resources which the scientists require to pursue their interests in either the pure or applied sciences. The only way through which the scientists and technologists can realistically harbour any hope of garnering the resources which they need lies in mobilising first the interest, and then the commitment, of the producers. The one sure way of igniting this interest is to make it abundantly clear that the work on which they are engaged is concerned with developing responses to the practical problems which the producers face. Scientists who consider things like the gross domestic product or cost-benefit to be beneath their dignity will not require many Leucaena leaves to cover the dignity which they may have left.

But the responsibility for enlarging the resources available to relevant science and technology cannot rest on the scientists and technologists alone. The Governments have a role to play, both by increasing the allocations which they make to science and by adopting policies which will encourage others to provide necessary money and materials. At present the resources which Government allocates to science and technology is, euphemistically speaking, inadequate. What is more, even the limited amount of resources is continually at risk, and the scientific and technological infrastructure works almost from hand to mouth. We cannot advance in science and technology in that kind of environment. It is contradictory to take in terms of securing the nation's long term future and ten at the same time undermine the foundations on which this long term future will rest. Scientific and technological knowledge and capability are the surest bulwark for national economic security in the world of the future and the Governments must demonstrate their commitment to development of this bulwark by providing adequate funding on an assured medium term basis.

The producers also have a role to play both in enlarging the resource base and in ensuring that the research mix is appropriate. They can abdicate this responsibility only incuring the risk of heavy cost to themselves, both in the short term and the long term. I say this not only because of the experiences they have had that, in many cases, the benefits of external technological advice were sub-optimal as well found out in a recent survey of technological applications in the Chemical Industry. I say it also because the exploitation of the resources available locally often require solutions which are *sui generis* and these can be derived only through local research. In short, the less they spend on research and development now, the smaller will be the resource base which they will have for exploitation and income generation in the future. It does no good for producers to refer to the scientific and technological infrastructure as an ivory tower. At the very minimum they have a self interest in climbing into the ivory tower to see what is gong on and how they can influence this activities which take place there.

This imperative of promoting an early and effective merging of interest of the research community, the producing enterprises and the public sector has been the guiding factor shaping the way in which NIHERST has gone about its business since its inception. We believe that the method is producing results. The bagasse based animal feed plant, which Caroni (1975) Limited is about to construct, grew out of the collaboration which we promoted and directed between the research community and Caroni; the enhanced oil recovery, which the University is undertaking which NIHERST support, is being done with participation from the practitioners and it is already influencing, at the margin, certain of the operations in thermal oil recovery. We expect very shortly to be able to launch a plant tissue culture company as a joint venture involving the public sector, the University, State enterprises and large and small private farmers which will commercialise the research being undertaken in Tissue Culture at the University with NIHERST support; and we are advanced in negotiations to establish an Applied petroleum Research Institute which will combine the resources of the oil companies, the Ministry of Energy and NIHERST to begin the search for solutions to problems in the production and utilisation of hydrocarbons locally, particularly those relating to natural gas and heavy oils.

The scientific and technological infrastructure in this country is taking close interest in this First International "Leucaena" Conference. We are looking to the discussions at this Conference to indicate the way forward for the further development of this project so that the farmers, the foresters and the community at large can derive the benefit on research. But the Conference is expected to make a larger contribution for, through drawing together the experience of a wide group of committed people, it will enable us to shorten the process of advancing the plants, and other processes in agriculture, to the stage of commercialisation and thus strengthen the contribution which applied science and technology can make to the nation's economic security.

Opening Address

The Honorable Dr. Brinsley. Samaroo
Minister of Food Production and Marine Exploitation, Republic of Trinidad and Tobago

A conference such as this which begins today, will, certainly not catch the headlines. You would be studying a shrub but for purposes of large-scale publicity, not the right one. Nevertheless yours would be a conference of very far-reaching significance as you look at this very versatile leguminous shrub Leucaena. An area of particular concern for us in the Caribbean might be its application towards the enhancement of our dairy and meat industry. In that regard therefore, you would, I am certain, tolerate a few points by way of setting the study in a broader context.

The production of milk and/or meat constitutes the end product of a series of interactions between soils, climate, plants, animals and man. The specific ability of ruminants to convert feeds, fodder and other grazing resources into the final product (milk or meat) has been and continues to be the principal reason for our interest in ruminant production. This is more especially so since unlike many of the other types of livestock production systems, ruminants are not usually in direct competition with man for the cultivated species of food. Indeed, the economic viability of an intensive ruminant production industry, depends, in the final analysis upon the availability of high quality feeds and forages either in fresh or conserved forms throughout the entire year.

Livestock production systems, particularly for milk and meat generation, throughout our region and characterised by generally low productivity as well as a heavy dependence on imported proteinaceous inputs. In Trinidad and Tobago for example, imports of feed and/or feeding stuffs account for over TT$86 million annually. In addition, since local milk production amounts to only 11% of total consumption and beef production about 16% of our requirements, the shortfall is compensated by importation of finished products either as processed dairy products (milk, cheese, etc.) or beef (frozen, pre-chilled or canned meats). This configuration, I am advised, is equally valid for most of the other territories in our region. In any event, a consequence of this situation is a serious drain on our foreign exchange as well as an adverse effect on the region's food security ratio.

If the projected demand to the year 2000 for meat and milk in the developing countries were to be met entirely from domestic production, it is estimated that the projected deficits can be met only if production of meat were accelerated by 25% and 35% for milk. While these figures relate to the global situation, given our estimated local population growth and income levels for a similar period, these projects appear to be extremely conservative. We would certainly need to produce a much higher percentage than the global average.

It is against this background that attention is being focused on Leucaena, that fast growing leguminous shrub. Although native to South and Central America, I understand that Leucaena has not been extensively cultivated in the Caribbean. It is only within the relatively recent past that several agencies within the region have been encouraging it's cultivation for it's application in feed, fuel and forestry. However, its use is widespread in the Far East, for example in the Philippines over US$350 million has been spent on an electrification programme using Leucaena fuel; in Taiwan more than 10,000 hectares have been planted for soil conservation, green manuring and animal feed; in India, the crop has been planted near small towns for sale as fuel, and in Australia, it is used primarily for fodder.

Our own national effort in livestock production places emphasis on increasing the productivity of existing livestock holdings. We are very conscious that the scope for increasing production and productivity depends not only on climate and environmental factors, types of farming and physical resources but equally important are the availability of inputs and infrastructural facilities. Feed, the major input in livestock production, particularly locally produced feed, is inadequate to support anticipated demand. Today's conference on Leucaena has set out specific goals namely:

(i) exchange of information on the role of Leucaena in agricultural development;

(ii) presentation of Caribbean research findings at an international forum;

(iii) determination of the status of research carried out internationally;

(iv) facilitating collaborative programmes;

(v) heightening the awareness among the farming community of the usefulness of Leucaena and its commercial applications.

This last mentioned objective must be of primary concern because of the challenges to us as policy makers and technocrats in the region with a responsibility for the orderly development of our agriculture and livestock production systems. We must be aware that this challenge will only be met when there is full participation of our farming communities. Your technical sessions are indeed very necessary and useful but we must be conscious at all times of our collective responsibility to our farming communities. And we must make every effort to provide them with the results of our research.

I wish to acknowledge and to thank the O.A.S. who were the prime initiators of the Leucaena Project whichstarted in 1982, with the active participation of some six Caribbean territories. This project involved the collection and evaluation of 129 Leucaena accessions from the region.

There are now activities on-going in Antigua, Barbados, Grenada, Jamaica, St. Lucia, Suriname and Trinidad and Tobago.

As host country, Trinidad and Tobago in Association with:

(i) University of the West Indies (UWI);

(ii) The Sugar Cane Feed Centre (SFC);

(iii) The National Institute of Higher Education (Research Sciences and Technology) (NIHERST);

(iv) The Caribbean Agricultural Research and Development Institute (CARDI);

(v) The Ministry of Food Production and Marine Exploitation (MFPME); and

(vi) United Nations Education Scientific Organization (UNESCO)

welcome you all, invited guest and participants alike. During the next few days you must provide further theoretical basis for agricultural development in this most important area.

In declaring this conference open, may I express the hope that at the end of your deliberations, as a region we shall be some where nearer to mobilising our farming communities, whose awareness level would have been greatly enhanced. This is no doubt absolutely necessary if we must successfully respond to the challenges ahead.

Breeding and Development

Genetic Improvement in Leucaena

E.M. Hutton

Introduction

Feeding trials with dairy cows at the University Agricultural Experiment Station in Hawaii using the naturalised free-seeding "Hawaii" strain of *Leucaena Leucocephala* (Lam.) de Witt showed high protein and milk yields and no harmful effects on cow reproduction (Takahashi and Ripperton, 1949). It was apparent that Leucaena had considerable forage potential so work on a range of accessions was commenced in 1954 at the CSIRO Cunningham Laboratory, Brishbane, Australia (Hutton and Gray, 1959), even though officers of the Queensland Department of Primary Industries regarded Leucaena as a noxious toxic weed. it precluded its use as a forage. However, the CSIRO work showed daily liveweight gains in cattle up to a kilogram per day and resulted in the release of the varieties Peru (Barnard, 1972) and El Salvador to farmers so that trials were commenced.

With the identification at CSIRO of Leucaena as an important cattle forage for the future, it was necessary to develop breeding methods which could ensure its continued genetic improvement and adaptation to pasture conditions in the tropics. Description of these methods and results achieved form the basis of this paper.

Breeding System and Crossing Technique

Studies of the breeding system of the *L. leucocephala* showed it to be predominantly self-fertilised although the flowering pattern and bee visitation gave the possibility of some cross-pollination (Hutton and Gray, 1959). *L. leucocephala* has up to 180 small white florets packed into globular heads. At the Samford Pasture Research Station near Brisbane (Lat. 27°S), in mid summer flower buds opened soon after midnight and at sunrise (5:00 a.m.), the non-dehisced anthers stood about 1mm above the stigmatic cups. Anther dehiscence took place about 7:00 a.m. to 8:00 a.m. and the clumped pollen lodged in the stigmatic cups where it germinated. Reproductive efficiency of *L. leucocephala* is low and among the varieties studied it was calculated that the percentage of ovules producing seed varied from 1.0 in Bald Hills to 0.04 in Peru.

To avoid the tedium of hand emasculation of *L. leucocephala* at sunrise at the Samford Pasture Research Station, pollen in the ripe anthers or which had commenced shedding in the stigmatic cups, was burst by rotating the flower heads in a 0.1% solution of a non-toxic detergent (Gardinol K, a sulphonated lauryl alcohol) for a minute or two. After drying, the emasculated flower heads were enclosed in small waxed paper bags. Pollen was collected from the male parent in a glass dish and applied thoroughly to the stigmatic cups with thumb and forefinger, kept free from variable pollen between pollinations by dipping the detergent solution or 75% ethanol. The pollinated and tagged flower heads were enclosed thoroughly in the small waxed paper bags which were removed after two or three days. Control flower heads, emasculated and bagged without pollination invariably set no pods.

The emascualtion and pollination techniques described (Hutton and Gray 1959) has been used with success throughout the Leucaena breeding work discussed in this paper, not only at the Samford Pasture [illegible] Cali Colombia (Lat. 4°N). Difficulties with this method, as mentioned by Sorensson (1988) could have been due to ineffective application of pollen to the stigmatic cups of emasculated flowers or the use of a toxic detergent. The crossing technique described by Sorensson (1988) is obviously well designed and adapted to a wide range of interspecific crosses.

Crosses to Study Inheritance of *L. leucocephala* Characters and to Improve Peru

Of the two Leucaena varieties released by the CSIRO Cunningham Laboratory in the 1950s, Peru was preferred by farmers but it was apparent that its vigour, branching and leaf yield could be improved. A number of crosses were made at Samford to determine the inheritance of the characters in the range of accessions being studied, but also to improve Peru (Gray 1967a). The Peru crosses included Hawaii x Peru, Guatemala x Peru and Peru x El Salvador.

In the crosses, it was found (Gray 1967a, b, c) that erect habit was dominant over bushy habit and that absence of strong basal branching was dominant over its presence. Also the F_2 segregation gave a 3:1 ratio with two major gene pairs probably involved. Stem length and number were apparently controlled by multiple genes affecting vigour, these being independent of the genes controlling branching habit.

At the Lansdown Research Station near Townsville (Lat. 19.5°S) evaluation of 28 of the hybrid Leucaena lines in the F_4 and F_5 generation from Samford was followed by reselections within the three most promising lines including Guatemala x Peru 3 and Peru x Hawaii 5 and 27a (Hutton and Beattie, 1976). There were two yield trials in a large plot of these, Peru being the control. The first trial over the main growing period (Sept. to March) in 1971-72 involved three complete tree harvests 15cm above ground level and separation into edible dry matter (EDM) and wood DM. The succeeding trial in 1972-73 involved well established uncut trees and the harvest of plucked EDM (leaf, stem up to 6mm diam) covered the September to March period as well as the critical dry season May to June periods. In these trials Guatemala x Peru line 3, (later release as variety Cunningham) gave significantly the highest EDM and Peru the lowest, the other two hybrid lines being intermediate.

In the breeding of var. Cunningham the well branched habit of Peru was combined with the greater wood production of Guatemala, giving Cunningham a larger woody framework, higher bud numbers and more EDM. However, the trials results cited, indicated that Peru gave the highest EDM relative to wood DM so this desirable character was not incorporated in Cunningham.

Mimosine as a Factor in Leucaena

After the inclusion of *L. leucocephala* among the available tropical forages in Australia, its use for cattle feed was severely restricted for some 15 years because its' content of the toxic amino acid mimosine was of considerable concern to agricultural advisors and farmers. It was known that animals with access to Leucaena could suffer loss of tail and rump hairs due to the depilatory action of mimosine. Also, prolonged feeding could cause severer symptoms, including loss of appetite and weight, excessive salivation and enlarged thyroid glands (Jones *et al.*, 1976). In addition, breeding cows could produce dead goitrous calves.

The severe chronic symptoms from Leucaena feeding are induced by the effect on the thyroid glands of the goitrogen DHP (3-hydroxy-4 [1H] -pyridone) being continually produced by the breakdown of mimosine in the rumen (Hegarty et al., 1979). Mimosine-DHP toxicity was identified as a problem mainly in Australia and Papua New Guinea, but was absent in Hawaii, Indonesia, Mexico and other countries. Research with goats in Hawaii, Indonesia, Australia resulted in the isolation and culture of a DHP - degrading ruminal bacteria which was successfully transferred to Australian goats and cattle and eliminated mimosine-DHP toxicity problems (Jones and Megarrity, 1983). Cultures of the DHP degrading bacteria can be obtained from Dr. R.J. Jones at the CSIRO Davies Laboratory, Townsville. When random cattle or goats in herds are inoculated with these, in areas where animal symptoms of mimosine-DHP toxicity occur and DHP is present in the urine (Megarrity 1981), problems from Leucaena feeding disappear.

The progress with the mimosine-DHP problem achieved makes it unnecessary to breed low-mimosine Leucaena for cattle and goat feeding. However, where the problem exists, especially in less developed countries, obtaining, maintaining and distributing the DHP degrading bacteria may be difficult, so a low-mimosine Leucaena would be advantage.

Leucaena leaf meal, as a protein supplement and vitamin A source, is an important export from several countries including Thailand and Indonesia. The depression in growth and sexual cycle of chickens and pigs when it is fed at more than 5-10% in a ration could be due to mimosine or tannin. In chickens labadan (1969) implicated mimosine whereas D'Mello and Acamovic (1982) found that the adverse effects in weight gain could be due to both the mimosine and tannins of Leucaena. It seems that low-mimosine varieties could enhance the value of leaf meal for poultry and pig rations.

Attempts to Reduce Mimosine in Leucaena by Breeding

In a study including varieties of *L. leucocephala* and four other important Leucaena species, only *L. pulverulenta* (Schlech) Benth and Hook had potential as a source of low-mimosine (Hutton 1985). Prior to the work on elimination of the mimosine-DHP problem in Leucaena feeding of cattle and goats using ruminal DHP degrading bacteria (Jones and Megarrity, 1983). *L. pulverulenta* has 2n=56 chromosomes compared with 2n=104 in *L. leucocephala* and 2n=52 in the main diploid species (Hutton 1981). L. pulverulenta crosses naturally with L. leucocephala despite their chromosome differences (Bray and Fullon, 1987) and vigorous F_1 shade trees have often been reported.

Gonzalez *et al* (1967) were the first to attempt the development of low-mimosine Leucaena varieties from crosses of *L. pulverulenta* with *L. leucocephala*. However, they were unable to produce a low-mimosine Leucaena. At CSIRO Davies Laboratory, Townsville, crosses were made in 1974 of a low-mimosine segregate of *L. pulverulenta* with Cunningham, followed by three backcrosses of low-mimosine segregates with Cunningham the male recurrent parent. All crosses and backcrosses were fertile but all open-pollinated selections, except one from the second backcross were sterile. The fertile selection gave 20 fully fertile vigorous low-mimosine segregates which were grown and studied at CIAT, Cali, Colombia (Hutton 1985a). From these segregates the F_2 and F_3 generations of 104 and 157 trees gave 12 and 16 selections respectively with the vigour of Cunningham and half its mimosine content. In the F_4 from the F_3 low-mimosine trees there were ten vigorous selections but only tow of these had low-mimosine.

The progressive loss of the low-mimosine character from F_2 - F_4 was explained by the chromosome changes in the different progenies. The Cunningham bivalents were at the centre of the cells of the metaphase 1 meiotic chromosomes and the larger *L. pulverulenta* univalents dispersed towards the poles. In the vigorous selections from the F_2 - F_4 generations, bivalents in metaphase 1 increased from 50 - 78% while univalents decreased from 50% to 22%, showing a gradual loss of *L. pulverulenta* univalents carrying the low-mimosine character. The loss would continue in succeeding generation so stable low-mimosine lines could not be obtained from *L. pulverulenta* x *L. Leucocephala*. The difficulties with this cross could not be avoided because of the lack of homology between the chromosomes of *L. pulverulenta* and *L. Leucocephala*.

BREEDING LEUCAENA FOR ADAPTATION TO ACID SOILS WITH PH<5

Current varieties of *L. leucocephala*, including Cunningham, are productive and persistent in the tropics in soils with pH's in excess of about 5.5. However, in considerable areas of the tropics, including 55% of South America, 40% of Africa and 37% of Asia (Sanchez and Salinas, 1981) where soil pH's are about five or less, *L. leucocephala* varieties are often unproductive and lack persistence. In Brazil in a leached acid Oxisol (pH 4.5-4.7) the growth of adequately fertilized Cunningham had deteriorated significantly four years from planting, a number of trees having died. The degeneration of the trees was considered due to Al inhibition of Ca uptake by the roots (Hutton and de Sousa, 1986). Further work with Cunningham (Hutton and de Sousa, 1987) given at planting adequate P and K and heavy applications of dolomite and gypsum, the latter increasing Ca levels at depths of 50-100cm, failed to prevent degeneration of the trees after 2 1/2 years growth. In the trees, rooting was mainly sub-surface, young expanded tip leaves averaged only 29% of the Ca in mature leaves and 73% of the trees had dead branch tips, all these observations indicating lack of Ca uptake by roots.

With the finding that *L. diversifolia* (Schlecht) Benth and Hook had a high level of acid-soil tolerance (Hutton 1981, 1985b) both 52 and 104 chromosome types of this species were crossed with *L. leucocephala* varieties at CIAT, Cali, Colombia in 1980-81. Acid-soil tolerant Leucaena lines in the populations of the various *L. leucocephala - L. diversifolia* crosses were selected in a fertilised tropical Oxisol (pH 4.5-4.7) during 4 1/2 years from November 1982 at EMBRAPACPAC, Planaltina DF Brazil (Hutton in press). Among the established hybrid trees the taller, vigorous, acid-soil tolerant segregates with dark green leaves, better branching and trunk growth, could be easily distinguished from the shorter and weaker non-tolerant segregates often with some leaf yellowing.

In the crosses, acid-soil tolerance was inherited quantitatively in the F_1, F_2, F_3 and F_4 generations. The crosses with the Cunningham and its backcross (BC) involved two 52 chromosome lines (25 and 26) of *L. diversifolia*. Vigorous acid-soil tolerant trees averaged 24% in the F_2's and 61% in the F_4's, overall man height being 2.5m. Among the controls there were no vigorous trees in Cunningham while the *L. diversifolia* lines grown with the F_4's had an average of 79% acid-soil tolerant trees with an overall mean height of 3.5m. Inheritance of acid-soil tolerance was clearly evident in the above crosses of Cunningham and its backcross with the 52 chromosome *L. diversifolia* lines.

In the crosses (11 x 25, 11 x 26, 11 x 31) of the tall acid-soil tolerant *L. leucocephala* selection 11 with *L. diversifolia* involving the two 52 chromosome lines and a 104 chromosome line (31), mean percentage of vigorous acid-soil tolerant segregates was 57 in F_1 and 51 in F_2, their overall mean height being 3.3m. The selection 11 and *L. diversifolia* 31 controls increased their percentage of vigorous acid-soil tolerant trees to 75 and 67 respectively, their mean height being similar to that of the hybrids. In the above crosses of *L. leucocephala* selection 11 (apparently an old *L. diversifolia* cross) the F_2's as expected had a relatively high percentage of acid-soil tolerant segregates.

From the breeding work described the crosses 11 x 25, 11 x 26 and 11 x 31 involving the tall selection 11 and *L. diversifolia* lines gave tall very productive acid-soil tolerant selections. These could be more difficult to manage under grazing that the shorter, less productive, but well branched acid-soil tolerant selections from the crosses Cunningham BC x 25 Cunningham x 26.

All the progeny from the cross 11 x 31 and 60% from 11 x 26 had small leaflets (+- 2mm diam) and were more suitable for forestry. However, 11 x 25 and the *L. diversifolia* crosses with Cunningham and its BC had mostly large leaflet (3-4mm Diam) selections suitable for grazing. From these and other observations it seems that in crosses of *L.*

leucocephala with "tetraploid" *L. diversifiolia* lines, fine leaflet selections predominate and that crosses with "diploid" *L. diversifolia* lines are necessary to obtain plenty of large leaflet selections. Cunningham and Hybrid trees lacking acid-soil tolerance invariably had shallow rooting depths to about 75cm and total lateral root lengths of about 150 cm while vigorous acid-soil tolerant trees of *L. leucocephala* selection 11 and the hybrids had rooting depths of 150 cm or more and total lateral root lengths of about 450cm. Vigorous *L. diversifolia* trees usually had a rooting depth of 200cm and lateral root length up to 800cm.

Fertiliser application per hectare in the 1982 planting was 300kg single superphosphate, 100kg KCI and only 200kg dolomite while in the 1984 and 1985 plantings it was 400kg single superphosphate, 100kg KCl and 100kg each of dolomite and gypsum. Average percentage saturations of Al and Ca in the soil profile to 1m depth in the 1982 planting were 78 and 14 respectively, while for the 1984 and 1985 plantings were 59 and 31 respectively. It was not necessary to impose the high Ca stress causing death of numbers of trees as used in the 1982 plantings. In the well fertilised 1984 and 1985 plantings sufficient Al-Ca stress was maintained for acid-soil tolerant and non-tolerant trees in populations to be distinguished easily without death of trees.

Acid-soil tolerance in trees of *L. diversifolia* and the *L. leucocephala-L. diversifolia* hybrids as expressed by vigorous growth and deeper more extensive rooting is though to be due to the reduction of the known (Andrew *et at*, 1973) inhibiting effect of exchangeable Al on root absorption of Ca. This would enhance Ca translocation to root and shoot tips where meristematic activity would be stimulated and result in more extensive root and top growth. That more efficient root absorption of Ca and its translocation was important in acid-soil tolerance was indicated by trends in Ca levels of young leaves in vigorous and weak trees. Cunningham and its weak hybrids averaged 0.26% foliar Ca about half the mean level of 0.51% Ca for *L. diversifolia* and vigorous Cunningham hybrids.

Involvement of Other Leucaena Species in Acid-Soil Tolerance

At CIAT other interspecific crosses made included *L. leucocephala* section 11 x *L. esculenta* (Moc and Sesse), *L. leucocephala* selection 11 x *L. shannoni* (Donn. Smith) and Cunningham BC x *L. shannoni*. The hybrids were grown in a tropical Oxisol at EMBRAPA-CPAC Brazil and segregation of acid-soil tolerant trees in the populations studied (Hutton 1988).

In 11 x *L. esculenta*, 53% of the F1 hybrids were vigorous and acid-soil tolerant but sterile, so further progress was prevented. As *L. esculenta* was non-tolerant the acid-soil tolerance in the F_1's was inherited from *L. leucocephala* selection 11.

In the Cunningham BC x *L. shannoni* F_2 a few acid-soil tolerant trees survived in the 1982 planting. From the most vigorous of the F_2's and F_3's, relatively large F_3 and F_4 populations were grown in the 1985 planting and 49% and 45% respectively of the trees were acid-soil tolerant with large leaflets. It was apparent that *L. shannoni* had potential to produce acid-soil tolerant Leucaenas in crosses.

L. leucocephala 11 x *L. shannoni* had a high level of sterility so it was not possible to grow large populations for selection. The few F_2 trees grown had small leaflets so had no potential for forage.

It seems that other Leucaena species could be considered in programmes for breeding acid-soil tolerant varieties. For example *L. pallida* and some of its F_1 hybrids made available by Dr. J.L. Brewbaker, have shown a high degree of acid-soil tolerance in an acid-soil (pH 4.5) in Malaysia. However, sterility could be an impediment in a breading programme.

CYTOLOGY OF THE LEUCAENA SPECIES AND HYBRIDS IN THIS STUDY

Chromosome number and meiotic behaviour were studied by Cardoso de Freitas et al ([illegible]) in *L. leucocephala* and the hybrids described. Somatic chromosome numbers in *L. leucocephala* averaged 95, in "diplois" *L. diversifolia* 58 and in "tetraploid" *L. diversifolia* 86. In *L. leucocephala* x "diploid" *L. diversifolia* somatic chromosome numbers averaged 52 in the F_1, 89 in the F_2 and 91 in the F_3, the progressive increase in chromosomes being related to selection in each generation of large leaflet segregates like the *L. leucocephala* parent. However, there was no correlation between the chromosome number and acid-soil tolerance of the selections. Only the F_1 was studied in *L. leucocephala* x "tetraplois" *L. diversifolia* and somatic chromosome numbers averaged 88. It was significant that all the selections in the *L. leucocephala* - *L. diversifolia* crosses produced ample seed irrespective of their chromosome numbers.

Meiotic behaviour was regular in all species and hybrids and the chromosomes of *L. leucocephala* and *L. diversifolia* were similar and homologous. As the chromosomes of the two species were indistinguishable it was not possible to determine the extent of interspecific and intraspecific chromosome pairing in the crosses. Segregation in the populations indicated crossing-over between the chromosomes of *L. leucocephala* and *L. diversifolia*.

The F_1 hybrids of *L. leucocephala* x *L. esculenta* and *L. leucocephala* x *L. shannoni* examined had mean 2n chromosome number of 52 and 54 respectively. A study of meiosis in the first cross did not provide an explaination for its sterility.

FUTURE BREEDING IN LEUCAENA

With the knowledge now available, Leucaena can be adapted by breeding to most field conditions. Acid-soil tolerant varieties have been needed for some time with the extension of Leucaena into the less fertile, low pH soil areas of South America, Africa and South East Asia. However, acid-soil tolerant lines for forage or forestry can be obtained from *L. leucocephala* - *L. diversifolia* crosses which are fully fertile and easy to manage in a breding programme. Some *L. diversifolia* types are very vigorous and with selection would be satisfactory for forestry in spite of their small leaflets and low in vitro digestibility. Acid-soil tolerant varieties are possible form crosses with other Leucaena species but sterility could cause problems in these.

For forage, more attention could be given to breeding large leaflet varieties that are vigorous and multibranched with a larger number of active buds/50cm of branch length. In Leucaena trees a framework more adapted to grazing is needed. Maintenance of high digestibility is necessary in forage varieties for cattle and goats, but it is doubtful whether a reduction in the tannins to achieve this would be beneficial. It appears that tannins could form rumen bypass proteins responsible in part for the high feeding quality of Leucaena.

In monogastric animals like chickens and pigs often fed in South East Asia and other countries with Leucaena leaf meal as part of their ration, a reduction by breeding of both mimosine and tannins in varieties would be advantages. D'Mello and Acamovic (1982) suggest the addition of ferric sulphate and polyethylene glycol to counteract the adverse effects of mimosine and tannins in leaf meal from current Leucaena varieties.

In many countries today, a very important need in Leucaena varieties, is tolerance to the psyllid insect pest (Heteropsylla Cubana) which apparently is able to ingest the leaf mimosine and pass it through its digestive tract unchanged (Lowry *et al*, 1986). However, Sorensson and Brewbaker (1986) have identified several Leucaena species, including *L. pallida* and *L. diversifolia*, with outstanding psyllid tolerance.

In Malaysia *L. pallida* has a high resistance to psyllids whereas *L. diversifolia* has high tolerance. It appears that it would be difficult to transfer the resistance of the fine leaflet *L. pallida* to large leaflet *L. leucocephala* hybrids because of sterility factors. In the *L.*

leucocephala - L. diversifolia crosses, psyllid tolerance is correlated with the small leaflet segregates which probably have higher tannin content and lower digestibility. At this stage, it seems essential that work be instituted on the factors involved in psyllid tolerance so that enlightened programmes on breeding Leucaena for psyllid tolerance can be started.

It seems likely that the psyllid problem will eventually be overcome by the introduction of efficient predator complexes. Apparently the Yucatan Peninsula and other parts of Mexico have evolved such predator complexes which prevent serious psyllid attack on the abundant native Leucaena.

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Breeding Strategies for Leucaena Species Hybrids

Charles T. Sorensson

INTRODUCTION

Breeding Strategies of our Leucaena improvement programme, like those of CSIRO (Australia) and EMBRAPA (Brazil), have changed substantially during the past few decades. Emphasis has broadened from a principally one-species approach on giant varities of *L. leucocephala* to three tetraploid species and the hybrids. There were three reasons for this change.

Firstly, there had been concern for some time about *L. leucocephala's* possibly narrow genetic base. The devastation caused by pantropical invasion of psyllid insects (*Heteropsylla cubana* Crawford) confirmed the problem. *L. Leucocephala* is more sensitive to psyllid attacks than most of the other fourteen Leucaena species (Table 1, 2 and 3). *L. leucocephala* is also more sensitive than certain other Leucaena species to temperatures below about 15^0 C (Brewbaker, 1987), frost, and low soil calcium (particularly when calcium uptake is inhibited by high aluminum levels in acidic soils; Hutton, 1984).

Secondly, there was a need to utilize better the vigor and adaptability of species hybrids exhibited by hybrids like *L. pulverulenta* x *L. leucocephala* ($2n=3x=80$). This triploid was our best demonstration of hybrid vigor until 1984 when psyllids invaded Hawaii (it was susceptible). It is naturalized in Texas, U.S.A., Indonesia (Lowry, 1984), and Papua New Guinea. Seedless varieties derived from it are grafted for intercropping in Indonesia (Brewbaker, 1988). Dr. E.M. Hutton concentrated on the hybrid in two of his earlier breeding efforts (low mimisome and acid soil tolerance) because of hybrid's potential. Fifty years ago, Dutch foresters in Indonesia were selectively producing seed of this hybrid because it outyielded *L. leucocephala* in cool upland coffee plantations and produced few seeds (Djikman, 1958).

Lastly, germplasm collections by Dr. Brewbaker and collagues and other international groups made more research on the poorer known taxa possible. Although many of our species hybrids (Brewbaker and Sorensson, 1989) do not deserve further attention based on their poor growth rates, they comprise an important reservoir for basic studies in genetics, cytology, phylogeny and physiology. Results from such studies have begun to have a positive influence on our breeding programme.

Table 1
Leucaena species, Somatic Chromosome Numbers, and Species Codes. Leucaena Taxonomy is in a State of Flux and Species Listed Below May be Reclassified in Future Treatises.

No.	Species	Chromosome No.	Code
1.	*L. Collinsii* ssp. *collinsii* Britton and Rose	56	COLL
0.	*L. collinsii* spp. "*zacapana*" (Hughes-pending)	56	COLZ
2.	*L.* sp. ("*L. confertiflora*" Zarate-pending)	112	"CONF"4
3.	*L. cuspidata* Standley	—	CUSP
4.	*L. diversifolia* spp. *diversifloia* (Schlecht.) Bentham	104	DIVE4
0.	*L. diversifolia* spp. *trichandra* (Zucc.) Pan & Brewbaker	52*	DIVE
5.	*L. esculenta* spp. *esculenta* (Moc. and Sesse) Bentham	52	ESCU
0.	*L. esculenta* spp. *matudae* Zarate	52ca	ESCM
6.	*L. greggii* S. Watson	56	GREG
0.	*L. lanceolata* spp. *lanceolata* S. Watson	52	LANC
7.	*L. leucocephala* spp. *glabrata* Rose	104	LEUC4
0.	*L. leucocephala* spp. *leucocephala* (Lam.) de Wit	104	LEUL4
8.	*L. macrophylla* spp. *macrophylla* Bentham	52ca.	MACR
9.	*L. multicapitula* Scherv	52ca.	MULT
10.	*L. pallida* spp. *pallida* Britton and Rose	104*	PALL4
0.	*L. paniculata* Britton and Rose	104	PALN4
11.	*L.pulverulenta* (Schlecht.) Bentham	56	PULV
12.	*L. retusa* Bentham	56	RETU
13.	*L. salvadorensis* Standley	56	SALV
14.	*L. shannoni* ssp. "*chiquimulensis*" (Hughes-pending)	52ca.	SHAC
0.	*L. shannoni* spp. *shannoni* Donn. Smith	52	SHAN
15.	*L. trichodes* ssp. *trichodes* (Jacq.) Bentham	52	TRIC

* Beta chromosomes reported in some accessions (Pan and Brewbaker, 1988)

Table 2
Leucaena speices Code, Example of University of Hawaii Accession ("K" Number) and its Native Licale, and native Elevation Range (Meters) of the Taxa.

Code	K No.	State, Country and Locale of Accession		Elevation
COLL	K450	Chiapas, Mexico	16 45"N 93 07"W	650 - 850
COLZ	K740	El Progresso, Guatemala	15 02"N 89 40"W	100 - 800
"CONF"4	K745	Puebla, Mexico	17 38"N 97 37"W	2000 - 2400
CUSP	—	(Hidalgo, Mexico)	20 45"N 99 20"W*	1200 - 1500
DIVE4	K156	Veracruz, Mexico	18 56"N 97 00"W	600 - 1500
DIVE	K483	El Paraiso, Honduras	14 01"N 86 21"W	900 - 2600
ESCU	K138	Puebla, Mexico	18 53"N 97 44"W	800 - 2300
ESCM	K838	Guerrero, Mexico	17 50"N 99 34"W	400 - 600
GREG	K867	Nuevo Leon, Mexico	26 30"N 100 25"W	500 - 1850
LANC	K393	Oaxaca, Mexico	16 44"N 95 00"W	0 - 700
LEUC4	K636	Coahuila, Mexico	25 25"N 101 00"W	0 - 1200
LEUL4	K356	Campeche, Mexico	18 45"N 90 43"W	0 - 500
MACR	K837	Guerrero, Mexico	17 20"N 99 28"W	1000 - 1800
MULT	K880	Guanacaste, Costa Rica	11 05"N 85 13"W	0 - 300
PALL4	K376	Oazaca, Mexico	17 08"N 96 46"W	1650 - 1950
PALN4	K804	Puebla, Mexico	18 37"N 97 24"W	1900 - 2000
PULV	K19	Texas, U.S.S.	26 10"N 98 10"W	500 - 1300
RETU	K502	Texas, U.S.A.	29 33"N 103 05"W	500 - 1650
SALV	K746	Morazon, Honduras	13 52"N 87 18"W	500 - 0800
SHAC	K769	Chiquimula, Guatemala	14 40"N 89 42"W	450 - 900
SHAN	K445	Campeche, Guatemala	19 41"N 90 40"W	0 - 800
TRIC	K738	La Guajira, Colombia	10 33"N 73 12"W	100 - 700

* Based on limited information from herbarium specimens.

Table 3
Species Code and Traits of Each Leucaena Taxa. Where Data were Lacking, Probable Values were Suggested by the Author.

Code	Biomass Yield	Cold Tolerance	Max. Acid Tolerance	Max. Psyllid Tolerance	Max. Tree Height (m)	Pinnule Legth. (mm)
COLL	high	low	low	high	15	9
COLZ	medium	low	low	high	18	11
"CONF"4	low	mdium	medium	medium	4	10
CUSP	low	high	low	—	4	5
DIVE4	high	medium	medium	medium	20	5
DIVE	high	medium	high	high	18	4
ESCU	high	medium	low	high	15	5
ESCM	low	low	low	high	8	6
GREG	low	high	low	medium	7	16
LANC	high	low	high	medium.	10	38
LEUC4	high	medium	high	meidum	22	15
LEUL4	high	medium	low	low	16	14
MACR	medium	low	low	high	8	83
MULT	medium	low	low	medium	20	63
PALL4	high	medium	low	high	9	7
PALN4	high	medium	low	medium	11	6
PULV	high	medium	medium	low	20	5
RETU	low	high	low	high	7	23
SALV	medium	low	low	medium	18	15
SHAC	high	low	medium	high	16	29
SHAN	medium	low	high	medium	14	19
TRIC	medium	low	low	low	9	44

*Based on limited information from herbarium specimens.

Leucaena Taxa

Diploid Species

The twelve diploid species comprise an important but poorly tapped pools of genetic variability (Table 2). Some accessions of *L. diversifolia*, *L. lanceolata*, and *L. shannoni*, for example, tolerated acid Brazilian oxisols with pH 4.8 and 70% aluminum saturation (Hutton, 1984). *L. greggii* and *L. retusa* are frost-resistant. Most diploid species are psyllid resistant, some highly so (Sorensson and Brewbaker, 1987a; Table 2). *L. salvadorensis* appeared to be drought-tolerant, and competed well at a dryland Honduran trial with *L.*

leucocephala (1988, Hughes and Sorensson, pers. observ.). *L. shannoni* from Chiquimula, Guatemala (e.g. K769) and *L. lanceolata* (e.g., K385) from southern Oaxaca, Mexico looked promising for fodder yields in Hawaii.

Tetraploid Species

Three tetraploid species are widely recognized as having economic potential: *L. diversifolia, L. leucocephala* and *L. pallida* (all 2n=4x=104). Of these, *L. diversifolia* and *L. leucocephala* are self-compatible. Substantial morphological variability has been observed in *L. pallida* and greater variability reported (1989, Hughes, pers. comm.), *L. pallida* is the only self-incompatible tetraploid species. Its outcrossing breeding system probably maintains or enhances the morphological variability in the species. Crosses among these three species produce economically important hybrids ("KX"s) when crossed in any combination. Herbarium specimens of the taxa termed *L. paniculata* (Zarate, 1984) have appeared to be similar to *L. pallida* K804 which is native to the town of Chapulco in Puebla, Mexico.

Little is known about a fourth tetraploid species, although we have grown two accessions given to us by CSIRO. Previously this species was incorrectly attributed to L. *cuspidata*. S.P. Zárate has tentatively named it "*L. confertiflora*", and recognizes two morphotypes (1989, Zárate; Hughes; pers. comm.). The taxon we have at Hawaii grows as small shrubs. They are psyllid resistant and self-compatible (Sorensson, 1989a). R.E. Bray found it had 112 chromosomes (1988, Bray, pers. comm.). This has been confirmed by Sorensson (Brewbaker and Sorensson, 1989). Hybrids have been grown from crosses between this species and eight other Leucaena species. Its hybrids with other tetraploid species have been vigorous and moderately fast-growing.

DIPLOID AND TRIPLOID LEUCAENA SPECIES HYBRIDS

Diploid Species Hybrids

A few diploid species hybrids appear promising. One of these is *L. diversifolia* x *L. collinsii* (2x=54), whose open-pollinated progeny have also segregated fast-growing trees (R.A. Wheeler, pers. comm.). Some *L. lanceolata* x *L. shannoni* hybrids looked promising in obervational yield trials. Most of the six diploid species hybrids produced with *L. retusa* have had better growth than the *L. retusa* parent, and they may be frost resistant. Three of the six *L. retusa* hybrids have been seedless, however.

Triploid Species Hybrids

The most commonly used method for incorporating genes of diploid species into tetraploid species has been to produce triploid hybrids. Attractive qualities of the better triploid species hybrids include partial or complete seed-sterility, high psyllid resistance, and fast growth (Brewbaker and Sorensson, 1989). Two of our outstanding triploids are *L. diversifolia* x *L. leucocephala* (2n=3x=78) and *L. pulverulenta* x *L. diversifolia* (2n=3x=80). *L. leucocephala* K8 x *L. esculenta* K138 hybrids segregated for gum-production, and this produced high gum yields (about 1kg $tree^{-1}$ yr^{-1}). Gums of this hybrid, referred to as "*L. leucocephala*" by Anderson (1988), was determined to be similar in composition to gum arabic.

Dr. E.M. Hutton (EMBRAPA-CPAC, Brazil) has bred Leucaenas from open-pollinated seed of triploid species hybrids for a number of years and has succeeded in producing acid soil tolerant Leucaenas (Hutton, 1989, in press). He has worked with several triploid hybrids, especially (Hutton, 1988), including those derived from diploid *L. diversifolia* (lines 25 and 26) x *L. leucocephala* var. Cunningham K500 (Hutton, 1984), and more recently hybrids with *L. pallida* (Hutton, 1989, pers. comm.).A small triploid species hybrid programme was started in Hawaii but problems with poor seed production and genetic stability associated with fluctuation chromosome numbers are expected.

TETRAPLOID LEUCAENA SPECIES HYBRIDS

"KX1" Hybrids (*L. diversifolia* x *L. pallida*)

F_1 hybrids of *L. diversifolia* x *L. pallida*, or the reciprocal cross are being called (KX1). They are highly psyllid resistant, fast-growing, and produce medium quantities of open-pollinated seed. They have been easy to use as males or females in hand crosses, and some of their progeny have had superb growth. KX1s grow as tall trees with a wide crown. F_1s of KX1s having K804 as a parent are arboreal.

"KX2" (*L. leucocephala* x *L. pallida*)

F_1 hybrids of *L. diversifolia* x *L. pallida*, or the reciprocal cross are being called (KX1). These hybrids are largely psyllid resistant, fast-growing, (Glover, 1988), but produce medium quantities of seed in Hawaii. Hand crosses using KX2s as females and males have been largely unsuccessful.Tree form and size of F_1s of KX2s produced from certain hand crosses was variable (Sorensson, 1987). Low-growing "dwarf" KX2 trees have since elicited interest as fodder trees whose foliage can be reached by browsing animals. Like KX1s, F_1 hybrids involving K804 are arboreal. Beetle infestation rates of KX2s are often high. Seed harvested from several KX2 lines in spring 1989 were 79% infested, about 30% higher than average infestation rates in seed of other species and hybrids (Sorensson, pers. obs.).

"KX3" (*L. leucocephala* x *L. pallida*)

Hybrids of *L. diversifolia* x *L. pallida*, or the reciprocal cross are called (KX3). They are fast growing and arboreal. To date, all KX3 were self-compatible, although self-incompatible hybrids could hypothetically occur (Brewbaker, 1986). Although KX3s may overproduce seed, and have lower levels of psyllid resistance than most KX1s or KX2s, at many sites they have been the highest yielding of all lines tested. Psyllid resistance has been adequate, when trees were not coppiced, or when psyllid populations were low (certain high evaluation or north latitude sites). KX3s set seed easily in hand crosses as either females and males, but require emascualtion.

Segregation of F_2s at highland sites in Hawaii was more striking than that at lower elevations. At Maelani, Hawaii (850m elevation, mean annual temperature 14° C, pH 6.3) above-ground biomass volumes of KX3 were estimated at 61.2 $m^3\ ha^{-1}\ yr^{-1}$. This volume was higher than that of either parent. *L. leucocephala* K8 produced only 0.06 $m^3\ ha^{-1}\ yr^{-1}$ and *L. diversifolia* K156 produced with 40.8 $m^3\ ha^{-1}\ yr^{-1}$ (modified from Brewbaker *et al.*, 1988).

Multi-Species Breeding

One of the newest breeding efforts of the University of Hawaii (UH) is multi-species breeding. The aim of the programme was to transfer varying low numbers of chromosomes (or genes via crossing over) from two or more tetraploid species or hybrids into *L. leucocephala*. Numbers of chromosomes transferred from each species into *L. leucocephala*-based hybrids can be controlled in three ways:

(1) producing multi-ways hybrids in hand crosses which differ in parentage;

(2) backcrossing to strengthen the contribution of L. leucocephala; and

(3) selfing or sibbing.

The programme has had limited success. Several of the three-way hybrids originating from hand crosses (KX1 x *L. leucocephala*) or open-pollination have had promising growth rates. Three-way hybrids which have flowered had high pollen stainability and produced viable seed. Some three-way hybrids were self-compatible (Sorensson, 1989a). KX1 and L. pallida both worked well as females for three-way hand crosses.

Breeding Systems of Tetraploid Hybrids

Trees grown from open-pollinated seed of KX1s and KX2s vary in size, habit, flower color, seediness and other traits. This is partly due to thier F_1 hybrids being outcrossers (Sorensson, 1989a). Self-incompatible segregants are expected to occur, and would probably increase in frequency with time (Brewbaker, 1986). Self-compatible lines (KX3) or segregants (from KX1 and KX2) can be improved using pure line selection, and the resulting inbreds maintained separately or composited. They can also be used as parents for composite crosses, although this would require emasculation (Sorensson, 1988). Self-incompatible lines can be handled as small half-sib families or bulked as heterogeneous synthetics. A mass-selection programme has been initiated by UH on all KX lines and emphasizes KX2s for fodder.

Incorporation of Genes from Diploids into Tetraploids via Unreduced Gametes.

Attempts have been made to overcome ploidy barriers using unreduced gametes (UR) in order to avoid some of the problems associated with breeding triploids (Sorensson and Brewbaker, 1987b). UR gametes are eggs or pollen which contain twice the normal complement of chromosomes. Sorensson had produced three tetraploid hybrids using UR gametes. Two of these have *L. retusa* (diploid) as a parent. The other has *L. diversifolia* (diploid) as a parent. Of the two tetraploid which have produced seed, one was determined to be self-compatible (Sorensson, pers. obs.). In order to beat the odds (roughly 1/1000 +) encountering UR gametes, large numbers of crosses $\geq$ 30 inflorescences) are made emphasizing those species combinations which produce largely abortive triploid seed.

The hybrids produced via UR gametes may have some of the valuable qualities of the diploid parents such as frost-resistance, acid soil tolerance and psyllid tolerance. Two of these hybrids have been crossed with *L. leucocephala*, and one of the resulting three-way hybrids has been backcrossed to *L. leucocephala*.

The theoretical implications of overcoming ploidy barriers with UR gametes are attractive. One of that UR gametes resulting from irregular chromosomal division in Meiosis I (first division restitution) can have all of the heterozygosity of the diploid parent tree, depending on chiasma formation. UR gametes formed during Meiosis II would, however, be less heterotic and therefore less desirable for breeding (Mendiburu and Peloquin, 1976). UR-derived hybrids generally have better seed produciton than that of autotetraploids because of fertility restoration, particularly in species between combinations whose triploids are seed sterile. UR gametes are used in the breeding of crops like alfalfa and potatoes.

The success rate of our UR programme will remain low until one of three conditions are met:

(1) Trees are discovered which produce high frequencies of UR gametes,

(2) Flowers can be artificially induced to produce high frequencies of UR gametes, or

(3) Micromanipulation methods for separating and pollinating with UR pollen (identifiable by their large size) are developed.

Incorporation of Genes from Diploids into Tetraploids via Autotetraploids

Another method for transferring genes from the diploid level to the tetraploid level is induction of autotetraploids of diploid species or hybrids by mutagens. Attempts by Dr. F.J. Pan (TFRI, Taiwan) and Sorensson to convert diploids with colchine have failed, but it appears that Pan's group has recently been successful. Other mutagens, e.g., ethylmethylsulfonate (EMS) should be tested, as should induction of polyploids for calli sectors propagated in tissue culture.

HYBRID SEED PRODUCTION

There are several ways to produce interspecific hybrid seed via open pollination (Brewbaker and Sorensson, 1989). The simplest involves the isolated planting of a single self-incompatible tree used as a female among pollen-donor trees. Problems with this approach are two-fold; one is that limited quantities of seed which can be harvested from a single tree, and the other is the difficulty associated with finding an adequately isolated site.

Some problems encountered by the first method can be overcome using a second approach. For this, one had to identify either tetraploid trees with genotypes of $S_xS_xS_xS_x$ and $S_yS_yS_yS_y$ or diploid trees with genotypes of S_xS_x and S_yS_y. Progeny resulting from sibbing these trees would be incapable of sibing or selfing (precluding self-compatibility via "competition interaction" in teraploids), but would set hybrid seed (Brewbaker and Sorensson, 1989).

Another approach would involve cloning self-incompatible trees for use as females. Attempts to propagate Leucaenas vegetatively at Hawaii have failed, although air-layering now looks rather promising, and was successful elsewhere (Ghatnekar *et al.*, 1982). Varying success with vegetative propagation, both rooting and grafting, has been variously reported from Tiawan, Indonesia, the Philippines and Australia. Theory on production/discovery of self-incompatible *L. leucocephala* was detailed by Brewbaker (1986). Induction/discovery of male-sterile *L. leucocephala* also deserves attention. Two pollen-sterile tetraploid *L. diversifolia* K785 were located (Brewbaker and Sorensson, 1989). They appear to have been successful in emasculated crosses (Sorensson, personal obs.).

BREEDING WITH LARGE POPULATIONS

Slow segregation rates of polyploids mean larger populations of segregating progenies must be screened to make rapid progress. Limitations, both in land availability and budgetary constraints as well as the other sundry hgeadaches associated with large long-term trials, necessitate that other approaches to large-scale field trials be considered. Two of these options are direct seeding and seedling selection.

Direct seeding of breeding nurseries at high densities is an attractive possibility. Direct seeding by hand or machine obviates the work and cost involved in establishing and transplanting thousands of seedlings. These savings may be negated by the difficulties of weed management and seedling roguing; both which would probably be done by hand. Further research in herbicide tolerance of Leucaena seedlings and use of herbicides for spot-kiling young trees is needed. Diesel oil can be an effective and inexpensive Leucaena eradicant (Evensen, 1982: Sorensson, 1989b), but its application is laborious since each tree must first be cut off near ground level.

Seedling selection, as opposed to selection in mature trees, is another attractive option. Relationships between the reaction of seedlings and mature trees to levels of stress need to be elucidated. Seedling selection is effective if the relationship is strongly positively correlated. Sensitivity to psyllid attack was found to change with tree age in *L. esculenta*.

however (Sorensson, 1987). Methods to simulate stress conditions induced by salt, drought, temperature, disease, soil pH, calcium, and aluminum, as well as mass rearing of psyllids need to be refined for use in the greenhouse and laboratory.

Problems Encountered in Hybrid Seed Production

Several organizations are involved in production of species hybrids. These include UH Hawaii, NFTA, and international (LPT) and (F/FRED) seed nurseries. At Hawaii problems with seed production of certain hybrids have made it difficult to match the international demand for improved Lecaena seed. Our worst problem is seed damage caused by insects, followed by low seed production of some hybrids (KX2).

Our primary seed pest in Hawaii is the koa haole seed beetle (*Arecerus levipennis* Jordan), followed by scolytid beetles (*Hypothenemus* sp.) and bruchids. Typical losses are about 30%, although infestation rates in species seed harvested during the winter 1988 and 1989 seasons averaged about 50% (Sorensson, pers. obs.). High levels of seed damage from seed beetles and bruchids have been observed in Latin America, Florida and the Philippines. Seed pods can be protected by being inserted inside nylon organdy or parchment bags. Insecticides are less effective since, at best, they do not prevent oviposition and the subsequent fungal infections.

Summary and Conclusions

Breeding strategies have changed dramatically in the past few decades. Emphasis has moved away from a pure species approach on *L. leucocephala* to three tetraploid species and their hybrids. Strategies being used presently include interspecific hybridization, mass selection, pure line breeding from self-compatible segregants, and production of synthetics from selected heterogeneous lines. Mutation breeding, *in vitro* selection and mutation, haploid breeding, gametic selection and other techniques hold promise, but enormous gains can probably be achieved solely through classical breeding techniques. Ploidy manipulation could be an exception to this since the majority of genetic variation in the genus is found in diploid species.

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Cytological Investigations in Leucaena Benth. (Leguminosae) at the Botanical Garden (UNAM)

G. Palomino, V. Romo and Z. Zarate

INTRODUCTION

Biodiversity

Mexico is extremely rich both in plant and animal species, being the fourth most diverse country in the world. It is considered as the geographical centre of genetic diversity of some cultivated plants (*Capsicum annum, Zea mays, Phaseolus vulgaris*) and their wild relatives. It has sometimes been described as the Central American centre of origin and diversification of species. Plant and animal diversity in the country can be explained based on the wide variety of geographical, hydrological and geological conditions that are present in Mexico and that are responsible for the different habitats found (Rzedowski, 1978). Even though a considerable amount of investigation has been done, the incredible richness of the Mexican Flora has not been completely determined and is only partially studied and/or known. New data for the phanerogramic Flora provided by Dr. Rzedowski (in press) indicates that about 220 families, 2,410 genera and 22,000 of plant species can be found. The proportion of endemisms, for genera and species has been estimated in 17% and 72%, when natural (ecological) boundaries are considered.

In our country, as in other areas in the world, we are concerned with the knowledge and investigation of plant genetic resources mainly because of the extended range of variation of the species, and the immense value of germplasm collections for genetic, cytogenetic, plant breeding and evolutionary studies. On the other hand, our interest is heightened by the awareness of the threat and danger of disappearance of the gene pools in their diversity areas. It is a well known fact nowadays that many plant resources disturbances which are mainly caused by human activities. At the present time the loss is taking place so fast that there is cause for concern for numerous crop races in the centres of diversity or "former diversity" (Bennett, 1970). It is a shame that even before our priceless genetic resources have been adequately explored, let alone investigated, they will be completely lost.

The Genetic Resources Investigation Unit at UNAM (UNIRGEN)

With the previous ideas in mind, a multidisciplinary research group, UNIRGEN, was established at the Botanical Garden of UNAM (Universidad Nacional Autonoma de Mexico). Research is mainly focused on the exploration, biological investigation, evaluation, propagation and management of novel and non-conventional plant resources with interesting biological and economical perspectives for human feeding, fodder or medicinal purposes. Even though the investigation of plants with a mere scientific interest, and specially those in danger of extinction, is also considered.

Among other investigation areas, UNIRGEN comprises the following: Ethnobotany, Cytogenetics, Taxonomy, Systematics, Horticulture, and Tissue Culture. Many plant families are currently studied, being the legumes among the largest groups.

The Cytogentics Laboratory

The Cytogenetics Laboratory of the Botanical Garden is mainly concerned with the contribution to the biological knowledge of the species, providing cytological data as: chromosome numbers (haploid, diploid and basic), karyotypes, meiotic-behaviour and DNA C-amounts per genome determinations. Among the economically interesting genera which are currently being studied are: Amaranthus (Amaranthaceae); Phaseolus, Crotalaria, Leucaena (Leguminosae), and Sabal (Palmae).

The study of the genus Leucaena is comprised in a Biosystematic investigation project, supported by the Organization of American States, and is conformed by the following main areas at UNAM (investigators in charge are indicated):

1. Systematics: M.Sc. Sergio Zarate. Botanical Garden
2. Cytogenetics: Dr. Guadalupe Palomino. Botanical Garden
3. Ethnobotany: B.Sc. Alejandro Casas. Botanical Garden
4. Pallinology: Dr. Enrique Martinez. Geology Institute

Cytological Investigations in Leucaena (Leguminosae) Chromosome Numbers and DNA C-Values

Most of the species comprised in Leucaena are considered as native from Mexico (Claveran, 1978; Zarate, 1982), with several geographical areas of genetic diversity (Brewbaker, 1986). The names of "huaxim" in the Yucatan Peninsule and "Guaje", in the rest of the country, are commonly applied to these plants. The genus has a natural American distribution and the species are concentrated in Mexico and Central America (Brewbaker, 1986; Zarate, 1982). In Mexico, the genus can be found in a wide variety of growing conditions and habitats from acidic soils in Tabasco with high rainfall values, to the calcareous soils in Yucatan and Chiapas, where the highest diversity of species is present (Claveran, 1978). Leucaena plants are extremely valued in some parts of Mexico as an important resource in the traditional diet of certain populations (Vazquez, 1986; Casas Viveros, Katz and Caballero, 1987), being also used for fodder, construction of handcrafts and fences, and with medicinal purposes (Zarate, 1982). Given its great genetic variability it is considered as a potential plant resource with interesting biological and economic perspectives.

Aim of Investigation and Results

The aim of the present study is to contribute to the knowledge of Leucaena cytology. The preliminary results obtained and presented here, are with respect to the determination of chromosome numbers in several taxa distributed in Mexico. Namely: Oacaca, Puebla, Chiapas, Guerrero and Veracruz. A total of 20 collections have been analyzed so far. As Leucaena chromosomes are extremely small, which makes karyotype studies almost impossible, the determination of DNA C-values was also done.

Chromosome numbers and DNA C-values obtained appear to be correlated, even though no ecological or phytogeographical trends in the latter were found.

In general, chromosome numbers varied from: $2\underline{n}$=52, 56, 104 and 112; while DNA C-values ranged from: 1.41-3.67 pg.

Leucaena confertiflora subsp. *adenotheloidea* individuals, both cultivated and from the wild, had $2\underline{n}=8\underline{x}=112$. DNA C-values ranged from 1.28-3.67 pg, with differences among cultivated individuals. A condition that could have resulted from the hybridization with sympatric cultigens.

Leucaena diversifolia s. ampl. - sub-species *stenocarpa* and *diversifolia* had $2\underline{n}=4\underline{x}=56$. DNA C-values of 1.82, 1.51 and 1.47. Differences with chromosome numbers could be due to previously taxonomic misindentifications by other authors.

Leucaena esculenta s. ampl. - *L. esculenta* s. str. Two different chromosome numbers and ploidy levels were encountered: $2\underline{n}=4\underline{x}=56$ and $2\underline{n}=8\underline{x}=112$. It must be noted, that *L. esculenta* s. str. is widely cultivated in Mexico. The differences observed could be indicating the presence of genetic exchange with other subspecies. DNAC amounts varied from 2.53-2.77 pg in the latter and from 1.28-3.02 pg in sub-species *esculenta*.

CONCLUSIONS

Cytological data obtained showed, as previously stated, a correlation between chromosome numbers and DNA amounts per genome. Further investigation will be needed to determine possible geographical trends in DNA C-values and correlate them to the cultivated and wild condition of the plants. It will also be necessary to widen the number of populations and individuals analysed and study chromosome pairing behaviour, so as to increase the understanding of the cytology of the genus as a whole.

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New Opportunities in Leucaena Genetic Improvement*

C.E. Hughes

INTRODUCTION

In 1982, Michael Benge presented a paper entitled "The Miracle Tree: Reality or Myth?" (Benge, 1983) at a meeting in Singapore to review Leucaena research in the Asian-Pacific region. Even then the value, success and benefits of this widely promoted leguminous "miracle" tree were not universally accepted. Six years later, the verdict in Asia is no longer debated; the miracle tree myth has disintegrated. Following devastation by the psyllid defoliator *Heteropsylla cubana* across Asia, *Leucaena leucocephala* can no longer be recommended for planting in that region (Napompeth, Mac dicken, McFadden and Oka, 1987). It may therefore seem surprising that two special papers at this Thailand meeting are devoted to genetic improvement of Leucaena when farmers, foresters and development workers are now disillusioned with Leucaena and devoting attention to alternative species and native trees in particular (e.g. Djogo, in press). However, these papers while drawing important lessons from previous failures, show that Leucaena is now better placed than ever before to contribute to non-industrial tree planting schemes throughout the world, given the very advanced state of knowledge and research on the genus and the availability of broadly based genetic material. The genus Leucaena has been the subject of a recent comprehensive review (Brewbaker, 1987a) including its history of genetic improvement. This paper, while including relevant background information, does not aim to repeat this.

To date most research on Leucaena genetics and improvement has been carried out by agronomists whose primary interest has been production of livestock feed (Brewbaker, 1987a; Hutton, 1983; Jones and Bray, 1983). This has not only influenced genetic improvement strategy but is giving rise to confusion amongst foresters and forest geneticists who may be unfamiliar with the agronomic terminology widely used in the literature. The term "variety" and particularly the "K varieties" designated by the University of Hawaii are widely used but do not correspond directly to any of the conventional forest genetics terms provenance, family or progency and bear no relation to the varietal rank used in botanical nomenclature. K varieties are used to describe anything from a single family to a bulked provenance collection of any Leucaena taxon. In this paper conventional forest genetics nomenclature is used throughout although reference is made to the "varieties" as used in the literature.

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* Paper previously published at the IUFRO Tropical Tree Genetics meeting in Thailand, and reprinted here with the kind permission of the author.

BACKGROUND

The limitations of *Leucaena leucocephala* including lack of cold and drought tolerance, poor growth on acid soils, heavy pod production, low wood durability and susceptibility to the psyllid that have contributed to its mixed reputation, are largely attributable to the extremely narrow genetic material that has been used in the majority of Leucaena plantings to date. Just how extreme this lack of genetic variation is has not always been fully realized by foresters or development agencies despite reminders from researchers (Brewbaker, 1985) and without tow decades one or a few largely self-pollinate progenies have become dominant across the tropics. This rapid spread was possible due to prodigious seed production on most sites. In addition Leucaena, based on its ease of management, nutritional benefits and spectacular growth in some areas, has been widely promoted by national and international development agencies (e.g. NAS, 1984) at a time when the need for non-industrial tree planting was becoming more widely appreciated and urgent.

Until recently, only one species of Leucaena, *L. leucocephala* was used in tree planting. *L. leucocephala* has long been known to be polyploid and highly self-pollinated (Brewbaker, 1987a). The original widespread shrubby forms were superseded by new giant arboreal forms distributed from Hawaii from 1967 onwards (Brewbaker *et al.*, 1972). These giant varieties are now recognized as a distinct subspecies *L. leucocephala* subsp. *glabrata* (Zárate, 1987; Brewbaker, 1987b). The precise native distribution of *L. leucocephala* subsp. *glabrata* remains unknown even today being complicated by its extensive cultivation in parts of Mexico and Central America. It is speculated that it may have originated following species hybridization at a so far undiscovered restricted locality in South Mexico or Guatemala (Sorensson, pers comm.). Thus most planted material can be traced back to a small number of cultivated trees in Mexico and El Salvadór, subsequently replicated directly by self-pollination and rapid seed production. The most widely planted variety designated K8 by the University of Hawaii represents largely selfed progeny collected from one or a few cultivated trees in the northern Mexican state of Zacatecas in 1959. That there is minimal genetic variation between or within these progenies has been confirmed by varietal trial results in many areas (e.g. Brewbaker Plucknett and Gonzalez, 1972; Wheeler Brewbaker and Pecson 1987, in Hawaii and Arora, 1981, in India). The handful of currently planted Leucaena varieties is even more restricted than those included in these trials which showed that the few varieties which are distinct in growth and psyllid resistance have sparse seed production and have so far not been available for widespread use.

Although widespread planting of leucaena continued to depend on a very narrow genetic base, researchers, realizing its limitations and genetic vulnerability, started to explore, collect, evaluate and breed a wider range of Leucaena taxa. A number of exploration and collection expeditions to Mexico and Central America and assembly to exotic material from elsewhere led to the establishment of two major Leucaena germplasm collections at the University of the Hawaii, USA, where over 1000 accessions have now been collected (Brewbaker, 1987a) and in Queensland, Australia, where the CSIRO collection includes around 700 accessions (Jones and Bray, 1983). Although these collections are still dominated by *L. leucocephala* with its noted lack of genetic variation, other taxa have been progressively incorporated and rapid advances made on study of the genus as a whole (Brewbaker, 1983; 1987a). These collections have formed the basis of a number of specific breeding programmes to overcome some of the known limitations of *L. leucocephala* through use of more variable genetic material. The realization that species hybridization is possible for most species combinations has opened up exciting new avenues in Leucaena genetic development (Sorensson Pan, Booman, and Brewbaker 1984) and revealed that the entire genus can be considered an effective gene pool for breeding (Brewbaker, 1987a). In this progress has been made to improve cold tolerance (Brewbaker and Sorensson, 1987) using mainly the *L. diversifolia* complex and *L. pallida* as elucidated by Pan (1985). Similar progress is possible to improve tolerance to acid soils (Hutton, 1983) and psyllid resistance (Bray, 1987; Sorensson and Brewbaker, 1986).

New Leucaena Collections from Mexico and Central America

In 1984, the Oxford Forestry Institute, (OFI) started a new programme of exploration and collection of Leucaena genetic resources throughout Central America, Mexico and Northern South America alongside continuing work on other non-industrial tree species (Hughes and Styles, 1984) and intensive collections of the other leguminous genera Gliricidia (Hughes, 1987) Albizia and Parkinsonia in that region.

This was prompted first by the realization that a number of impressive leucaena taxa had been overlooked by previous collecting expeditions and were not included in the Hawaii or CSIRO collections. IN addition, the small quantities of seed collected in the past had never allowed testing of potentially valuable species across sites and lack of seed availability of broadly based leucaena genetic material had been a major obstacle to progress in genetic improvement in many tropical countries (e.g. gupta and Patil, 1981). Finally at a time when the limitations of *L. leucocephala* were becoming increasingly apparent, it was realized that depletion of native leucaena genetic resources in Central America and Mexico had reached critical levels and a number of important and little-known taxa were threatened (Hughes, 1986, 1988). As the psyllid *Heteropsylla cubana* spread across Asia in the last four years making the need to find alternatives to *L. leucocephala* more urgent, the OFI programme has been expanded to include comprehensive collections of all known leucaena taxa.

That previous leucaena collecting expeditions have missed or overlooked a number of important taxa altogether can be readily understood given the confusion surrounding leucaena taxonomy and the fact that a number of taxa in Central America have either very restricted distributions or are now severely depleted and rare (Hughes, 1986, 1988). For these taxa single unusual trees are readily dismissed and to find collectable populations requires meticulous exploration to locate relict stands. A number of other taxa being in remote localities often away from the main leucaena distribution such as *L. multicapitulata* in southern Central America and *L. lancedolata* subsp. *sousae* from southern, coastal Mexico, have also remained uncollected. These have now been included in the OFI collections.

The proliferation of named species common in many neotropical leguminous genera is apparent also in leucaena with over 50 named species. All authors agree that most are synonyms of a restricted group of 12-15 species (Brewbaker, 1987b; Zárate, 1984). A number of taxonomical problems remain despite some recent clarifications (Zárate, 1987; Hughes, 1988). The taxonomic importance of infraspecific taxa is widely acknowledged reflecting the disjunct distributions of many taxa and complex patterns of morphological variation demonstrated by Pan (1985) and others. Subspecies although often morphologically close, can be genetically quite distinct and perform in radically different ways exemplified by the two subspecies of *L. leucocephala* corresponding to the giant and shrubby varieties found by Brewbaker *et al.* (1972) to differ by two and half times in forage yield.

COLLECTION STRATEGY

The critical importance of infraspecific taxa in relation to genetic variation has been a major feature of the OFA seed collection strategy. The aim has been to collect as wide a range of leucaena genetic material as possible of species other than *L. leucocephala* which is known to be genetically uniform and already well represented in the major leucaena collections. Further than this, collecting has concentrated particularly on six taxa not represented at all in previous leucaena collections, with inclusions of two or more provenances of each. To date, some 35 collections including 660 families from 20 taxa have been collected as shown in Table 1. Characteristics of the previously collected taxa are described in outline by Brewbaker (1987b) and some of the salient features of the six additional taxa are given below. The distribution of seed collection sites is illustrated in Map 1 and covers the whole distribution of leucaena in Latin America over 30° in latitude and 2100 m in elevation indicating the great environmental adaptability of the genus.

These previously untested taxa (marked * in Table 1) represent some of the leucaenas with greatest potential so far discovered. Several form the largest trees of any species in the genus. *L. multicapitulata* often forms trees to 25 m in height and diameter breast height to 70 cm while *L. salvadorensis* and the giant form of *L. shannonii* commonly reach 20 m in height (Hughes, 1986) with dbh from 30-60 cm, rivalling the larger trees of *L. leucocephala* (Van den Beldt and Brewbaker, 1983). All are highly appreciated for a range of uses by local residents in their native range and several produce wood that is superior in quality to *L. leucocephala* both for fuel and construction material. *L. salvadorensis*, *L. multicapitulata* and the Guatemalan form of *L. collinsii* are used for corner posts in house construction because of their durability. In addition, initial indications from early growth in Hawaii are that *L. salvadorensis*, the giant form of *L. shannonii* and the Guatemalan form of *L. collinsii* are moderately or highly resistant to the psyllid and both *L. salvadorensis* and the giant form of *L. shannonii* are as vigorous as any other leucaena taxa being grown in Hawaii (Sorensson and Brewbaker, pers comm.2). Some of these taxa may be of particular importance in drier environments where *L. leucocephala* grows poorly, given that the Guatemalan form of *L. colliniss* and *L. esculenta* subsp. *Matudae* grow in areas with less than 500 mm annual rainfall and a seven to eight month dry season. At this early stage it is difficult to assess leaf quality of these lesser-known taxa and this may limit their potential to substitute for *L. leucocephala* as pointed out by Bray (1987).

Unlike *L. leucocephala* and the tetraploid subspecies of *L. diversifolia* which are highly self fertile, all other leucaena taxa studied so far have been found to be self-incompatible out-crossers (Brewbaker, 1987a; Sorensson and Brewbaker, 1987) and these require different collection and breeding strategies. Superior trees of *L. leucocephala* or tetraploid *L. diversifolia* can be selected and propagated directly as was done for a range of giant *L. leucocephala* progenies. Although not used to date, a number of superior selfed progenies could be used in mixture in the type of "multiline" suggested by Brewbaker (1985). This strategy is being adopted for the tetraploid *L. diversifolia* in the OFI collections and could provide a good test lot for *L. leucocephala* as well. For out-crossing taxa larger bulk provenance lots have been collected to include at least 50 parent trees where possible. For all collections a combination of individual-tree and bulk provenance lots have been collected both to provide enough seed of broad genetic base for evaluation on a range of sites and allow the establishment of a number of more intensive combined progeny-provenance trials for some species.

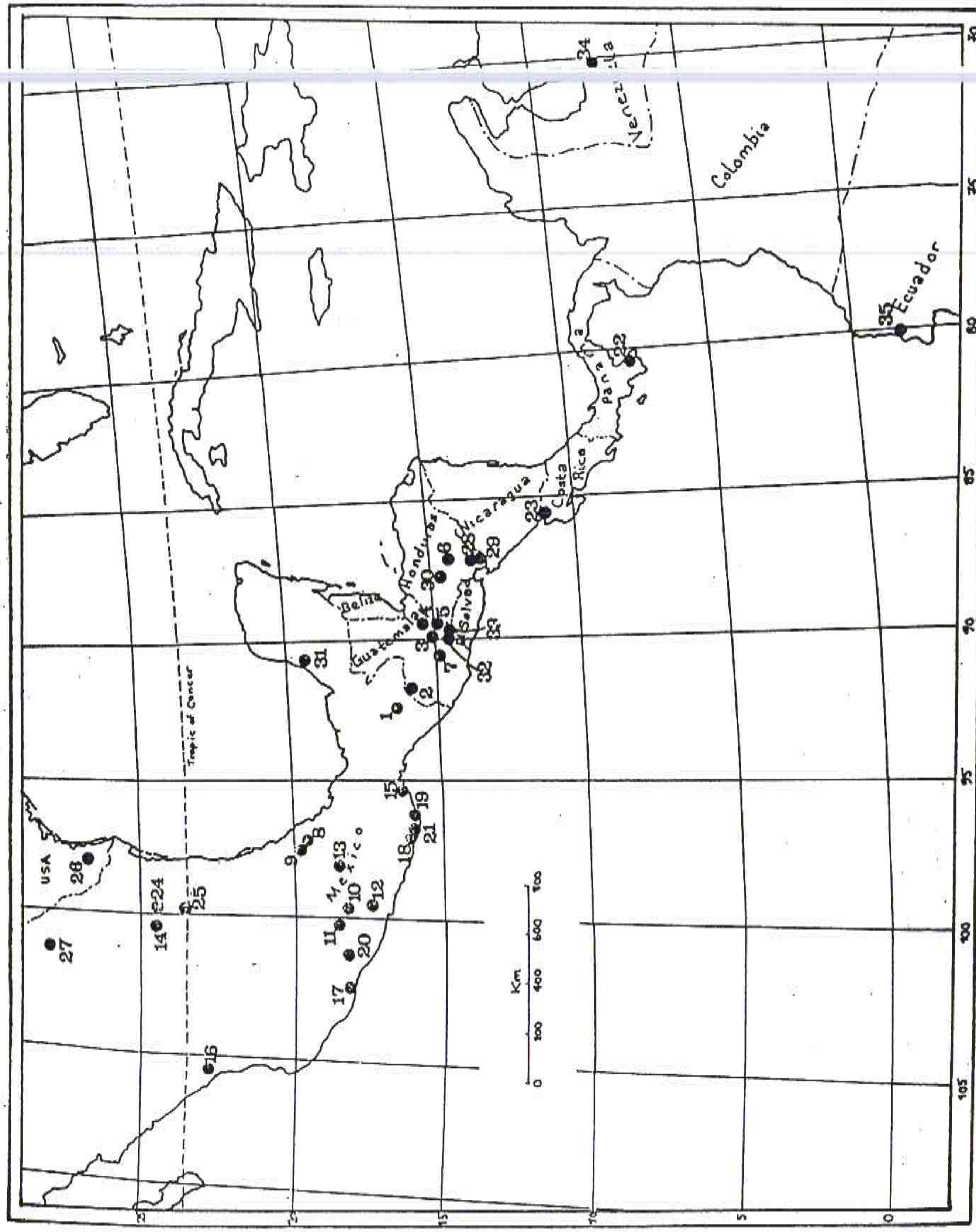
USA
Mexico
Tropic of Cancer
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Costa Rica
Panama
Colombia
Ecuador
Km

Table 1
Summary of Leucaena Seed Collections (several taxa are provisional named)

Species	Map No.	Provenance	Country	Ident Nos.	Lat. °N/S	Long. °W	Alt. (m)	No. Parents Trees	
								Separate	Bulk
L. collinsii	1	Narcisco Mendoza, Chapas	Mexico	45/85 + 52/88	16° 36'	93° 00'	400–500	25	50
	2	Chacaj, Huehutenango	Guatemala	51/88	15° 56'	91° 47'	700	25	50
*L. collinsii (Guatemalan form)	3	Puerto de Golpe, Progreso	Guatemala	15/83 + 18/41	15° 02'	89° 40'	480	25	30
	4	Gualán, Zacapa	Guatemala	56/88	15° 07'	89° 21'	100–200	20	40
L. diversifolia	5	El Carrizal, Chiquimula	Guatemala	57/88	14° 40'	89° 30'	500–600	18	18
	6	Zambrano, Francisco Morazan	Honduras	35/88	14° 14'	87° 30'	1150	10	25
	7	Los Guates, Guatemala	Guatemala	53/88	14° 49'	90° 37'	1400–1450	20	40
	8	Corral Falso, Veracruz	Mexico	45/87	19° 26'	96° 45'	800	20	30
	9	Zalapa, Veracruz	Mexico	46/87	19° 32'	96° 55'	1200–1350	15	30
L. esculenta ssp. esculenta	10	Pachivia, Guerrero	Mexico	47/87	18° 18'	99° 45'	1400–1700	24	50
	11	Tirinqucha, Michoacan	Mexico	48/87	18° 38'	100° 48'	600	10	25
*L. esculenta ssp. matudae	12	Mexcala, Kguerrero	Mexico	49/87	17° 51'	99° 40'	550–750	14	10
L. esculenta (ssp. paniculata (syn. L. pallida)	13	Chapulco, Puebla	Mexico	52/87	18° 38'	97° 24'	2100	20	25
L. greggii	14	El Barrial, Nuevo León	Mexico	26/86 + 82/87	24° 50'	100° 01'	1450–1700	20	60
L. lanceolata spp. lanceolata	15	San Jon, Oaxaca	Mexico	43/85	16° 02'	95° 39'	10	20	50
	16	Escuinapa, Sinaloa	Mexico	44/85	22° 46'	105° 54'	60	20	30
	17	Playa Azul, Michoacan	Mexico	46/85	18° 04'	102° 34'	0–30	23	–
*L. lanceolata ssp. sousae	18	Cacalote, Oazaca	Mexico	50/87	16° 02'	97° 35'	0–100	–	23
	19	Puerto Angel, Oazaca	Mexico	51/87	15° 40'	96° 30'	0–100	20	35
L. macrophylla ssp. macrophylla	20	Vallecitos, Guerrero	Mexico	55/88	18° 00	101° 18'	110–1200	10	25
L. macrophylla ssp. nelsoni	21	San isidro, Oaxaca	Mexico	47/85	15° 59'	97° 96'	10	20	20
*L. multicapitulata	22	Los Santos, Azuero	Panama	81/87	7° 55'	80° 25'	10–50	20	30
	23	Peñas Blancas, Guanacaste	Costa Rica	86/87	11° 10'	85° 37'	150	–	5
L. pulverulenta	24	Ejido Popote, Nuevo León	Mexico	22/86	24° 54'	99° 29'	320	3	–
	25	Altas Cumbres, Tamaulipas	Mexico	83/87	23° 36'	99° 14'	1000–1500	20	60
	26	South Texas, Texas	USA	84/87	26° 30'	97° 50'	10–30	10	30
L. retusa	27	Sierra La Encantada, Coahuila	Mexico	23/85	28° 44'	102° 20'	800–1500	10	10
*L. salvadorensis	28	La Garita, Choluteca	Honduras	17/86 + 36/88	13° 26'	87° 11'	480–600	55	60
	29	Yusguare, Choluteca	Honduras	34/88	13° 15'	87° 06'	350–500	18	25
L. shannonii	30	Comayagua, Comayagua	Honduras	22/83 + 26/84	14° 22'	87° 39'	600–700	24	30
	31	Champotón, Campeche	Mexico	53/87	19° 43'	90° 43'	0–20	20	30
*L. shannonii	32	El Ricón, Chiquimula	Guatemala	19/84	14° 40'	89° 42'	900	25	25
	33	Quetzaltepeque, Chiquimula	Guatemala	58/88	14° 37'	89° 27'	600–650	30	50
L. trichodes	34	Cuicas, Trujilo	Venezuela	2/86	9° 38'	70° 18'	450–700	20	30
	35	Jipijapa, Manabi	Ecuador	61/88	1° 21'	80° 34'	150–400	30	30

EVALUATION AND GENETIC DEVELOPMENT

To date most non-industrial tree evaluation and improvement has concentrated on selection for vigour and high biomass production of trees that can be used for many purposes in the expectation that a few uniform high-yielding selections will meet farmers' combined needs for fuelwood, light construction material, livestock fodder, green manure and other products. This has been the dominant trend in Leucaena also. While highly uniform material may be desirable for industrial uses such as pulp, sawtimber, veneer or dendrothermal power generation, it is becoming increasingly clear that farmers' needs will not be met by such an approach for non-industrial trees (Robinson and Thompson, in press). What is needed is highly variable material to supply farmers' needs adequately in terms of quality and timing of production, and to narrow genetic risks associated with widespread dependence on overly narrow genetic material (Brewbaker, 1985). For any one product, variable qualities and timing of production are required: for fuelwood variable size, quality and drying rates are preferred for different cooking iperations and seasons; for house construction local residents need access to material of different sizes, strengths and durability for different components; livestock fodder needs to be of different qualities for different animals and optimal nutrition and timing of production to coincide with feed gaps is vital (Robinson, 1984); for green manure timing of production is also critical and variable material with differing rates of decomposition may provide a better mix of nutrient inputs and mulching characteristics than uniform rapidly decomposing leaves of a single type.

This has important implications for leucaena evaluation and genetic improvement. The complex needs of farmers cannot be met by a few highly productive selections which are inherently narrowly based. What is required is a gamut of different selections as suggested by Bray (1987) for different purposes, incorporating differing qualities and timing of production planted in mixtures or at any rate in different parts of the same farm. This will automatically reduce the risks involved in narrowing the genetic base within any one selection. While a start has been made towards different leucaena selections for different environments, this needs to be expanded to improve product quality. Such an approach closely resembles the multiple population breeding strategy being pioneered in industrial tree improvement (Namkoong, Barnes and Burley 1980), maintains genetic flexibility by breeding differently enhanced populations for different objectives and has numerous advantages for genetic conservation.

It is anticipated that seed from the rangewide OFI leucaena collections can be incorporated into such a framework in a number of different ways.

1. For the first time it will be possible to test a wide range of lesser-known taxa against commonly planted *L. leucocephala* and *L. diversifolia* on a range of site types. Early indications are that on many sites one or several will out-perform *L. leucocephala* even in psyllid-free environments. This will provide the opportunity to investigate these taxa as potential alternatives to *L. leucocephala* and assess genotype-environment interaction which to date has been largely neglected in leucaena evaluation. In the search for psyllid resistance, seed of *L. collinsii* and *L. esculenta* from these collections along with other material from the University of Hawaii has already been distributed for the establishment of the international leucaena psyllid trial (LPT) network being coordinated in Asia by the Nitrogen-Fixing Tree Association (Glover, 1987). Observations of early plantings in Hawaii of some of the new OFI collections outlined above indicate that these also deserve wider testing in Asia. At present preliminary experiments on seed pre-treatment methods and nursery practice are underway for the lesser-known species prior to wide distribution of seed.

2. In addition to direct use of other leucaena taxa in tree planting, the scope for hybridization and incorporation of desirable traits into *L. leucocephala* has been amply demonstrated (Brewbaker, 1987a). Research in Hawaii (Brewbaker, 1987a) has shown that the whole genus can be treated as a large breeding complex and these new collections are already being used in hybridization and breeding experiments in Hawaii. It is anticipated that material will be supplied not only to the already well advanced programmes in Hawaii and Australia but also to projects elsewhere in a range of tropical countries (e.g. in India, Gupta and Patil, 1987) creating a broadly-based decentralized network of leucaena improvement programmes.
3. The direct improvement of some of the out-crossing, self-incompatible leucaena species through conventional recurrent selection and breeding has not yet been attempted, although work is starting on *L. salvadorensis* in Honduras (Gibson, pers.comm), and these collections will provide an ideal base for such improvement programmes.

In all leucaena improvement activities considerable care and effort will be required to maintain purity in seed production areas and seed orchards. By bringing a diverse range of taxa together on one site for trials, pure seed production of any one taxon cannot be expected from the trials.

Conclusions

In combination, the direct use for a wide range of different leucaena species and on-going longer term production of an increasingly powerful range of hybrid material can readily meet farmers' needs for a wide variety of products on many tropical lowland, subtropical and tropical highland site types. Progress and success are not limited by lack of knowledge in that research on some aspects of leucaena is now well advanced, nor by lack of broadly based material which is now becoming available, but will depend, as emphasized by Brewbaker (1987a), on the investment that national and international agencies are willing to make in this non-industrial, non-food crop tree. Strong support is needed for coordinated evaluation to test leucaena material on a range of sites, for breeding programmes in a range of different countries and perhaps most critically for establishment of seed production areas of a wide range of improved genetic material.

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The Evaluation of Leucaena Germplasm in Trinidad and Tobago

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INTRODUCTION

One of the main objectives of the Caribbean OAS Leucaena Project was the collection and agronomic evaluation of a range of leucaena germplasm which can be utilized for different purposes, including forage, wood, fuel and erosion control. In addition there is a need to evaluate extra-regional leucaena germplasm under Caribbean conditions for the identification of cultivars adaptable to acid soils. Emphasis was however placed on the collection and evaluation of the leucaena germplasm indigenous to the Caribbean. Since there does not appear to exist a full description of the range of agronomic and morphological variability in the indigenous leucaena germplasm of the Caribbean, this paper reports the classification and preliminary agronomic evaluation of a number of introduced and indigenous Caribbean accessions of leucaena on a slightly acid soil in Trinidad at the University Field Station, Valsayn, Trinidad.

GERMPLASM COLLECTION AND EVALUATION

Six Caribbean islands were visited and collections of leucaena seed wee made from several locations in each territory resulting in a broad sample of the indigenous populations. A total of 295 accessions were collected including from Jamaica 66, Antigua 21, Barbados 26, Grenada 103, St. Lucia 54 and Trinidad and Tobago 25. From the total collection, a representative sample of 175 accessions were planted for observation and evaluation. These were all the species *L. leucocephala* except for one sample of *L. brachycarpa* which was collected in Jamaica. The germplasm collection also contained a few accessions from extra-regional sources. There were thirteen accessions of leucaena including three different species (*L. leucocephala*, *L. diversifolia* and *L. shannon*) and one hybrid (*L. leucocephala x L. diversifolia*). These were obtained from the University of Hawaii in Honolulu, Hawaii, Centro Internacional de Agricultura Tropical (CIAT) in Colombia and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia.

The germplasm collection was established at the University of the West Indies Field Station (UFS) in Valsayn, Trinidad. The soil type at the UFS is River Estate Loam (Fluventic eutropept) which is a slightly acid, (pH 6.0), relatively free draining, soil derived from detrital micaceous phyllites and schists of the Northern Range. The nitrogen content of the soil is moderately good, phosphorus and potassium are low but calcium and magnesium are in fair supply.

Two trials were conducted at the UFS in which 142 accessions of *Leucaena sp.* were evaluated agronomically and classified on the basis of selected morphological and agronomic characteristics. The nutritive value of the accessions in terms of protein content (% CP) and *in vitro* digestibility were also assessed. The first trial consisted of 18 accessions from extra-regional sources, representing three species, *L. leucocephala, L. diversifolia* and *L. shannoni*), and one hybrid (*L. leucocephala* and *L. diversifolia*). Table 1 lists the accessions included in Trial 1 and gives the sources from which they were obtained. The second trial consisted of 124 accessions of *L. leucocephala* which were collected from six Caribbean territories (Jamaica, Trinidad and Tobago, Grenada, Antigua, Barbados and St. Lucia). The number of accessions included from each territory in Trial 2 is represented in Table 2.

THE MAJOR FINDINGS

In the first study three phenetic groups (Groups A, B and C) were defined based on the overall similarity of the morphological and agronomic characteristics of the 18 extra-regional accessions. Principal component analysis indicated that group formation was influenced by a number of leaf and flora characteristics. Group A was characterised by *L. leucocephala*, Group B by *L. diversifolia* and Group C was constituted by a single poor growing accession of the hybrid. There were significant differences in plant height, diameter breast height and number of lower branches among the groups (Table 3). At twelve months after transplanting the Group B accessions were taller and had larger diameter breast height than the accessions in Group A. The average crude protein content and *in vitro* digestibility of the leaves of the accessions in Group A were 22.9 per cent and 56 per cent respectively, which were significantly higher ($P<0.05$) than those of the Group B accessions (Batson, 1987).

Table 1
Leucaena Species and Number of Plants Used in Trial 1

Species	Variety/Identify No.	Source	No. Plants
L. Leucocephala	K4	U. of Hawaii	25
L. Leucocephala	K67	U. of Hawaii	15
L. Leucocephala	CF 95	CSIRO	8
L. Leucocephala	CIAT 17474	CIAT	24
L. Leucocephala	CIAT 17476	CIAT	19
L. Leucocephala	K6	U. of Hawaii	26
L. Leucocephala	CIAT 17486	CIAT	22
L. Leucocephala	CIAT 17475	CIAT	10
L. Leucocephala	CIAT 17477	CIAT	3
L. diversifolia	CIAT 17388	CIAT	3
Leucaena sp.	CIAT 17478/1	CIAT	1
Leucaena sp.	CIAT 17478/2	CIAT	1
Leucaena sp.	CIAT 17478/3	CIAT	1
Leucaena sp.	CIAT 17478/4	CIAT	1
Leucaena sp.	CIAT 17478/5	CIAT	1
Leucaena sp.	CIAT 17478/6	CIAT	1
Leucaena sp.	CIAT 17478/7	CIAT	1
L. shannoni	CIAT 17487	CIAT	5

Table 2
Country of Origin of the Accessions Included in Trial 2

Country	No. of Accessions	Species
Jamaica	16	*L. leucocephala*
Trinidad and Tobago	22	*L. leucocephala*
Grenada	31	*L. leucocephala*
Barbados	15	*L. leucocephala*
St. Lucia	24	*L. leucocephala*
Antigua	14	*L. leucocephala*
Hawaii	1	*L. leucocephala*
Australia	1	*L. leucocephala*
Total	124	

Table 3
Plant Height, Basal Diameter and DBH at 12 Months of the Groups Formed from Cluster Analysis of 18 Accessions in Trial 1

Accessions	Plant Height (m)	Basal Diameter (cm)	DBH (cm)
Group A			
K4	3.16	4.93	2.58
K67	4.07	6.73	3.56
CF95	3.27	5.48	3.02
CIAT 17474	3.19	4.77	2.27
CIAT 17476	2.98	4.68	2.19
K6	3.76	5.36	3.18
CIAT 17486	2.77	3.81	2.26
CIAT 17475	2.98	5.07	2.68
CIAT 17477	2.86	4.32	2.13
CIAT 17478/2	6.00	11.90	5.61
CIAT 17478/5	5.00	3.33	9.19
Mean	3.64	6.02	2.98
±S.E.	0.31	0.73	0.30
Group B			
CIAT 17388	3.93	4.31	2.74
CIAT 17478/1	4.50	5.83	3.93
CIAT 17478/3	6.30	9.08	6.22
CIAT 17478/6	5.50	5.66	5.97
CIAT 17478/7	6.70	8.72	4.28
CIAT 17487			
Mean	5.46*	6.41	4.42*
±S.E.	0.43	0.82	0.57
Group C			
CIAT 17478/4	1.75	2.12	1.10

*Significant at the five per cent level

The *L. leucocephala* germplasm from the Caribbean Region was classified into two broad phenetic groups. These groups were identified as *L. leucocephala* var. *leucocephala* or the common type of leucaena, and *L. leucocephala* var. *glabrata* or the giant type leucaena. The main distinguishing morphological features were the pilosity of the apices and the number of glands per leaf. Apices of the common type leucaena were finely pubescent and the leaves were with or without a gland. The giant type leucaena had glabrous apices and one or two glands per leaf. The common type leucaena was concluded to be typical of the region as it was present in all the territories in which collections were made. Also, with 107 accessions it was the larger of the groups. The giant type leucaena was found mainly in St. Lucia. The giant type was significantly taller, more vigourous and higher yielding at eight months after transplanting than the common type. The average yield of 2.46 kg/plant; the giant type was significantly higher ($P<0.01$) than the 0.35 kg/plant recorded for the common type. The giant type also had a higher nutritional quality in terms of crude protein content and dry matter digestibility. The mean crude protein content and dry matter digestibility of the giant type were 22.9 per cent and 63.5 per cent respectively, while the corresponding values for the common type were 20.7 per cent and 54.6 per cent (Batson, 1987). From the results of the preliminary agronomic evaluation of the two trials a number of outstanding accessions have been identified. A summary description of these accessions and their potential usage are presetned in Table 4. These accessions have been selected primarily on the basis of their dry matter production, crude protein content and dry matter digestibility.

The varieties K67, K8 and K6 are giant types which were released from the University of Hawaii. The most outstanding of these is K67 which is a particularly robust plant. It has been the highest yielding variety in our trials and seems ideally suitable for wood production. The variety K8 also displayed good growth characteristics and both K8 and K6 may be suitable for forage and or wood production. The Peru type variety "Cunningham" was released by CSIRO in Australia in 1975 and has been the most widely tested variety in the Caribbean. In these trials it continued to demonstrate its good potential for forage production. The other Peru type in our trials, CF 95, also showed potential for forage production. This is the variety which is presently being cultivated at the Sugarcane Feeds Centre (SFC) in central Trinidad and fed as a supplement to animals on a sugarcane-based diet. It has been producing fairly well on the very acid (pH 4.5), waterlogged soils at the SFC. The varieties L173, L141, L142, L154, L156 and L159 are giant types which collected the vicinity of Patience on the east coast of St. Lucia. Their agronomic performance and nutritive values have been similar to that of Cunningham in our trials. These varieties are emendable to forage and or wood production. Another giant type which was collected in the Caribbean is the variety B77 from Barbados. In our evaluation trial its crude protein content and dry matter digestibility were lower than the mean of the other giant types but it was vigorously growing, high yielding and had good lower branching. With proper cutting management it should be suitable for forage production.

The releases from CIAT, 17475 and 17487 which belong to the species *L. leucocephala* and *L. shannoni*, respectively, have not been previously tested in the Caribbean. They were bred by Dr. Mark Hutton as part of the CIAT programme for development of acid tolerant lines of leucaena. The variety CIAT 17475 is comparatively short, very leafy, has good lower branching and nutritional qualities and would be suitable for forage production or use as a green manure. On the other hand, CIAT 17487 is very tall, and woody and may be suitable for fence posts, stakes or wood production.

Table 4
Summary Description and Recommended Usage of Selected Cultivars

Cultivar	Description	Recommended Use
K8	very vigorous, tall, woody, high yielding	wood, windbreak, forage, green manure
Cunningham	vigorous, tall, leafy, high yielding, highly branched	forage windbreak, erosion control, green manure
L142	vigorous, medium height, leafy, high yielding, low branching	forage, green manure, erosion control
B77	vigorous, medium height, leafy, high yielding, low branching	forage, green manure, erosion control
L173	vigorous, medium height, leafy, high yielding, few lower branches	forage, green manure, stakes
L148	vigorous, short, leafy, high yielding	forage, green manure
L154	vigorous, short, leafy, highly branched	forage, green maure
L141	very vigorous, tall, woody, few lower branches	wood, windbreak, erosion control

EVALUATION OF THE GERMPLASM AFTER FIVE YEARS

Five years after establishment the Caribbean Leucaena Germplasm was further evaluated and it was found that between 77 and 100 per cent of the plants have survived, from Jamaica and Trinidad and Tobago respectively (Table 5). The findings also indicated that 12 per cent of all the accessions were over four meters (Table 6). However, all the better Caribbean accessions which came from St. Lucia (identified by the letter L) were in excess of seven meters with only one approaching the magnitude of the height of the K8 Giant from the University of Hawaii (Table 7). Table 8 also shows the height of some of the shorter accessions. The basal diameter of some of the selected Caribbean accessions measured at five years indicated none to be close to that of K8 (17 cm), (Table 9). At five years the basal diameter of some of the common types ranged from 4.0 to 5.8 cm, while that of the "Caribbean Giants" ranged from 8.0 to 12.8 cm; Table s 9 and 10 respectively.

Several of the CIAT bred *L. leucocephala* after five years all had a basal diameter of over 10 cm (Table 11). One in particular CIAT 17475 had a basal diameter of 18.9 cm comparable to that of K8 (17 cm Table 9), as well as CIAT 17461 which was also outstanding 20.3 cm (Table 12). However the height of only CIAT 17478 was comparable to that of K8 after five years (Table 7 and 13). The calculated wood yield of none of Caribbean accessions were comparable to the K8, however Caribbean accession L141, L155, and L156 show some measure of promise (Table 15).

Table 5
Evaluation of Caribbean Leucaena Germplasm Five Years after Establishment

Origin of Accessions	% Surviving after 5 years
Antigua	96
Barbados	96
Grenada	92
Jamaica	77
St. Lucia	97
Trinidad and Tobago	100

Table 6
Evaluation of Caribbean Leucaena Germplasm Five Years after Establishment

Plant Height (m)	% of Accessions
<3.1	38
3.1–4.0	50
4.1–5.0	6
>5.0	6

Table 7
Height of Selected Caribbean Accessions at One and Five Years after Establishment

Giants	1 Year (m)	5 Years (m)
L141	2.8	9.2
L142	2.2	7.3
L144	1.5	6.3
L154	2.3	6.0
L155	2.2	7.7
L156	2.9	7.1
L159	2.6	7.6
K8	3.4	9.4

Table 8
Height of Selected Caribbean Accessions at One and Five Years after Establishment

Common Types	1 Year (m)	5 Years (m)
A112	1.0	2.0
B78	1.3	2.3
G247	1.4	3.6
J5	1.1	2.9
L176	1.2	3.3
T322	1.3	3.2

Table 9
Basal Diameter of Selected Caribbean Accessions at One and Five Years After Establishment

Giants	1 Year (cm)	5 Years (cm)
L141	2.8	8.0
L142	3.5	10.3
L144	2.3	9.8
L154	4.4	8.6
L155	3.2	12.2
L156	3.3	12.8
L159	3.4	7.8
K8	4.6	17.0

Table 10
Basal Diameter of Selected Caribbean Accessions at One and Five Years After Establishment

Common Types	1 Year (cm)	5 Years (cm)
A112	1.7	4.8
B78	1.8	4.4
G247	1.4	5.8
J5	1.6	4.9
L176	1.5	5.0
T322	1.6	5.0

Table 11
Basal Diameter of Selected International Accessions at Five Years After Establishment

	1 Year (cm)	5 Years (cm)
L. Leucocephala		
CIAT 17474	4.8	10.2
CIAT 17475	5.1	18.9
CIAT 17476	4.7	12.1
K6	5.4	10.2
CF95	4.8	14.0

Table 12
Basal Diameter of Selected International Accessions at One and Five Years After Establishment

	1 Year (cm)	5 Years (cm)
Hybrid (*Leucocephala x diversifolia*)		
CIAT 17478	8.8	17.6
L. diversifolia		
CIAT 17461	–	20.2
CIAT 17388	4.31	16.8
L. shannoni		
CIAT 17487	4.9	11.3

Table 13
Height of Selected International Accessions at One and Five Years After Establishment

	1 Year (m)	5 Years (m)
Hybrid (*Leucocephala x diversifolia)*		
CIAT 17478	5.6	9.3
L. diversifolia		
CIAT 17461	–	5.2
CIAT 17388	3.9	6.5
L. shannoni		
CIAT 17487	5.8	7.0

Table 14
Height of Selected International Accessions at Five Years After Establishment

	1 Year (m)	5 Years (m)
L. Leucocephala		
CIAT 17474	3.19	3.673
CIAT 17475	2.98	6.66
CIAT 17476	2.98	5.04
K6	3.76	6.05
CF95	3.27	6.30

Table 15
Wood Yield of Selected Caribbean Accessions Cubic Meters/ha

Accession	Calculated Wood Yield
L141	21.9
L142	15.9
L144	15.9
L154	17.3
L155	24.0
L156	25.0
L159	15.6
K8	31.7–61.4

CONCLUSION

Among the *L. leucocephala* accessions, the giant type has a greater potential for forage production than the common type. further selections for forage production should be from among this type. Although the common type is lower producing, it is suggested that naturally existing populations, particularly in the islands of Antigua, Barbados and Grenada, may make a valuable contribution to the quality of "roadside grazing" and household fuelwood needs.

The germplasm collection present at the University of the West Indies is of great value to the Region as a whole. The selected accessions should now be tested in various production systems under the range of agro-ecological conditions prevailing in the Caribbean.

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An Overview of Research on Leucaena (*Leucaena leucocephala*) in Trinidad and Tobago

K.A.E. Archibald

INTRODUCTION

Leucaena (*Leucaena leucocephala*) is a fast growing, versatile leguminous shrub or tree which is native to South and Central America and is now found widespread in the Caribbean especially where neutral and alkaline soils exist. It may be found from sea level up to 1,500 metres and is relatively drought-tolerant. Whether uncultivated or cultivated it has a variety of uses. The forage is high in protein 20-30% Crude Protein [CP] on a dry matter [DM] basis and thus useful as livestock feed; while the main stem is a source of valuable timber or fuelwood. The tree may also be used as a windbreak or for erosion control, and recently has found its place in cropping systems as a supplier of green manure for companion crops, as in alley cropping systems. It is therefore not surprising that it is now found widespread throughout the tropical world and that considerable attention has been given to its breeding and to the exploitation of its wide genetic variation in growth habit and productivity (Brewbaker, 1976; Brewbaker and Hutton, 1979).

In the Caribbean region it was found that efforts had not been made to evaluate the leucaena germplasm available here and to compare their performance with improved cultivars (cvs.) available from extra regional sources. Additionally no efforts were made to introduce other species of the Genus: Leucaena. Moveover, within *L. leucocephala* there is considerable genetic variability with three main types: (i) the Hawaiian or Common type as it is known in the Caribbean, (ii) the Salvador or "Aboreal" type from which the "Hawaiian Grants" have been developed and (iii) the intermediate leafy, extensively branched Peru type. The variety "Cunningham" was developed in Australia from this latter type.

THE REGIONAL PROGRAMME

A Regional Programme was initiated around 1979 with financial assistance from the OAS in order to study and evaluate Leucaena and other germplasm within that Genus in the Caribbean Region, and with participation originally from six countries, Barbados, Haiti, Jamaica, St. Lucia, Suriname and Trinidad and Tobago. Each country placed emphasis on the particular area of the plant's production that was of greatest importance to it and the overall activities were initially coordinated by the author as a collaborative network. An Annual Review Meeting was held each year in rotation at which results of studies undertaken were presented and discussed and recommendations offered for additional work or for the exchange of materials and literature. This effort also helped to strengthen the on-going programmes (of which leucaena formed a part) of the collaborating countries institutions or ministries.

Leucaena Programme in Trinidad and Tobago

The author also was the country co-ordinator for Trinidad and Tobago within the OAS Caribbean Leucaena Project. The work was undertaken at the University of the West Indies (UWI) at St. Augustine in the Departments of Crop and Livestock Sciences, and at the Sugarcane Feeds Centre (SFC). The Leucaena programme of the SFC was started in 1978. The Forestry Division of the Ministry of Agriculture (now Forestry Division of the Ministry of the Environment and National Service) began work with *L. leucocephala*, *Albizia falcataria* and *Sesbania grandiflora* in 1982 for use as a forest tree species(Lackhan, 1986). Their work did not constitute part of the regional collaboration and would not be described in this paper. It is the subject of another paper at this workshop.

Under the leucaena programme a Masters degree and a Ph D degree has been successfully completed and another Masters degree is expected to be completed shortly. Moreover, the opportunity was provided for the initial agronomic evaluation of a range of leucaena germplasm and this was carried out in Trinidad with leucaena material collected from several countries within the Caribbean as well as from outside the region. Also a series of studies were carried out on the production and utilisation of dehydrated leucaena forage by Holstein cattle for growth and milk production conducted exclusively at the SFC as part of its ongoing technical programme.

Two reviews of the leucaena literature were undertaken. The first review examined the variabilities that existed in the genus: Leucaena with special reference to the Caribbean (Batson, Ferguson and Archibald, 1984). The other review examined the place of leucaena in systems of livestock production and its potential for contributing to livestock development in the Caribbean (Batson *et al*., 1986). These reviews established the status of leucaena in the literature and the value of leucaena as an important natural resource in the Caribbean. The presence of mimosine in leucaena is considered in the above review, but no special emphasis was placed on this undesirable factor in the research programme in Trinidad and Tobago as no serious effects of mimosine on animal performance were expected at the levels of inclusion of leucaena in the sugarcane-based diets. However, observations were made of mimosine content in the plant tissues in the germplasm evaluation and it was found to be generally low.

Leucaena Germplasm Evaluation

A study was undertaken of leucaena germplasm found in the Caribbean region that was indigenous, naturalised and well-adapted. Also, at the same time leucaena germplasm from extra-regional sources or introduced into the region were obtained to undertake similar agronomic evaluation and to attempt to classify them phenetically, based on morphological and agronomic characteristics, such as leaf morphology and branching pattern, leaf yield, plant height, diameter breast height (DBH) and also the scoring of pest incidence, during the first two years (24 months) of establishment.

Germplasm collection visits were made to Jamaica, Antigua, St. Lucia, Barbados and Grenada and seed collected from individual plants (trees) in various parts of these countries. Similar collection was made here in Trinidad and Tobago. A total of 124 accessions were selected and identified for study of the collections, these were established at the University Field Station on a slightly acid (pH 6.0), fertile inceptisol belonging to the River Estate Loam soil series. The introduced leucaena germplasm were obtained from a wide range of extra-regional sources which included G.S.I.R.O. in Australia, the Waimanalo Station of the University of Hawaii and from C.I.A.T. in Colombia. A total of 18 accessions were selected for study representing three important leucaena species, namely, *L. leucocephala*, *L. diversifolia* and *L. shannoni* and one promising hybrid (*L. leucocephala* x *L. diversifolia*) from the introduced material. These were established at the University Field Station on the same site (Table 1). Both studies were undertaken simultaneously with a total of 142 accessions established in contiguous plots under natural climate conditions and given the same treatment. Since only small numbers of plants could be established it was necessary to use Cluster Analysis and Principal Component Analysis in order to classify the germplasm into phenetic groups (similar tuosphological and agronomic characteristics) and differences observed in the agronomic characteristics of the accessions where determined by univariate statistical methods. The research was conducted by Batson (1987). The overall results indicated that the *L. leucocephala* germplasm from the Caribbean region was classified into two broad phenetic groups namely, *L. leucocephala* var. *Leucocephala* or the Common type leucaena, and *L. leucocephala* var. *glabrata* or the Giant type leucaena. The Common type leucaena was typical of the region as a whole and more especially the countries from which the material came and covered 107 of the 124 accessions. Thus, this type constituted the larger of the two groups while the Giant type was observed to come almost exclusively from St. Lucia where there might have been a Giant type of leucaena introduced a considerable time ago which has now become naturalised and dominant. This Giant type was observed to be significantly taller, more vigorous and higher yielding than the Common type with higher CP content and DM digestibility (*in vitro*) and thus appears to have good potential for forage production.

Table 1
List of Organisational Taxonomic Units (OTU's) Species and Number of Plants Used in the *Leucaena* sp. Trial

OTU	Species	Accession No.	No. Plants
1	*L. Leucocephala*	K4	25
2	*L. Leucocephala*	K67	15
3	*L. Leucocephala*	CF95	8
4	*L. Leucocephala*	CIAT 17474	24
5	*L. Leucocephala*	CIAT 17476	19
6	*L. Leucocephala*	K6	26
7	*L. Leucocephala*	CIAT 17486	22
8	*L. Leucocephala*	CIAT 17475	10
9	*L. Leucocephala*	CIAT 17477	3
10	*L. diversifolia*	CIAT 17388	3
11	*Leuceana* sp.	CIAT 17478/1	1
12	*Leuceana* sp.	CIAT 17478/2	1
13	*Leuceana* sp.	CIAT 17478/3	1
14	*Leuceana* sp.	CIAT 17478/4	1
15	*Leuceana* sp.	CIAT 17478/5	1
16	*Leuceana* sp.	CIAT 17478/6	1
17	*Leuceana* sp.	CIAT 17478/7	1
18	*L. shannoni*	CIAT 17478	5

Source: Batson (1987)

With respect to the introduced leucaena germplasm three phenetic groups were observed with significant differences between them particularly in plant height, (DBH and number of lower branches. Overall, when compared with the indigenous leucaena germplasm the performance of the introduced accessions was generally superior; but some indigenous accessions particularly those from St. Lucia (with accessions numbers commencing with L) were promising and showed good potential not only for forage production but also for wood, fuelwood and erosion control and also for use as windbreaks (Table 2). It would now be necessary to select the most promising leucaena accessions for more specific investigation for particular uses or a combination of uses under field conditions. Seed of these promising accessions are available from the Department of Crop Science UWI.

Table 2
Summary Description and Recommended Usage of Selected Cultivars

Cultivar	Description	Recommended Use
K8	very vigorous, tall, woody, high yield	wood, windbreak, forage, green manure
Cunningham	vigorous, tall, leafy, high yielding highly branched	forage windbreak, erosion control, green manure
L142	vigorous, medium height, leafy, high yielding, low branching	forage, green manure, erosion control
B77	vigorous, medium height, leafy, high yielding, low branching	forage, green manure, erosion control
L173	vigorous, medium height, leafy, high yielding, fewer low branches	forage, green maure, stakes
L148	vigorous, short, leafy, high yielding	forage, green maure
L154	vigorous, short, leafy, high branched	forage, green maure
L141	very vigorous, tall, woody, few lower branches	wood, windbreak, erosion control
K67	very vigorous, tall, woody, high yielding, low branching	wood, windbreak, timber
K6	very vigorous, tall, woody, high yielding, low branching	wood, windbreak, erosion control, stakes
CF95	vigorous, medium height, leafy, high yielding, low branching	forage, green manure
CIAT 17475	vigorous, short, leafy, high yielding	forage, green manure
CIAT 17487	vigorous, tall, woody	wood, windbreak, stakes
L156	very vigorous, tall, woody, few lower branches	fuelwood, stakes, posts, windbreaks
L159	very vigorous, tall, woody, few lower branches	wood, windbreak, erosion control

Source: Batson, Ferguson, and Archibald (1987)

Leucaena Production and Utilisation Studies

The investigation of varying cutting/defoliation regimes for forage production from the *L. leucocephala* was undertaken at the Sugarcane Field Centre where feeding of leucaena forage in the dehydrated form as a major source of protein in sugarcane-based diets for mutton, beef and milk production was being developed. However, the SFC is located in an area with highly acid (pH 3.5 - 4.00), less fertile soils (Utisols) which have been treated with organic manure produced from the feedlot to raise their fertility. The type of leucaena cultivated on these soils was *L. leucocephala* var. *Cunningham* (CF 95).

The establishment of leucaena on these soils was very slow with much care being taken to minimise weed competition during the establishment period and the period of re-growth following defoliation or harvesting of the forage. A study was conducted by Garcia (1988) to investigate the establishment and harvesting regime for *L. leucocephala* (CF 95) at the SFC when allowed to grow for three or four months after planting followed by defoliation after one, two or three months. Models were proposed from the results of this study for year-round harvesting of forage. The results indicated that although a four month initial establishment period followed by a two or three month re-growth interval was optimal it might be important in order to obtain the highest production of forage DM and CP on a continuous basis to harvest first at three or four months after planting and to observe a re-growth period of only one or three months especially during the wet season (using the shorter re-growth interval). But, the total rainfall received was critical to maximising forage yield. The estimated maximum annual yield of forage CP was in the region of six tonnes/ha and the minimum could be as low as two month/ha. It was also observed that with increasing interval of re-growth the percentage leaf and percentage CP of the forage decreased while the percentage Neutral Detergent Fibre (NDF) increased.

A series of studies on the utilisation of dehydrated leucaena forage was also conducted. Young growing grade Holstein cattle and lactating grade Holstein dairy cows were fed diets in which leucaena was incorporated into sugarcane-based diets in order to supply dietary protein and to replace Soya Bean Meal (SBM) as the principal source of true or performed protein. Garcia (1988) undertook detailed studies on the nitrogen utilisation of Leucaena forage by growing dairy cattle given sugarcane-based diets, these included Nylon Bag and *in vitro* digestibility studies as well as growth trials; while Brown (1989 unpublished) undertook a full lactation study with Holstein dairy cows to compare the substitution of dehydrated leucaena forage for SBM in sugarcane-based diets for milk production. Work with sheep have also been done (Lallo, Neckles and Garcia, 1988).

The results of these animal utilisation studies have demonstrated that dehydrated leucaena forage can be efficiently utilised by young growing cattle and sheep for growth and by lactating dairy cows for milk production, and that the level of animal production though lower than when SBM was used is never the less highly satisfactory, especially when leucaena inclusion is optimised or blended into the formulation and is not the sole source of true protein. In all these studies Urea was used to provide a small part of the protein as Non-Protein-Nitrogen since Urea is available relatively cheaply for the fertilizer industry in Trinidad. The SFC also developed a cheap and efficient artifical dryer for dehydrating the leucaena which is to be incorporated into the animals' diets as a meal.

Some of the major findings of the work of Garcia (1988) and Brown (1986 unpublished) regarding the utilisation of dehydrated leucaena in sugarcane feeding regimes are:

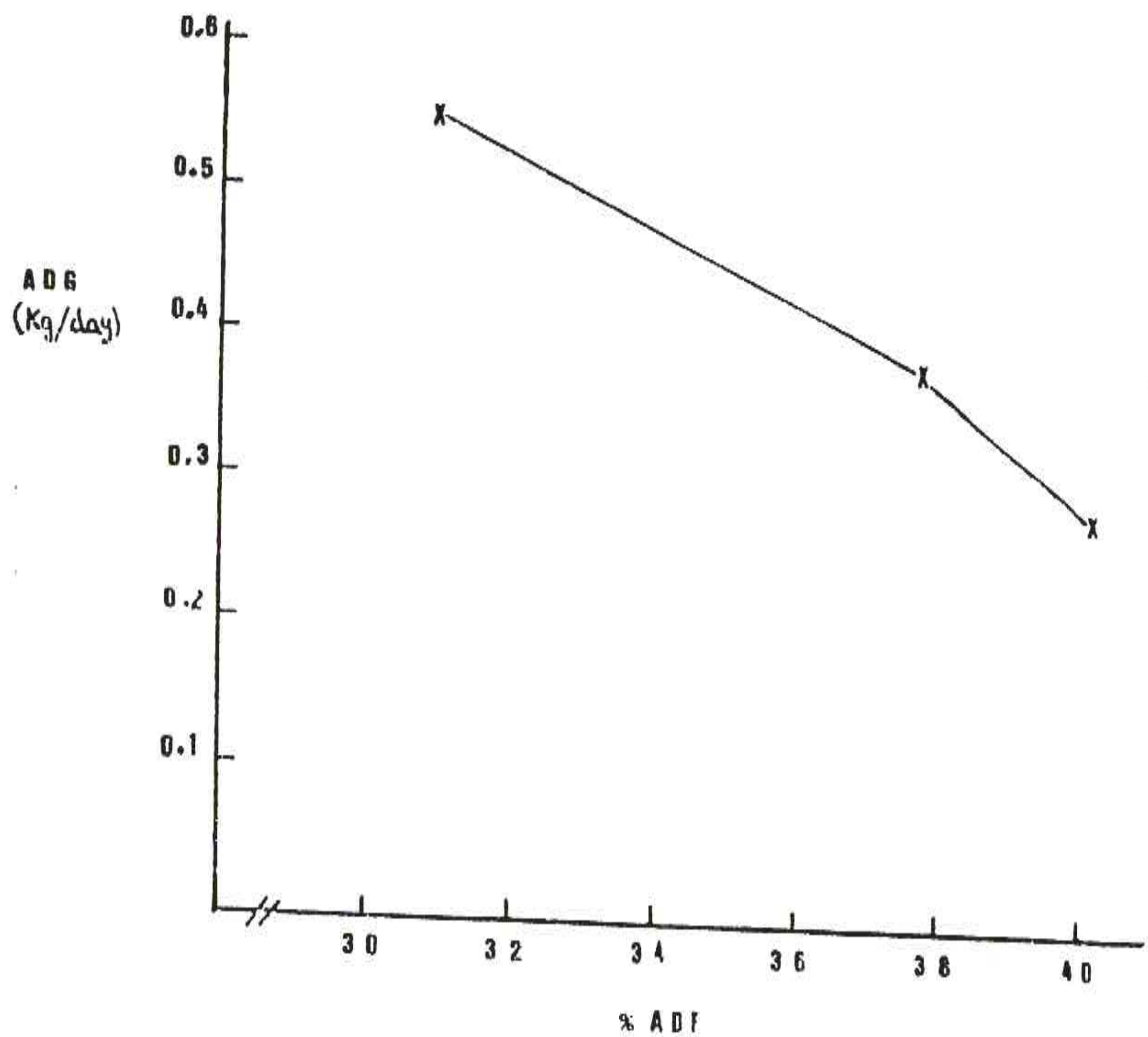
(i) the level of dietary fibre intake is critical to animal performance (affecting average daily gain [ADG], milk yield and app. digestibility adversely) and both sugarcane and leucaena are high in fibre [NDF or Acid Detergent Fibre (ADF)] thus an inverse relationship exists with animal performance (Figure 1);

(ii) higher levels of dietary fibre can be used at less productive stages but low fibre level are required during periods of rapid growth or in early lactation (high fibre, 30 to 40% ADF; low fibre 17 to 20% ADF);

(iii) Leucaena is a good source of by-pass protein to the ruminant animal and compares quite favourably with SBM in this respect; and

(iv) The level of dietary energy is important to animal performance on sugarcane-based diets and additional energy (corn rice bran or molasses) may need to be provided when the supply of dietary protein from leucaena is high.

It should be noted that the SFC has developed phase-feeding (or life cycle feeding) systems (Garcia, Neckles and Benn, 1982; Lallo, Neckles and Garcia, 1984) and the above findings should be fitted into this context.



Source: Garcia (1988)

Figure 1
The Relationship Between ADG (kg/d) and % ADF in Diet DM Intake

CONCLUSION

There is no doubt that a considerable store of information has been obtained from these studies on the research and development of leucaena carried out at the University Field Station and at the Sugarcane Fields Centre in Trinidad. Through the leucaena regional programme's network the general pool of information on leucaena in the region has been broadened considerably. However, it is now more important than ever before to direct attention towards promoting the development of economically viable systems or models for the production and utilisation of leucaena in the on-farm situation for the benefit of the producers and users in the various communities of the Caribbean.

The indigenous leucaena material has limited application in the region but can make a useful contribution to roadside grazing; while the exotic (introduced) leucaena cvs. and the St. Lucia Giants have considerable potential for contributing to increased regional production of forage, timber and fuelwood as well as green manure for systems of agroforestry (such as alley cropping).

Leucaena has the advantage over some of the other potentially useful fast-growing leguminous shrubs/trees, such as gliricidia, that it has been subjected to considerable efforts in research and development, thus superior cvs., accessions and ecotypes are presently available suitable for use in various systems of production (forage, wood and agroforestry systems or a combination of systems). Hughes (1988) has observed that *Gliricidra sepium* needs a considerable research and development effort if it is to be more widely used although it is a useful alternative to the fast-growing drought-tolerant leguminous shrub/tree *Leucaena leucocephala*.

With respect to further research required on leucaena in the region there is scope for additional investigation of Rhizobial requirements, and the need for initiation of work on innoculation with vesicular - arbuscular mycorrhiza (VAM) and the relationship with phosphate fertilisation to promote more efficient growth and development of leucaena plants as recent work in the Yucatan region of Mexico by Guzwan-Plazole, Feriera-Cerrato and Etchevers (1988) has reported positive results from these applications on acid soils.

It is hoped that this conference will result in the meaningful exchange of information that such an international forum can achieve and that it will provide the stimulus to more forward with the more practical implementation of the major findings.

ACKNOWLEDGEMENTS

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Soils and Conservation

Leucaena, A Strategy in Pasture Development in Tropical Ultisols

S.M. Griffith and M.C. Imamshah

INTRODUCTION

The inherent limiting factors of soil fertility in tropical Ultisols have been recognized as aluminium toxicity, water stress through short-lived droughts in the rainy season, low levels of available phosphorus and a general deficiency of most nutrients. Physically, these soils are susceptible to erosion losses and compaction of machinery. These problems can be solved agronomically but management strategies involve the cost and availability of fertilizers and lime, appropriate systems of irrigation (water quality etc.), with accompanying distribution and transportation costs. In such a setting, it becomes necessary to intensify production so that operations can be economically feasible. There are many tropical areas where fertilizer use is impractical or to expensive. It may be possible to include nitrogen-fixing legumes e.g. *lLucaena* spp., into the system of management. In addition to providing protein to the diet of animals, natural leaf-fall from harvested bushes and nitrogenous compounds from fixation processes may improve soil productivity, without the concomitant disadvantages of inorganic fertilizer use.

It has often been reported that unaided, *Leucaena* spp. grow well only in neutral or alkaline soils and poorly on acid soils, particularly where these soils are high in aluminium and often are molybdenum and zinc deficient (N.A.S., 1977). Exceptional yields on highly acidic soils occurred with the aid of rock phosphorus and calcium ameliorants (Brewbaker, Plucknett and Gonzalez, 1972). Recently, lines of some Leucaena species have exhibited variants with potentially high acid tolerance (Hutton, 1981, 1982) and uninhibited by aluminium in solution and in acid soil (Del Rosario and Salapare, 1980). Such variants may be useful in the fertility management strategy on Ultisols. In acid tropical soils, imbalance of exchangeable Al and Ca have been shown to inhibit Ca^{2+} uptake and require increased Ca^{2+} for root growth and productivity in Cunningham Leucaena. It was also stated that the carrier gypsum ($CaSO_4$) provided better Ca-ameliorants Ca-fertilizer carriers (Hutton and de Souza, 1986). This underscores the importance of an alternative strategy to the addition Ca-ameroliants to improve Ca-availability even when Al is at high concentrations, could possibly be the reduction of available Al to the extent that Ca becomes increasingly available.

In highly organic acidic soils of the Caribbean, previous research has indicated that inorganics interacting with colloidal organic matter contain large quantities of Al associated with organic-C and organic-N (Griffith, Holder and Munro, 1984; Griffith, Sowden and Schnitzer, 1976). Such interactions can reduce Al-availability in the plant/soil system and provide for an increasing availability of other ions to crops. Experiments were conducted to assess Leucaena as a strategy in the improvement of Piarco series and Las Lomas intergrade (acid Ultisols) used in pasture and arable crop development.

Material and Methods

Experimental Design

Seven pits were dug on selected sites in seven plot areas (Figure 1). Five horizons of similar depth intervals (0-15 cm, 15-30 cm, 30-45 cm, 45-60cm and 60-90 cm) were sampled at opposite faces of each pit. Similar samples at the depth of each horizon were combined, so that samples at five depths were provided for each pit. Samples were taken close to the Leucaena roots in each pit.

Plots were grouped according to the time during which Leucaena (variety CF 95) was continuously grown. A brief cultivation history of these plots is shown in Tables 1-3. Three major groups were obtained, A and B (two years continuous Leucaena) C, D and E (six years continuous Leucaena Var CF 95) and F and G (ten years continuous Leucaena (Figure 1). From this the analyses on soil samples, the effects of soil management practices on soil properties were assessed.

Analytical Methods

Organic-C was determined according to the method of Walkley-Balck (1934) and Total-N was assessed by the Kjeldahl method as outlined by Bremner (1965). The pH value of soil was determined by a glass electrode pH meter at a ratio of 1:2.5, soil:water (Hesse, 1971). Al and Ca determinations were carried out on a Perkin Elmer 460 Atomic Absorption Spectrophotometer; following extraction with 1.0 M KCI at a soil: solution ratio of 1:10 and centrifugation to remove extractable cations (Mc Clean, 1965).

Table 1
Site Location, Soil Taxonomy and Cultivation History of Two Year Old Leucaena Plots

Plots with Leucaena Cultivation (Years)	Site Location and Soil Taxonomy	Year	Cultivation Practice	Soil Amendments
2	A (N.W. Pokhor Road) Ultisols: Aquoxic Tropudults (Piarco Series dominant)	1975—1977 1977 1987 1989	Shifting Cultivation Ploughing and Fallowed Ploughed, Mixed Crops (corn/leucaena) Leucaena	
2	B (N. Central near ravine) Ultisols: Aquoxic Tropudults (Piarco series dominant)	1975—1977 1977—1979 1979—1985 1985—1986 1986—1988 1989	Shifting Cultivation Cleared and Fallowed Sugarcane Fallowed Leucaena Leucaena	Fertilizer (15:5:10) at planting liquid manure during cultivation

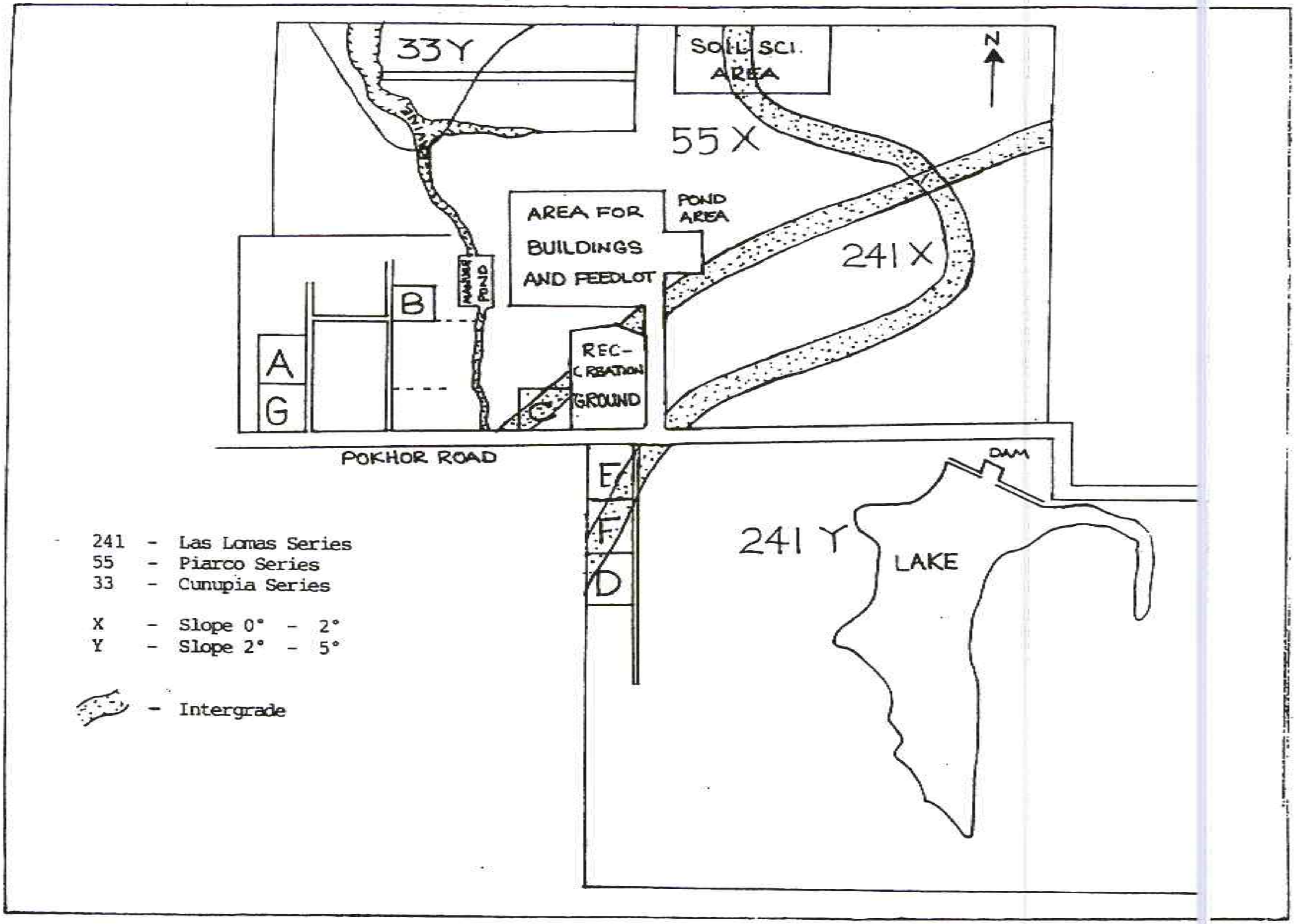
Table 2
Site Location, Soil Taxonomy and Cultivation History of Six Year Old Leucaena Plots

Plots with Leucaena Cultivation (Years)	Site Location and Soil Taxonomy	Year	Cultivation Practice	Soil Amendments
6	C (N. Central adjacent to playfield) Ultisols: Piarco/Las Lomas series intergrade	1975—1977 1977—1980 1980—1982 1982 1985 1989	Shifting Cultivation Ploughing and Fallowed Cleared & Fallowed (major earthworks) Leucaena planted Leucaena Leucaena	 Quarry dust, 2000 kg/ha; 33% Ca
6	D (S. Pokhor Road 3rd Plot) Ultisols: Las Lomas/Piarco series intergrade	1975—2977 1988—1982 1989	Shifting Cultivation Ploughed, harrowed, ridged beds 3 ft apart. Leucaena planted Leucaena	
6	E (S. Pokhor Road, adjacent to road) Ultisols: Las Lomas/Piarco series intergrade	1977 1981—1982 1989	Shifting Cultivation Ploughed, harrowed, ridged beds 3 ft. apart. Leucaena planted Leucaena	Fertilizer (11:11:11) at planting and 3 months later (Residual cane trash)

Table 3
Site Location, Soil Taxonomy and Cultivation History of Ten Year Old Leucaena Plots

Plots with Leucaena Cultivation (Years)	Site Location and Soil Taxonomy	Year	Cultivation Practice	Soil Amendments
10	F (S. Pokhor Road, 2nd Plot) Ultisols: Las Lomas/Piarco series: Intergrade	1975—1977	Shifting Cultivation	
		1978	Ploughed, harrowed banked 5 ft apart. Leucaena/Macropitilium sp. (CIAT 535 planted)	33% Ca, Quarry dust, 2,000 kg/ha Fertilizer (11:11:11) at planting and 4 months later
		1982	Leucaena/Macroptilium	Quarry dust, 33% Ca, (2000 kg/ha)
		1989	Leucaena/Macroptilium	
10	G (N. Road, adjacent to road) Ultisols: Aquoxic Tropudults (Piarco series dominant)	1975—1977	Shifting Cultivation	
		1978	Ploughed, harrowed banked 5 ft apart	33% Ca, Quarry dust, 2,000 kg/ha Fertilizer (11:11:11) at planting and 4 months later
		1982	Leucaena	
		1989	Leucaena	Quarry dust, 33% Ca, (2000 kg/ha) some years later

FIG. 1: Layout of the Sugarcane Feed Centre showing location of sites A-G, soil series and slopes.
(Source: Ahmad and Gumbs, 1978)



DISCUSSION OF RESULTS

Preliminary work in the establishment of Leucaena on the soils indicated that the soils remained acid over a thirteen week period. $CaCO_3$ was applied at rates of 1,500 to 3,000 kg/ha at establishment, but at these rates there was no significant response with respect to changes in soil reaction. Over the period, (table 4) soil pH values ranged between 3.7 to 4.1 in the 0-15 cm depth and the 15-30 cm depth of soil in the control treatments. In the plots treated with $CaCO_3$, pH values ranged between 3.9 to 4.3 (at 1,500 kg/ha) in the 0-15 cm depth and was within a similar range at the pa 15-30 cm depth. At an application rate of 3,000 kg/ha, soil pH values ranged between 4.0 to 4.6 at the 0-15 cm depth and between 4.0 to 4.3 at the 15-30 cm depth. Even in the treated soils establishment was difficult an dearly growth was slow.

During ten years of soil management under Leucaena growth, equilibrium changes in soil reaction occurred such that soil pH values ranged between 4.0 to 4.9 (at two years), 4.6 to 5.8 (at six years) and 5.1 to 6.1 (at ten years) in the 0-15 cm layer. This trend was consistent at depths of 15-30 cm, 30-45 cm and 45-60 cm on the Ultisols (table 4).

Extractable—Al and extractable-Ca concentrations (cmol/kg) were inversely related at all the sites (table 5). At sites C to G in which leucaena was established and consistently grown for more than two years, the concentration of extractable-Al was generally significantly less than 0.1 cmol/kg. This was particularly so at levels up to 45 cm in soil depth.

At these sites, except for site C, extractable-Ca concentrations were adequate, ranging from 10.5 cmol/kg at lower soil depths to 26.0 cmol/kg at higher soil depths. Management history at site C indicated previous root-crop production, harvesting and major earthworks. This indicated the possibility of sub-soil intervention in the upper soil layers. The consistent removal of Ca^{2+} and high concentrations of Al are therefore possible at this site. At site B, under a two year growth of leucaena, where there was recent soil modification, higher concentrations of extractable-Al are evident (table 5) in the upper soil horizons and extractable-Ca levels are adequate.

All the sites, except site C, provided adequate levels of organic-C, ranging from 1.7 to 3.2% in the 0-15 cm depth. These levels were maintained throughout the years as indicated at sites D to G. The levels of organic-C were inversely related to concentration of extractable-Al and showed a direct relationship to extractable-Ca concentrations. Adequate levels of total-N are also presented up to 30 cm soil depth at all sites, except sit C. It is apparent therefore that sites with adequate organic-matter may be undertaking the immobilization of extractable-Al in soluble or insoluble organic-complexes. This mechanism requires a supply of suitable complexing agents and depositional sites which may possibly be served by the degradation of leucaena.

Table 4
Changes in Mean Soil pH Values Over Time, Depth, $CaCO_3$ Applications and Leucaena Management on Tropical Ultisols

Soil Depth (cm)	Age of Leucaena (Years)																	
	0			0			0			2			6			10		
	Control			1500 kg/ha (lime)			3000 kg/ha (lime)			–			Mixed			Quarry dust 33% Ca: 2 x 103 kg/ha		
0 - 15	3.7*	3.9	4.1	3.9	4.1	4.3	4.0	4.3	4.6	4.0	4.5	4.9	4.6	5.1	5.8	5.1	5.6	6.
15 - 30	3.7	3.9	4.1	3.9	4.1	4.3	4.0	4.1	4.3	4.8	4.5	4.2	4.6	4.9	5.4	5.0	5.1	5.
30 - 45		–			–			–		4.5	4.6	4.7	4.6	4.7	5.4	4.7	4.9	5.
45 - 60		–			–			–		4.4	4.5	4.6	4.2	4.6	4.8	4.8	4.7	4.
60 - 90		–			–			–		4.1	4.3	4.4	4.2	4.4	4.8	4.2	4.3	4.

– Not Determined
* Ranges of Measures

Table 5
KCl Extractable-Al and -Ca, % Organic-C and Total-N at Sites Under Two Years, Six Years and Ten Years Management with Continuous Leucaena.

Depth (cm)	2 Years								6 Years												10 Years							
	Site A				Site B				Site C				Side D				Site E				Site F				Site G			
	cmol/kg		%		cmol/kg		%		cmol/kg		%		cmol/kg		%		cmol/kg		%		cmol/kg		%		cmol/kg		%	
	Al	Ca	C	N	Al	Ca	C	N	Al	Ca	C	N	Al	Ca	C	N	Al	Ca	C	N	Al	Ca	C	N	Al	Ca	C	N
0 – 15	0.01	17.50	2.5	0.8	0.19	17.50	3.2	0.7	0.00	6.50	0.5	0.3	0.02	22.80	1.7	0.5	0.01	24.50	2.3	0.6	0.00	23.00	2.7	0.8	0.00	22.50	2.7	0.8
15 – 30	0.03	8.80	1.0	0.7	0.17	11.50	3.0	0.7	0.07	5.50	0.4	0.2	0.02	21.80	1.6	0.4	0.02	22.50	1.3	0.5	0.00	23.00	1.1	0.5	0.00	26.00	1.1	0.6
30 – 45	0.09	5.30	0.7	0.3	0.20	8.80	2.1	0.6	0.18	1010	0.2	0.1	0.07	10.30	1.5	0.3	0.15	12.20	1.2	0.4	0.00	16.80	0.5	0.2	0.05	15.80	0.5	0.3
45 – 60	0.27	0.70	0.6	0.3	0.23	1.30	0.7	0.3	0.26	0.60	0.2	0.1	0.09	0.07	1.4	0.3	0.17	10.80	1.1	0.3	0.30	10.00	0.4	0.2	0.14	5.80	0.4	0.3
60 – 90	0.84	0.00	0.6	0.4	0.65	0.00	0.5	0.3	0.43	0.00	0.2	0.1	0.18	1.40	0.8	0.3	0.22	8.00	0.6	0.2	0.26	2.00	0.3	0.1	0.80	4.00	0.3	0.3

CONCLUSION

There has been an increase in soil pH over a continuous period of ten years, with the growth of leucaena. As a strategy in the management of tropical Ultisols (Piarco series and Las Lomas/Piarco intergrade) for pasture and arable crop development, the use of Leucaena var CF 95 is strongly supported.

Concentrations of extractable-Al have been considerably reduced in the six to ten years period of soil management. Concentrations of extractable-Ca have improved as well as levels of organic-C. Levels of total-N have been maintained. It is suggested that the immobilization of extractable-Al by soluble and/or insoluble organic complexes formed through Leucaena degradation is possible mechanism for extractable-Al reduction.

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The Use of Leucaena to Control Erosion

R. T. Paterson

INTRODUCTION

Soil erosion is a potential hazard in many parts of the world, but it generally only becomes a serious practical problem where unsuitable methods of land-use are employed, or where poor land management becomes a factor. The loss of small amounts of top-soil each year can be considered normal under almost all forms of land use, but when excessive losses occur, they must be considered to be irreversible, since soil formation is a process which takes place in a geological, rather than a human time frame.

Those climax vegetation complexes which maintain a complete vegetative cover over the soil (forest, woodland, savannah) allow very little soil loss through the processes of erosion, but where man intervenes to grow crops or to graze animals, problems of inappropriate methodology or mis-management frequently occur, with serious consequences. The aim must be to prevent excessive erosion through good land husbandy.

LEVELS OF EROSION

Estimates of the soil losses due to erosion vary according to soil type, slope, land use and management, total and distribution of rainfall, etc. Some typical figures are presented in Table 1.

While these figures over a large range of lasses, the erosion under complete, well managed pasture cover is consistently and considerably less than the losses under annual crops or bare soil. Crops such as maize, which are grown on a wide spacing, result in greater losses than wheat which gives a more complete soil cover by virtue of the narrower inter-row width. At a bulk density of 1.0 g/cc, the loss of 100 t/ha represents the removal of an average of 1 cm of topsoil every year. The effect of soil loss on crop yield can be enormous. Lal, Kang, Moorman, Juo and Mooman (1975) showed reductions in maize yields of 50% and 90% on the removal of the surface 2.5 and 7.5 cm respectively, on an Alfisol in Nigeria, because of poor root penetration into the clayey, gravelly sub-soil.

Table 1
Annual Soil Losses by Erosion (t/ha) Under Differing Management

Country	Rainfall (mm)	Slope %	Soil (t/ha/year) Bare soil	Annual crop	Pasture	Forest	Reference
Temperate							
USA (Ohio)	965	12	–	241.4	0.05	–	USA, 1945, cited by Russell, 1961
Tropical							
Colombia	2775	22	225.4	–	7.1	–	Sanchez, 1976
Ivory Coast	–	–	108 - 170	0.1 - 90	–	0.03	Charreau, 1972
Senegal	–	–	21	7.3	–	0.2	Charreau, 1972
Costa Rica	–	Steep	–	27	1.5	–	Vicente - Chandler *et al*, 1974

THE EROSION PROCESS

It is generally accepted (e.g. Russell, 1961) that soil particles can move by three distinct process, they can be blown away by wind, washed away by water, or soil may slide or slump down a hill-side. Erosion creates problems, not only by the loss of the most fertile soil fractions from the erosion site, but also by their deposition at the receival site, since there they can smother crops and silt up water-ways. What is often seen as a local problem then assumes national, or even regional importance.

Wind Erosion

Winds move soil in three ways depending upon the particle size. The smallest fractions are carried over large distance in the air as dust, while the largest particles are rolled along the soil surface. The fractions of intermediate size move by saltation. In this process, an eddy of wind at the soil surface picks up a grain of sand, carrying it for a few centimetres, and imparting to it considerable momentum, before allowing ti to fall back to the surface. On impact, it may cause other grains to fly into the air. These in turn can dislodge others in a classical chain-reaction. The soil must be dry in order for wind erosion to take place, and unobstructed runs of at least 50 m are necessary to build up a large body of moving soil. Fine sands and calcareaous clays are most susceptible to blowing through the Caribbean region, the undulating topography tends to lessen the importance of wind erosion, even in the drier countries.

Water Erosion

Water is generally the most serious erosion agent in most parts of the world. When the rate of rainfall exceeds the rate of water infiltration into soil, run-off occurs. During heavy tropical down-pours, not only is the rate of rainfall very high, but the physical battering effect of the large raindrops can break down soil aggregates, blocking up the pores in the soil and reducing the water infiltration rate almost to zero, even when the soil close to the surface is still dry and porous. In this situation, almost all of the rain will run off the land. Erosion will therefore be reduced by measures when help to maintain the porosity of the surface soil by protecting it from the battering and splash effect of heavy rains.

Once the water starts to run off the land, its erosive power will depend upon the velocity of flow and, to a lesser extent, stock trails are particularly dangerous, since they can form temporary, unobstructed water courses in times of heavy rain. They can lead to the formation of deep gulleys, since rapidly moving water can remove all soil fractions, including stones.

Land Slips

When steeply sloping soil becomes saturated, it can slump down the hillside in sheet. Shallow soils, formed over relatively unweathered rock or an impermeable sub-soil are prone to this problem, particularly where they carry a shallow-rooted vegetation which is incapable of binding the soil together. Over-grazing can aggravate the problem, since apart from the trampling effect of the animal, severe defoliation is known to reduce both root growth and root mass of pasture plants (Davidson, 1978).

CHARACTERISTICS OF LEUCAENA

The general characteristics of *Leucaena leucocephala* have been described by many authors (e.g. NAS, 1977) and have been recently summarized by Proverbs (1985). Those which influence its ability to control erosion are discussed below.

Leucaena will grown and persist for many years on a wide range of soil types ranging from moderately acid to highly alkaline, being highly productive in soils which range from light sands to heavy clays. It shows tolerance to moderate levels of soil salinity. It will grow on as little as 600 mm annual rainfall, and in well-drained soils, it will tolerate up to 2,300 mm. Best production is obtained at altitudes below 500 m, but it will grow at heights of 1,000 m or more. Both light frosts and the passage of a fast-moving grass fire will cause the leaves to fall, but once conditions improve, it will produce abundant new growth, often from buds situated below ground level. It is not well adapted to either water-logged or highly acid soils, but its tolerance of a wide range of edaphic and climatic conditions allows its use in many tropical and sub-tropical conditions.

Depending on the variety, Leucaena is either a large shrub or a small tree. It has a deep tap-root system which commonly penetrates the soil to a depth equivalent to, or greater than the height of the foilage. It has the ability to penetrate deeply, even into relatively impermeable soil. This, together with the formation of strong lateral roots, has the effect of binding the soil together to prevent slippage. The deep root system improves the infiltration of water into the lower soil horizons.

Leucaena is a legume which is capable of fixing large quantities of nitrogen. Usual estimates are about 500 kg per ha per year, but Whitney (1975) quotes a figure of 905 kg per ha in Hawaii. It will absorb minerals from the lower soil strata. Also it is capable of improving both the physical structure and the chemical fertility of the soil. This can lead to better growth of a shade-tolerant under-storey (e.g. Guinea grass). The double layer of foliar cover provided by both the improved soil structure will increase the infiltration of water into the soil and the presence of a vigorous grass below the trees will slow the run-off of water. These factors will all tend to reduce the danger of soil erosion.

The giant, Salvador type Leucaena varieties are trees which grow to heights of about 20 m. It is not uncommon in Antigua for them to reach half of this height in three years. Since they grown well on both light, sandy soils and on calcareous clays, they are ideally suited to the formation of wind-breaks to shelter delicate crops and to prevent wind erosion. Russell (1961) indicates that shelter-belts and wind-breaks will moderate surface wind speeds for distance of up to five times the height on the windward, and 20 to 30 times the height on the leeward side. Under Caribbean conditions, giant leucaena strips, planted at intervals of about 100 m, running across the direction of the prevailing winds, would provide a high level of protection from wind erosion.

Leucaena therefore has several characteristics which make it an ideal plant for sowing to control soil erosion, whether by wind, water or land slippage.

MANAGEMENT OF LEUCAENA

Attention has been drawn in recent years to the use of Leucaena in animal production (e.g. Hill, 1971). Clearly, to a greater or lesser extent, defoliation of the legume by animals would be antagonistic to its use for the control of erosion, since the presence of the foliage is necessary to protect the soil from heavy rain and from wind.

In soil with little or not risk of erosion by virtue of good permeability to water and lack of slope, the plant cover can be managed in any way conducive to the sustained production of high yields of forage. As the risk of erosion increases, the utilization of the legume must become lenient, so that it can also play a part in soil stabilization. In this regard, its management as a protein reserve or bank, for use only in the dry season, will assure both the exclusion of livestock and the presence of a good foliar cover during the critical period of maximum rainfall at the height of the wet season. On steeply sloping land which is particularly prone to erosion, and on which the role of Leucaena is mainly to prevent soil movement, utilization of the plant for other purposes should be minimal, at least in the first few years. Once the stand is mature, a proportion of the trees could be cut each year to allow them to coppice. The foliage from the cut trees could then be used as animal feed and the timber as posts, firewood or for the making of charcoal.

EXAMPLES OF EROSION CONTROL WITH LEUCAENA

While much has been written about Leucaena, and may texts mention its role in erosion control, well documented studies are hard to find. Nevertheless, the following examples serve to illustrate the effectiveness of the species in this role.

The missionary work of H.R. Watson and his colleagues on the island of Mindanao in the Philippines has been recently documented by Ravenholt (1985). More than 60% of the farmers in the country work steep, easily eroded hillsides. The traditional land use in these areas was swidden (slash-and-burn) agriculture, but as population pressure has increased sharply during the present century, the periods of fallow between cropping cycles has decreased. Falling soil fertility and increases erosion have resulted from the increased pressure on the ecosystem. Amongst other attempts to help the upland farmers, conventional terracing was tried, but proved to be too costly and demanding in terms of construction and maintenance, and the soil was too poor to produce good crops without the use of expensive fertilizers. Leucaena has been successfully used to form natural terraces in the following system.

1. Leucaena seed is sown into a ploughed area 1 m wide, in two continuous rows, 50 cm apart along the contours. In general, 4 m is left between the hedges, although this distance is decreased on the steepest slopes.

2. Alternate strips between the hedges are cultivated initially, until the Leucaena is well established. Permanent crops (bananas, coffee, fruit trees) are sown in some strips, annual leguminous crops (beans, peanuts) in others.

3. Once the Leucaena is well established, the remaining strips are ploughed and sown to annual legumes. Non-legumes (maize, sweet potatoes, pineapples) follow the legumes in the rotation. The Leucaena is trimmed about ten times per year, the leaves and twigs being used as a mulch and fertilizer for the crops.

4. The terraces are reinforced by piling stalks, branches and stones at the base of the Leucaena hedges. Weed and pest control measures are applied to both hedges and the cropped areas.

With this system, one hectare of upland has generated sufficient income to provide the basic needs of a family of seven. Maize yields of 2,500 kg per ha of shelled grain per crop (7,000 kg per ha per year) have been achieved on one plot for almost three years, a yield of from three to five times the production of typical upland farms. For more acid soils, other legumious trees, including *Gliricidia sepium*, *Albizzia falcataria*, *Calliandra callothyrsus* and *Sesbania* spp. are being tested as alternatives to the Leucaena.

Closer to home, in Barbados, on a soil prone to slippage at Springhead Estate, Leucaena seedlings are planted in an attempt to stabalize the steep slopes. The results are briefly summarized by CARDI (1985), while details have been supplied by Proverbs (pers. comm.). Sowing took place at the start of the 1984 wet season. Giant K8 leucaena was established both from seed and from seedlings. The seed, scarified in hot water to ensure germination in excess of 80%, was sown in rows about 1.20 m apart, while the seedlings were planted on a grid at 1.0 m spacing. All plants were protected from weed competition in the early stages, but volunteer Guinea grass was allowed to grow where it was not too close to the developing seedlings. Vegetative material of the same local Guinea grass was planted between the legumes where the population was considered to be inadequate. Establishment tool place in a relatively dry year, but the legumes grew well, reaching a height of some 2 m in the first year. Stock were not permitted to enter the area. When the legumes were about 15 months old, 450 mm of rain fell in a two day period (760 mm in about ten days) onto soil that was already moist as a result of lighter rains in the preceeding two months. Land slippage on similar, neighbouring, unprotected sloped were severe, several stretches of up to 30 or 40 m in length slumping into the valley below. The slope that was protected by the Leucaena showed some surface soil loss as a result of an incomplete grass cover close to the soil, but no slipping was experienced. In the second wet season after establishment, 450 m of rain fell in about a week. Some slippage was again observed on neighbouring slopes. But the protected area remained stable. The Guinea grass cover had improved in the intervening period and little surface erosion took place. Although no sample cuts were taken, the grass was obviously more productive under the Leucaena cover than in adjacent areas without the benefit of legume.

CONCLUSION

Leucaena has a wide range of adaptation, being a fast-growing shrub or small tree which lives for many years. It produces a spreading canopy and its deep, extensive root system will recycle nutrients from considerable depths. It is a legume with the ability to fix large amounts of nitrogen and to improve soil structure. All of these characteristics make it an obvious candidate for a role in the control of erosion, particularly in high-risk areas. It's suitability for this purpose has been demonstrated in several countries and scope exists to extend its use in the Caribbean region.

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The Growth and Biomass Production of *Leucaena leucocephala* in Haiti

C. A. Beliard

INTRODUCTION

During the last decades, the forest resources of Haiti have been seriously damaged. Great forest areas have been destroyed by shifting agriculture. Wood represents about 72% of the fuel consumption on the country. Almost 95% of the wood used in the country is for fuel, and the demand will have an annual growth of 6% according to expectations. Many reasons could be used to explain the degradation of the forest; a heavy human pressure on the land and the forests, scarcity of low sloped lands and lack of appropriate technology for the natural resource management in the mountain and the plains are but a few. The results of forest destruction are well known. Therefore replanting of the deforested areas must be tackled urgently in order to provide the forest products, especially the fuel resources which are needed.

During the last years, emphasis has been put on multipurposes tree species and appropriate technology in order to maximise the wood production and meet the ever-growing forest product demand, and reduce the destruction of the natural resources. As a result, some studies have been done to evaluate the yield of different species in various sites of the country. Among those species, *Leucaena leucocephala* stood out for its fast growth, easiness of coppicing, good fuelwood, wood and fodder production as well as soil protection ability, and its great adaptability. Although the species was introduced in Haiti in 1974-1975 by Michael D. Benge with the giant varieties; there was, at this time, a wild variety regarded as one of the most hard-to-eliminate weeds. The first formal plantations were established by USAID and shortly it was introduced in borderline plantation (roads and farms) by USAID through the PVO (Private Voluntary Organization) and the "Ministére de l"Agriculture" through the "Project Forestier National" financed by the World Bank and the International Development Research Center. Various plots were established in different areas with many objectives. This paper will try to present the evaluations of the growth and the yield of *Leucaena leucocephala* in most of the trials established in Haiti.

SITE DESCRIPTION

Site One

Many studies were conducted by the Madsen tree farm. This site is located 14 Km. North of Port-au-Prince on land formerly planted in sugar cane or naturally regenerated with *Prosopis juliflora* and Acacia spp. The 45 hectare site was planted in the spring and fall of 1981 with several fast-growing hardwood species. The selected tree species and their approximate coverage are as follows: Leucaena (31 Ha), *Azadirachta Indica* (8 Ha),

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Eucalyptus spp., and various other exotics including *Cassia siamea, Casuarina* spp., *Sesbania grandiflora, Gmelina Arborea*, and *Acacia auriculiformis* (4 Ha).

The site characteristics are typical of the flat, agricultural land of the Cul-de-Sac plain. The area receives an annual rainfall of 1100 mm that falls for the most part in two pronounced intervals during the year: May-June and September-November periods. Daily temperature ranges do not fluctuate greatly throughout the year, averaging a maximum mean in July (34.8° Celsius) and a minimum typically basic with the pH ranging from 7.2 to 10.0. A moderately high organic carbon content (4-6%) in the upper 15 cm of the soil profile make the Madsen site relatively fertile for short-rotation forestry. The growth is limited by adverse site conditions such as the poor drainage due to alkanization, salinity, and clay hard-pans at varying depths (0.5-1.0 m).

Site Two

The second site is a hillside plantation near Camp Perrin, North of Les Cayes in the Southern Peninsula of Haiti. The plantation was established in 1980 on a hillside (57% slope) previously utilized for farming and grazing. The soil is 10-15 cm deep under the tree canopy, dark brown, clayish with little humus formation and pH ranging between eight and nine, on limestone parent material. Average annual precipitation in this area ranges from 1800 to 2320 mm. The area is included in the humid sub-tropical forest of the Holdridge (1963) classification and is located at 150 m above sea level (a.s.l.).

Site Three

The third site is located 38 km North of Port-au-Prince, in one of communal sections of Cabaret. The plantation was established in 1983. The area is included in the dry sub-tropical forest of the Holdridge (1963) classification. There, the rainfall does not exceed 800-900 mm annually, with two rainy seasons: April-May and September-October, a long-drought period from December through March and a less rigourous one from June to October. It is located at 80 m above sea level (a.s.l.), with xerophytic plant cover including Cactacea, Prosopis and Acacia with annual agricultural cultivation and grazing.

Soils are alluvial calcareous, with pH more than 6.7. There is variation in the slope (1-12%) and a rapid interior drainage due to the soil structure. It is 50-150 cm deep.

Survival

In general, the survival of the plants at sites #1 and #2 was very good. Even after three years of establishment, the plantations of *Leucaena Leucocephala* had over 90% plant survival. But in some plots in the third site, the survival was 80%. The reduction of the survivance in the site three can be explained by rainfall scarcity poor soil conditions.

Height and Diameter Measurements

At the first two sites, the average height was 12 m and the average diameter was 8 cm after three years. The annual average increment was over 4 cm in height and 3 cm in diameter.

In the site three, several varieties were tried: K 8, K 29, K 67, K 156, K 28. The first three ones had an annual average height increment of about one meter in spite of the bad conditions of the site. Those results were similar to those of other countries. For example, in Jamaica, the annual height increment is 3.4 cm for K 8 and 32 cm for K 67 for the three years old trees. In other countries of Central America the average height was 3 m for K 29 and 5.8 cm for K 67, but with better soil and weather conditions than at site three.

FUELWOOD AND BIOMASS PRODUCTION

A three-year old *Leucaena leucocephala* stand was harvested at the site one (The Madsen tree farm) in June, 1984. Yield was analysed both in terms of dry weight and saleable volume. The site exhibited a mean annual productivity rate of 14.9 metric tonnes dry matter/Ha/Year and yielded 45.89 mt/ha of above ground biomass. Two-thirds of the yield was considered saleable as either poles or fuelwood, equivalent to 30.42 mt/ha and 50.74 m^3/ha respectively. Non-saleable biomass, defined previously as all dead wood, branches $\leq$1.5 cm basal diameter, twigs, leaves and fruiting bodies, represents one-third of the total Leucaena tree biomass. The correlation between saleable biomass per tree and DBH is excellent (r^2=0.951) (Timyan 1984). An experiment established at the site one to study the response of a stand of *Leucaena leucocephala* to fertilizer treatments. The data was collected during the following ten month period. No significant differences were detected between treatments means for basal area and saleable wood volume growth at the (0.05 significance test).

The fuelwood production potential of *Leucaena leucocephala* K8 was estimated on the site two (a hillside with 57% slope) in a five years old plantation. Plantation density is approximately 800 trees/ha with spacing ranging from 2.5 meters to 4.5 meters. On the lower part of the plantation where the hillside meets the plain, the growth of trees was clearly better than on the higher part of the plot. A sample of trees from this plantation was cut at 10 cm from the ground. Ground diameter, stump diameter (at 10 cm) DBH and total height were measured for each tree in the sample. Weights of poles, branches of more than 2 cm in diameter (fuelwood) and leaves and smaller branches were weighed separately. Samples from each section of the tree were collected for laboratory analysis to determine moisture content and specific gravity. Statistical analyses of field data revealed high positive correlations between DBH (diameter at 130 cm) or stump diameter (at 10 cm) and fuelwood, total biomass and saleable volume production. Figure 1 Nevertheless, approximately 56% of all saleable wood volume was cut into poles with an average length of 8.2 cm charcoal wood constituted about 39% of the total saleable volume, while the remaining 5% was cut into logs (saw-timber). The fuelwood production and the total biomass are estimated in tables 1, 2 and 3. Laboratory analysis of the tree samples revealed a moisture content of the saleable section of the trees of 44% and a specific gravity of 0.59 gr/mm^3. The remaining biomass, mainly small branches, twigs and leaves contained 69 gr of water for every 100 gr of green biomass (Erlich, 1985).

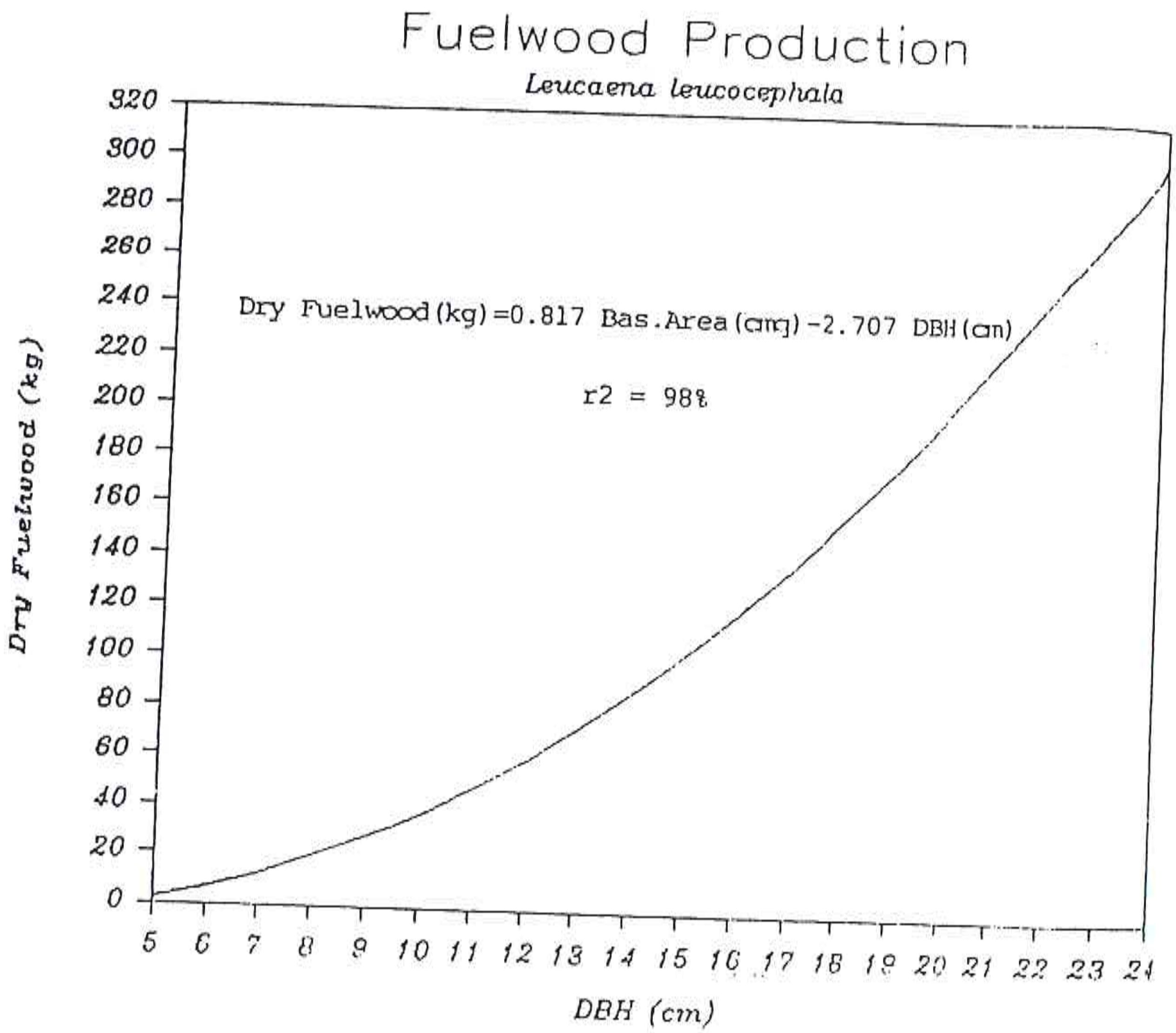

Figure 1
Fuelwood Production for *Leucaena Leucocephala* in Haiti as a Function of DBH

Table 1
Production of Leucaena Fuelwood (dry weight) as a Function of DBH

DBH (ca)	Bas. Area (caq)	Number of Trees									
		1	2	3	4	5	6	7	8	9	10
5	19.64	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.1	22.6	25.1
6	28.27	6.9	13.7	20.6	27.4	34.3	41.1	48.0	54.9	61.7	68.6
7	38.48	12.5	25.0	37.5	50.0	62.5	75.0	87.5	99.9	112.4	124.9
8	50.27	19.4	38.8	58.2	77.6	97.1	116.5	135.9	155.3	174.7	194.1
9	63.62	27.6	55.2	82.8	110.4	138.1	165.7	193.3	220.9	248.5	276.1
10	78.54	37.1	74.2	111.3	148.4	185.5	222.6	259.7	296.8	333.9	371.0
11	95.03	47.9	95.7	143.6	191.5	239.3	287.2	335.1	382.9	430.8	478.7
12	113.10	59.9	119.8	179.8	239.7	299.6	359.5	419.4	479.3	539.3	599.2
13	132.73	73.3	146.5	219.8	293.0	366.3	439.5	512.8	586.0	659.3	732.5
14	153.94	87.9	175.7	263.6	351.5	439.3	527.2	615.1	703.0	790.8	878.7
15	176.72	103.8	207.5	311.3	415.1	518.9	622.6	726.4	830.2	933.9	1037.7
16	201.06	121.0	241.9	362.9	483.8	604.8	725.7	846.7	967.6	1088.6	1209.6
17	226.98	139.4	278.8	418.3	557.7	697.1	836.5	976.0	1115.4	1254.8	1394.2
18	254.47	159.2	318.4	477.5	636.7	795.9	795.1	1114.2	1273.4	1432.6	1591.8
19	283.53	180.2	360.4	540.6	720.8	901.1	1081.3	1261.5	1441.7	1621.9	1802.1
20	314.16	202.5	405.1	607.6	810.1	1012.6	1215.2	1417.7	1620.2	1822.8	2025.3
21	346.36	226.1	452.3	678.4	904.5	1130.7	1356.8	1582.9	1809.0	2035.2	2261.3
22	280.13	251.0	502.0	753.0	1004.1	1255.1	1506.1	1757.1	2008.1	2259.1	2510.2
23	415.48	277.2	554.4	831.6	1108.7	1385.9	1663.1	1940.3	2217.5	2494.7	2771.8
24	452.39	304.6	609.3	913.9	1213.5	1523.2	1827.8	2132.4	2437.1	2741.7	3046.3

Leucaena Leucocephala - July 1985.
Dry Fuelwood (kg) =0.817 Bas. Area (caq) - 2.707 DBH (ca); r^2=98%
USAID/AFORP/UMO/Ehrlich, 1985.

Table 2
Production of Leucaena Fuelwood (dry weight) as a Function of Stump Diameter

DBH (ca)	Bas. Area (caq)	Number of Trees									
		1	2	3	4	5	6	7	8	9	10
2	4	1.1	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.0
3	9	2.5	4.9	7.4	9.9	12.4	14.8	17.3	19.8	22.2	24.7
4	16	4.4	8.8	13.2	17.6	22.0	26.4	30.7	35.1	39.5	43.9
5	25	6.9	13.7	20.6	27.5	34.3	41.2	48.0	54.9	61.8	68.6
6	36	9.9	19.8	29.6	39.5	49.4	59.3	69.2	79.1	88.9	98.8
7	49	13.5	26.9	40.4	53.8	67.3	80.7	94.2	107.6	121.1	134.5
8	64	17.6	35.1	52.7	70.3	87.8	105.4	123.0	140.5	158.1	174.7
9	81	22.2	44.5	66.7	88.9	111.2	133.4	155.6	177.9	200.1	222.3
10	100	27.5	54.9	82.4	109.8	137.3	164.7	192.2	219.6	247.1	274.5
11	121	33.2	66.4	99.6	132.9	166.1	199.3	212.5	256.7	298.9	332.1
12	144	39.5	79.1	118.6	158.1	197.6	237.2	276.7	316.2	355.8	395.3
13	169	46.4	92.8	139.2	185.6	232.0	278.3	324.7	371.1	417.5	463.9
14	196	53.8	107.6	161.4	215.2	269.0	322.8	376.6	430.4	484.2	538.0
15	225	61.8	123.5	185.3	247.1	308.8	370.6	432.3	494.1	555.9	617.6
16	256	70.3	140.5	210.8	281.1	351.4	421.6	491.9	562.2	632.4	702.7
17	289	79.3	158.7	238.0	317.3	396.7	476.0	555.3	634.6	714.0	793.3
18	324	88.9	177.9	266.8	355.8	444.7	533.6	622.6	711.5	800.4	889.4
19	361	99.1	198.2	297.3	396.4	495.5	594.6	693.7	792.8	891.9	990.9
20	400	109.8	219.6	329.4	439.2	549.0	658.8	768.6	878.4	988.2	1098.0

Leucaena Leucocephala - July 1985.
Dry Fuelwood (kg) =0.2745 Stuap sqr. (caq); r^2=97%
USAID/AFORP/UMO/Ehrlich, 1985.

Table 3
Production of Total Biomass (dry weight) as a function of DBH

DBH (cm)	Bas. Area (cmq)	Number of Trees 1	2	3	4	5	6	7	8	9	10
2	3.14	2.1	4.2	6.3	8.4	10.5	12.6	14.7	16.8	18.9	21.0
3	7.07	4.7	9.4	14.1	18.9	23.6	28.3	33.0	37.7	42.4	47.1
4	12.57	8.4	16.8	25.1	33.5	41.9	50.3	58.7	67.1	75.4	83.8
5	19.64	13.1	26.2	39.3	52.4	65.5	78.6	91.7	104.8	117.9	131.0
6	28.27	18.9	37.7	56.6	75.4	94.3	113.2	132.0	150.9	169.7	188.6
7	38.48	25.7	51.3	77.0	102.7	128.3	154.0	179.7	205.4	231.0	256.7
8	50.27	33.5	67.1	100.6	134.1	167.6	201.2	234.7	268.2	301.7	335.3
9	63.62	42.4	84.9	127.3	169.7	212.2	254.6	297.0	339.5	381.9	424.3
10	78.54	52.4	104.8	157.2	209.5	261.9	314.3	366.7	419.1	471.5	523.9
11	95.03	63.4	126.8	190.2	253.5	316.9	380.3	443.7	507.1	570.5	633.9
12	113.10	75.4	150.9	226.3	301.7	377.2	452.6	528.1	603.5	678.9	754.4
13	132.73	88.5	177.1	265.6	354.1	442.7	531.2	619.7	708.3	796.8	885.3
14	153.94	102.7	205.4	308.0	410.7	513.4	616.1	718.7	821.4	924.1	1026.8
15	176.72	117.9	235.7	353.6	471.5	589.3	707.2	825.1	943.0	1060.8	1178.7
16	201.06	134.1	268.2	402.3	536.4	670.5	804.7	938.8	1072.9	1207.0	1341.1
17	226.98	151.4	302.8	454.2	605.6	757.0	908.4	1059.8	1211.2	1362.6	1514.0
18	254.47	169.7	339.5	509.2	678.9	848.7	1018.4	1188.1	1357.8	1527.6	1697.3
19	283.53	189.1	378.2	567.3	756.5	945.6	1134.7	1323.8	1512.9	1702.0	1891.1
20	314.16	209.5	419.1	628.6	838.2	1047.7	1257.3	1466.8	1676.4	1885.9	2095.4

Leucaena Leucocephala - July 1985.
Dry Biomass (kg) =0.667 Bas. Area (caq); r^2=97%
USAID/AFORP/UMO/Ehrlich, 1985.

General Observation

Leucaena leucocephala produces in general, considerable amounts of biomass, especially fuelwood. This tree species has proven to adapt well to difficult edaphic and climatic conditions in every region of Haiti. Its potential as a fuelwood tree is unquestionable.

This species may offer an answer to the problems of denudation and ecosystem imbalance in Haiti. Nevertheless it is not found at high altitudes in the country. It is therefore necessary to introduce other species of Leucaena into the high regions of Haiti.

The common variety of Leucaena is not appreciated by the Haitian farmers; experiments should be established to determine better management systems to improve the productivity. Possibly provenance studies and careful selection of seed trees could identify tree stock with a better form, thus increasing its usefulness as a producer of timber, while maintaining its characteristics as a fast growing and adaptable tree.

Leucaena demonstrated greater variance than any other tree species studied in Haiti. It is therefore suggested, that more samples of this species be studied in order to accurately determine the productive potential of this species with regard to Haiti's highly diverse countryside.

Leucaena experiments should be coordinated to avoid duplication of effort and to emphasize species, varieties, sites, and treatments that have not been adequately covered. Thus a system must evolve where information gained from these experiments can be easily transferred to be shared among cooperating scientists.

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Forestry Experiences with Leucaena in Jamaica

Keith D. Porter

In 1979 the Department of Forestry and Soil Conservation began to take a serious look at Leucaena as part of a Hardwood Provenance Trial in the Research and Development Unit. Experiments were established to investigate the performance of the K67, K8 and K28 varieties. These trials were established in both unreclaimed and reclaimed Bauxite lands at relatively high elevations. *Calliandra calothyrsus* was also established on the unreclaimed site for comparison. The trials on the reclaimed land were later expanded to include *Calliandra calothyrsus* and *Acacia auriculiformis*. The results of these early trials are shown in table 1. It was quite noticeable that the Leucaena planted on both reclaimed and unreclaimed lands grew relatively well for the first 18-24 months after which diebacks set in. Eventually all the Leucaena on the reclaimed site died but those planted on unreclaimed lands remained alive although the growth was not fantastic. On the contrary the Calliandra on unreclaimed land grew very well although on the reclaimed land dieback began at about 24 months. *Acacia auriculiformis* grew steadily for six years after which some yellowing and dieback was seen.

The work with Leucaena was later expanded under the Fuelwood Research Programme. Under this programme the Island was divided into a number of ecological sites based on elevation, rainfall and soil type. Plots of fast growing species—of which Leucaena was the predominant—were established on these sites. In 1982 the OAS Regional Leucaena Project was launched and funding from this project gave a good boost to the Leucaena research. Through this project we were able to expand our seedling production, establish new plots and a major plantation of Leucaena was established at the Bernard Lodge site in St. Catherine. The establishment of this plantation was a decision taken by the regions coordinators who opted to donate portions of their project funds for this venture.

The objective of this plantation was to investigate aspects of establishment, agronomy, management and productivity of Leucaena in a plantation setting. Tied to this was the production of dried Leucaena leaves for further testing and refining of the ENERPLAN Biofermentation Process. The Forestry Department opted to manage the plantation for the foliage production by pollarding the trees at one metre height. The one metre wooden stump could be harvested later for fuelwood or charcoal. From this plantation, important data were generated. The input from the OAS Leucaena project in Jamaica has contributed significantly to the success of ENERPLAN which is now poised for commercialisation.

In 1984 the Department of Forestry and Soil Conservation participated in a USAID funded fuelwood project. funding from this project enhanced the Leucaena work. Preliminary data obtained from earlier trials were used to expand species trials into pilot plantations on several sites. Again Leucaena was the major species used. To a large extent this USAID project aimed at establishing fuelwood plantation on marginal sugar lands to supply wood fuel for the factory boiler. Valuable data and experience were gleaned from this exercise.

Table 1 gives a summary of the comparative performance of Leucaena under various climatic and edaphic conditions in Jamaica. Some analysis of data collected have been done and yield projections have been derived for some sites. These were as follows.:

1. *Grays Inn – St. Mary*

   This eight year old plot has yielded 288.0 tonnes/ha or 36.0 tonnes/ha/year; over dry matter (ODM); and moisture contents were 61.85% and 38.15% respectively.

2. *Mocho – Clarendon*

   This is a five year old plot and yield was calculated at 43.0 tonnes/ha or 8.6 tonnes/ha/year; ODM and moisture contents were 56.79% and 43.21% respectively.

3. *Monymusk – Clarendon*

   This four year old plot gave a yield of 20.7 tonnes/ha/year or ODM or 5.2 tonnes/ha/year. Moisture contents and dry matter were 37.48% and 62.52% respectively. Early tests using eight year old Leucaena to make charcoal was very promising. The quality (density) and burning characteristics of the charcoal were quite favourable. This hold excellent prospect for the charcoal industry which is estimated at 60,000 tonnes per annum. The activity of charcoal burning has already begun to adversely affect certain areas. The growing of Leucaena in some of these areas is envisioned as one approach to provide a sustainable supply of charcoal.

4. *Bernard Lodge*

   Table 2 gives analysis of yield data from this plot. Several acres of the species are planted for various applications, for fuelwood by the Forest Department and some sugar factories and several private farmers have established sizable tracts of Leucaena for animal feed and fodder production with additional requests having been made for seeds and seedlings.

The application of Leucaena in agro-forestry plantings is being actively promoted both by government and private farmers. To date there are established plots of Leucaena as shade for coffee and cocoa and as windbreak plantings for plantains, citrus and vegetables. Several major watershed rehabilitation projects are being implemented and others are in the planning phase. Most of these projects are looking at fast growing Leguminous species – including Leucaena for planting in denuded, impovished sites. There is no doubt that there remains much to be done in terms of local applied research in the Silviculture and management of Leucaena plantations. However, it is felt that Leucaena will have a significant place in forestry and related developments in Jamaica.

Table 1
Growth of Fast Growing Species at Various Location

Location	Elevation	Soil type	Rainfall (mm)	Species	Age (years)	Growth Data Height	Diameter (cm)
Bernard Lodge St. Catherine	30	Clay	750	Leucaena	3	4.58	4.0
Grays Inn St. Mary	30	Clay	1500	Leucaena	8	13.17	13.03
				Acacia	3	8.0	7.0
Hampden Trelawny	120	Alluvium	1250	Leucaena	2	5.34	4.2
				Calliandra	3	6.04	4.5
				Eucalypus	3	10.05	6.9
Richmond Trelawny	150	Shales	1875	Leucaena	5	11.45	6.69
				Calliandra	5	8.30	8.15
				Acacia	4	9.50	8.5
Knockalva Hanover	150	Limestone	1500	Leucaena	2	6.32	4.98
				Calliandra	2	5.65	6.06
				Acacia	2	6.31	5.5
Long Pond Trelawny	100	Limestone	1250	Leucaena	2	3.46	3.0
				Calliandra	2	5.00	3.3
Mocho Clarendon	500	Limstone/ Bauxite	1250	Laucaena	2	3.46	3.0
				Calliandra	2	5.00	3.3
Alderton St. Ann	700	Unreclaimed Bauxite	1800	Laucaena (K_{28})	3	3.50	3.5
				Calliandra	4	7.88	4.46
Golden Grove St. Ann	500	Bauxite	1800	Leucaena	2	1.40	2.2
				Calliandra	2.3	3.27	2.5
				Acacia	6	7.45	6.6
Cambridge Portland	360	Limestone	3370	Leucaena	3.5	5.47	3.6
				Calliandra	3.5	7.03	4.3
Monymusk Clarendon	50	Black Clay/ Limestone	600	Leucaena	4	5.90	6.0
Union Hill St. Ann	720	Un-mined Bauxite	1800	Leucaena (K_8)	3	1.50	2.2

Table 2
Leucaena leucocephala – Pollard Regrowth Yields in Jamaica (Experiment gi08)

KHBA (cm²)	Harvesting Date (months after pollarding) 4	5	6
Mean Total Biomass		(gm ODW per tree)	
0-10.00	312	414	494
10.01-20.00	623	988	1023
20.01-30.00	679	1374	1707
>30.01	1779	2332	2670
Mean	965	1004	1338
Mean Leaf Biomass		(gm ODW per tree)	
0-10.00	192 (2)	153 (23) [23.8]	157 (11)
10.01-20.00	340 (4)	366 (17) [36.4]	414 (10)
20.01-30.00	399 (2)	502 (14) [24.7]	734 (4)
>30.01	800 (4)	734 (5) [185.4]	1071 (5)
Mean Branch Biomass		(gm ODW per tree)	
0-10.00	85 (2)	123 (19) [14.1]	180 (60
10.01-20.00	173 (4)	251 (16) [31.1]	270 (9)
20.01-30.00	114 (2)	368 (15) [31.1]	390 (4)
>30.01	480 (4)	734 (5) [185.4]	555 (5)
Mean Woody biomass		(gm ODW per tree)	
0-10.00	35 (2)	134 (17) [32.2]	157 (7)
10.01-20.00	110 (4)	371 (19) [48.5]	339 (11)
20.01-30.00	166 (2)	504 (16) [53.7]	583 (5)
>30.01	499 (4)	694 (4) [309.1]	1044 (6)
Leaf Biomass as a % of Total Biomass			
0-10.00	62	38	32
10.01-20.00	55	37	40
20.01-30.00	59	37	43
>30.01	45	39	40

Key: KHBA - Basal Area at 50cm above the ground level
ODW - oven dry weight
No. of samples givne in parentheses ( )
Standard Error of means given in [ ] parentheses.

A Comparison of the Growth of *Leucaena leucocephala, Sesbania grandiflora* and *Albizia falcataria* for Seven Years at the Northern Range Reafforestation Project in Trinidad

N.P. Lackhan, S. Ramnarine and C. Ramsarran

INTRODUCTION

Rehabilitation of degraded watersheds of the Northern Range of Trinidad began in 1972 with the inception of the Northern Range Reafforestation Project. The use of indigenous hardwoods and Caribbean Pine (*Pinus caribaea* var. hondurensis) formed the main thrust of the reafforestation efforts during the last 16 years but small plots of exotic leguminous hardwoods were laid down from time to time. In 1980 two small trial plots of *Leucaena leucocephela* (K8 variety) were established on an area measuring 20m x 20m at the St. Michael and Maracas sub-watersheds. Both plots were established on existing fire traces. At the end of four years trees averaged 5 m in height and 6 cm in diameter at breast height. However most of the trees were felled by squatters after the measurement. At the Project nursery at St. Joseph two trees were planted next to the greenhouse. In four years they were 12.9 m and 11 m in height with diameters at breast height being 18 and 17 cm respectively. Two other plots were established at Carenage in 1981 and at Mt. St. Benedict in 1983. At Carenage squatters removed the trees and at the other location they survived and grew well but were not monitored.

In 1982 a single plot of *Leucaena leucocephela, Sesbania grandiflora* and *Albizia falcataria* was established to observe the performance of these species in watershed rehabilitation particularly on the denuded slopes of the Northern Range. Measurements of height and diameter were made annually during the first four years and once thereafter. This report presents and analyses the measurements over the period. The plot measures 0.5 ha and is situated in the upper reaches of the St. Michael sub-watershed at an elevation of 155 m above mean sea level. The plot lies at 10° 42' North latitude and 61° 20' East longitude. The mean monthly maximum temperature is 30°C and mean monthly minimum is 21°C with a mean annual temperature of 20.7°C. Mean annual rainfall is 2100 mm with peaks in July/August. The original vegetation of the site was the Lower Montane Rain Forest. This was removed and is replaced by successional vegetation consisting mainly of grasses and shrubs. The soil is a sandy clay loam that derived from micaceous phyllite and schist parent material. It belongs to the Maracas/Matlot soil series. This soil has a relatively low pH 5.5 and decreases with depth to about pH 5.2 at 50 cm. Status of all major nutrients are moderately low. It has both a deep (1-2 m) and shallow (0.3 m) profile, with free internal drainage and run-off that is moderate to rapid.

METHODS

The site was cleared manually with cutlass (machetes) and powersaws. All material was burnt on the site in the dry season of 1982. Plots were demarcated and individual planting spots were staked. Planting holes were dug with cutlass and grubbing hoes. Seedlings were grown at the Project's nursery in polythene bags with soil mixture being two parts top soil. One part manure and one part sand. Seedlings were three months old when transplanted in September, 1982. A (3 x 3) latin square was utilized to lay down this experiment. Each sub-plot measured 24 m x 24 m and contained 49 plants at 3 m x 3 m spacing. The central square of 25 trees were designated as interior trees for purposes of measurements. The outer row of 24 trees served as surround trees. For the first four years weeds had to be removed twice annually with cutlasses. Thereafter removal of weeds was once per annum. The area was protected from fire by a permanent fire trace.

Plot measurements were made at the end of three months, 12 months, 24 months, 30 months, 45 months and 80 months. Heights were measured with a measuring rod and diameter at breast height with a metal diameter tape. Total cubic volumes were not calculated. Data on survival was analysed using the arc sine transformation. Results were interpreted by Analysis of Variance and Fishers LSD. Significant differences were tested at the 0.05% level.

RESULTS AND DISCUSSION

Survival

Survival data is presented in Table 1. At the end of three months mean survival for all three species was 79% with Albizia being 90%, Leucaena 93% and Sesbania 45%. At the end of 12 months mean survival was 29% with Albizia 44%, Leucaena 14%, and Sesbania 32%. Due to this low survival rate all plots were restocked in September 1983. Despite this restocking mean survival in 1984 (18 months for original plants and 12 months for replacements) was just 56% with Albizia being 73%, Leucaena 47% and Sesbania 48%. Trees of all species continued to die particularly so during the dry season. The high mortality of Sesbania was caused by a fungal attack on some trees. At the end of 80 months survival was poor despite restocking for all three species. The micro climate of watershed with low waterholding capacity, water deficit months during the dry seasons may have contributed to this poor survival. In addition trees of all three species succumbed to high winds resulting in broken tops, and defoliation by the leaf cutting ants commonly called bachacs, (*atta species*).

Table 1
Survival Data for the Three Species over Seven Years

	Survival % at Age in Months					
Species	3	12	24	30	45	80
Albizia	90	44	73	50	44	32
Leucaena	93	14	47	47	42	29
Sesbania	45	32	48	27	16	6

Height Growth

Total height growth and mean annual height measurement for the three species were significantly different at three months and 12 months. However, these differences disappeared beyond 12 months although the same order of decreasing height from Sesbania to Albizia to Leucaena was maintained. Except that early burst of vigour, rate of growth in height peaked at six years for Leucaena, and 54 months for Albizia and Sesbania respectively. At the end of seven years all three species have maintained a mean annual rate of height growth of 7.4 cm/month or 89 cm/year.

Table 2
Mean Total Height in Centimetres over Period of Study

	Height Growth (cm) at Given Age in Months					
Species	3	12	24	30	45	80
Albizia	41	102	214	290	481	586
Leucaena	26	60	125	174	375	580
Sesbania	122	218	268	331	541	616

Diameter Growth

Diameters were not measured until the trees were 30 months old. There were no differences in mean diameter growth among the three species (Table 3). Mean rate of growth in diameter has not peaked as yet. However from the trends it is expected that the species will peak around 9-11 years.

Table 3
Mean Diameter in cm Over Period of Study

	Mean Diameter (cm) at Age in Months		
Species	30	45	80
Albizia	50	44	32
Leucaena	47	42	29
Sesbania	27	16	6

Other Observations

The leaf-eating ants (*Atta species*) defoliate the young plants. High Winds also led to breakage of the faster growing trees of all three species. Trees on all plots of Leucaena began producing seeds at the end of the first year. Self pruning of Leucaena trees commenced in less than 30 months. Natural regeneration of Leucaena and Albizia occurs on the site but are smothered by competing vegetation. Although the original seeds of

Leucaena had to be pretreated prior to sowing the locally collected seeds germinated very well without pretreatment. The crowns of Sesbania have been extremely narrow and somewhat light for the height of the trees. It does not seem as good a choice for soil protection in denuded watersheds. Shape and form of Albizia and Sesbania on this plot have been good but Leucaena is poor.

CONCLUSIONS

From a forestry viewpoint survival of the three species at this site at the end of seven years was unsatisfactory. Local indigenous and exotic species in trials at the same locality have survived better. The harsh conditions at the site particularly a nutrient deficit soil, low pH, extremely dry conditions in the dry season and an open wind swept slope may have contributed to this state of affairs.

All three species grew at the approximate rate of 1 m/year at the end of seven years. In comparison with *Acacia mangium* at the same site this rate can be considered poor on such a short period. The species grown are highly susceptible to attacks by the leaf cutting ant, stem breakage and competition from weeds in the early years but they recover from such damages.

The leucaena trees can occupy the site in a very short period but their main use would be soil protection, stabilization and improvement in critical watersheds of the Northern Range. Their use for timber production in this area remains in considerable doubt since other more valuable species can be grown. For purposes of timber production although the Leucaena trees have a single stem they are inherently of poor form. They were no 3 m log sections; a highly desirable characteristic for the timber industry. Further trials in the deeper fertile soils of the lowlands are required to evaluate this species for timber uses.

Wood Production of *Leucaena leucocephala* (Lam) de Wit Cultivars on the Acid Sandy Loams of Zanderij Formation in Suriname; Some Observations Concerning Yield Characteristics

P. Kerkhoff and M. Callebaut

Introduction

The type of *Leucaena leucocephala* occuring in Suriname, locally known as "lamtoro," showed a modest productivity of both wood and foliage and therefore never drew much attention. Interest in leucaena arose with the publication of reports on the giant types of leucaena which showed, in other countries in the tropics, a most favourable productivity. Although Suriname is covered for more than 90% with forest, it is thought that leucaena many serve as a quickly regenerating source of wood in the more densely inhabited areas outside the capital. Leucaena fuelwood could be used to power generators in isolated villages in the interior or to dehydrate leucaena foliage for use as animal feed in rural areas. Alternatively the use of leucaena fenceposts for pastures may be an option.

Within the framework of the Regional OASD-Leucaena Project (co-ordinator of Suriname, J. Ruinard), several experiments have been planned on various soil types it compare wood production of the local Surinam Lamtoro and the introduced giant types of leucaena. The present paper deals with the preliminary results of the first experiment, laid out early 1986 on the acid sandy loams of the Zanderij formation. Results of the experiment may be of a wider than local importance since relatively little is known about the performance of leucaena under the conditions of the lowland humid tropics on acid soils.

Material and Methods

The experiment was established in April 1986 in the experimental garden Coebiti, simultaneously with and adjacent to an experiment with leucaena for feed production. For detailed information on method of establishment and experimental site, the reader is referred to Callebaut and Kerkhoff, 1989. The cultivars used local *Leucaena leucocephala* (Surinam Lamtoro, SL) and the introductions K8, K28 and K67. The sole fertilization carried out consisted of liming with curacao phospate (33% Ca, 6% P) in an amount equivalent to two tons per ha, prior to establishment. Average precipitation during the three years 1986-1989 was 2046 mm per year, while the rainfall in the (exceptionally wet) first six months of 1989 was 1789 mm. Peaks in rainfall normally occur in the months of January to February and May to August.

The experimental design was a latin square with plots measuring 11m x 11m = 121 m^2; and contained per plot 121 trees at a spacing of 1m x 1m. No thinning was done. Each plot was surrounded by a 1 m wide path. On all sides of the latin square there was a twin border row of SL at 1m x 1m square.

Yield characteristics included in the observations were: height, measured from ground level to the tip of the highest twig and diameter of the trunk at breast height (DBH). Heights and DBH of trees were compared, at each observation date, by means of analysis of variance. The Duncan multiple range test (DMRT) was used to reveal statistical significance at 5% level. Trees heights were measured with an apparatus consisting of extendable calibrated plastic pipes. The diameters were measured with a marking-gauge. Five trees in each plot were selected for measurements. Throughout the time, heights and diameters of the same five trees have been followed. To choose trees the following procedure was used. A diagram of the plot was drawn and in it five trees were chosen randomly. The same co-ordinates were used to assign trees in each plot. Only trees substantially contributing to the biomas of a plot were taken in consideration. Missing trees and retarded specimens were skipped and replaced by adjacent trees. Observations were made in November 1987, in June 1988 and in June 1989.

RESULTS AND DISCUSSION

Average heights and DBH of trees are presented in Tables 1 and 2 respectively. The K-types were, at any date, clearly taller and thicker than Surinam Lamtoro. SL-trees reaching just over 6m in June 1989 while K-types trees were well over 9m at that date. Average diameters in June 1989 were 3.2cm and 5.5 - 6.0 cm for SL and the K-types respectively. Analysis of variance shows a highly significant (at 1% level) effect of treatment (cultivar) on tree height at all observation dates. The effect of treatment (cultivar) DBH was highly significant (at 1% level) at the time of first observation and significant (at 5% level) at the time of later observations. The DMRT shows that height and DHB means of the K-types, at any date, did not significantly differ from one another at the 5% level but that the K-types did differ significantly from Surinam Lamtoro.

It was observed that, once a closed canopy is formed, slow starters did not get a second chance. This observation was made with retarded specimens within plots of the same cultivar and also, at later date, with the slower growing Surinam Lamtoro amidst plots with its faster growing competitors. At the time of the third observation date, trees of adjacent K-plots were intercepting a substantial portion of the light energy over Surinam Lamtoro plots and the Surinam Lamtoro border rows.

Surinam Lamtoro growing along roadsides and in vacant lots, usually remains under six or seven meters in height, which suggests that this variety is not just a slow starter, but that it has an overall low growth potential. This indicates that there is little risk in rejecting a slow starting but potentially valuable tree on grounds of its lack of competitive power during early growth. It is necessary to make additional measurements to estimate the volume of wood produced by each of the cultivars.

Table 1
Average Heights (m) of Leucaena Cultivars at Three Dates of Observation: age after transplantation)

CV	Nov. 12, 1987 (19 months)	Stat. Sign *	June 30, 1988 (26.5 months)	Stat. Sign *	June 20, 1989 (38 months)	Stat. Sign *
SL**	4.52±0.63	b	5.38±0.97	b	6.06±0.84	b
K8	7.03±0.36	a	8.19±0.31	a	9.62±0.47	a
K28	6.68±1.01	a	8.12±1.06	a	9.60±1.63	a
K67	6.94±0.60	a	8.52±0.91	a	9.93±1.00	a

* Statistical significance; any two means having a common letter are not significantly different at 5% level

** Surinam Lamtoro

Table 2
Average Diameters at a Breast Height (DBH) (cm) of Trunks of Leucaena Cultivars at Three Dates of Observation (age after transplantation)

CV	Nov. 12, 1987 (19 months)	Stat. Sign *	June 30, 1988 (26.5 months)	Stat. Sign *	June 20, 1989 (38 months)	Stat. Sign *
SL**	2.7±0.5	b	3.1±0.6	b	3.2±0.6	b
K8	4.3±0.2	a	4.9±0.5	a	5.6±0.7	a
K28	4.4±0.8	a	5.2±1.2	a	5.9±1.6	a
K67	4.4±0.5	a	5.3±0.8	a	6.0±1.2	a

* Statistical significance; any two means having a common letter are not significantly different at 5% level

** Surinam Lamtoro

Conclusions

The data presented clearly show the superiority of the K-types in terms of height and DBH above the local Surinam Lamtoro, although the true potential of Surinam Lamtoro is somewhat underevaluated in the present small scale experiment.

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Leucaena in Agro-Forestry Development in St Lucia

Gabriel Charles

Introduction

Leucaena is a fast growing multi-purpose tree. It has been cultivated in St. Lucia since 1979 and through the assistance of the Organisation of American States (OAS). Approximately 24 hectares of Leucaena woodlots have been established including a 10 hectares plot community forestry project in the St. Urbain area of Vieux-Fort. In St. Lucia, Leucaena is recognised for its potential as a source of firewood and charcoal for which rural communities are highly dependent as a source of household energy. According to a recent survey, charcoal is used in 88% of all St. Lucian households and the total annual consumption in 1985 was estimated at 80,000 tonnes (Wilkinson, 1983) or about 114,000 m^2 of solid wood equivalent per annum (UNDP/World Bank, 1984). This represents the cutting of approximately 400 ha or close to 1,000[1] acres of tropical secondary forest each year. Deforestation therefore results from the clearing of forests to meet this high fuelwood demand. The establishment of Leucaena woodlots in St. Lucia are therefore oriented towards promoting rural development in densely populated areas with high unemployment and located on marginal or degraded environments (Charles, 1985) together with reducing the pressure on the natural forest caused by deforestation for charcoal.

Objectives

The pilot projects have been used to:

- identify methods of cultivating Leucaena for Forestry and Fuelwood, and Soil Conservation and Erosion Control.
- identify methods of integrating such systems with in rural communities and extension programmes.

The Project

Three large Leucaena pilot plantations have been established at St. Urbain in the south, Louvet in the north and the Mabauya Valley in the east. Smaller experimental sites were located all around the island in different ecological conditions, Union, Dennery, Parisoe

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[1] Assuming 300 cubic metres/ha volume

and Choiseul. All the Leucaena sites except Parisoe were situated in dry areas with an average annual rainfall of less than 100 inches (2,540 mm).

DESCRIPTION OF ESTABLISHED SITES

St. Urbain (Aupicon – Forestry and Fuelwood)

Area: 10 Hectares—Planting years : 1981, 82, 83

This Forestry Department/OAS project was initiated primarily to relieve the fuelwood shortage in the St. Urbain area near to Vieux Fort. The 10 hectares site consisted of a strip along a south facing hillside. The area is very dry receiving approximately 60 inches (1500 mm) of rainfall annually. The site has a sandy soil which was previously disturbed by construction work. The soil was very stony especially at the south-westerly end of the site. The silvicultural regime for the site comprised planting 2 hectares/year for five years. The Leucaena had been planted as a pure crop and in mixtures with Honduras Mahogany and Caribbean Pine. The Leucaena was maintained until it was free of competing weeds and coppiced for fuelwood at five years. The Pine or Mahogany remained as standards.

The site has been mapped and fenced and to date some six to eight hectares have been planted. Records of exact planting areas each are not available, however, most planting took place in 1981, 1983 and 1985. Both containerised and bare rooted Honduras Mahogany seedlings were used at St. Urbain. Bare rooted Mahogany failed to grow well on this site as did the containerised Caribbean Pine. As with all the St. Lucian sites containerised Leucaena seedlings were used. These have not grown well at St. Urbain reaching only 11 feet in height after three years.

Growth rates over the sites are very variable with exceptionally large trees growing in patches along the bottom of the hillside. The permanent sample plot is situated in the 1983 Leucaena. The height growth in this small (180 sq meters) plot has a coefficient of variation of 0.2. Previous sample data is not available and the analysis is based only on the 1987 sample. This showed the 26 month old Leucaena to have an average diameter at breast height (dbh) of 1.3 inches (3025) excluding trees smaller than 0.8 inches (2 cm). The average height of the sample plot was 11 feet. Based on the variation within the sample plot, the average height of the 1983 Leucaena is only accurate to within 4.2 meters (the confidence interval).

A problem on this site has been the grazing of goats and weed competition. Fencing has has little effect on the grazing which is likely to remain a constraint. Weed competition may be partly to blame for the Leucaena's poor growth rate which in many instances is less good that the Honduras Mahogany. An initial proposal to involve the local community in the maintenance work was not practicable and the work had to be undertaken by the Forestry Department.

Future maintenance work at this site may need to continue for three years after planting. Fire has has a disastrous impact on the St. Urbain Leucaena in 1987. Two fires in a planted 1985 area have destroyed half of the total area planted. Fire breaks and other fire prevention measures will need to be established at St. Urbain.

Louvet (Forestry and Fuelwood)

Site area: 10 hectares—planting year: 1983 (0.72 hectares)
1984 (7.48 hectares)
1985 (1.8 hectares)

This Forestry Department/OAS Project occupies an area of 10 hectares in the north of St. Lucia. It lies on the site of a valley which receives approximately 200 cm of rainfall annually. The site was previously farm land. The clay soil is unevenly drained and in places it is very acid (pH 3.5).

As at St. Urbain, the silvicultural regime for this site comprises planting two hectares a year for five years. The Leucaena has been planted as a pure crop and in mixtures with *Pinus oocarpa*, Caribbean Pine, Honduras Mahogany and Teak. The area planted to date are in eight compartments as described in the accompanying compartment and map. The Leucaena's growth rate at Louvet has been moderately good with height of 3.6 meters reached injust over two years. However, the growth on the waterlogged patches of soil has been very poor. Where the Leucaena has been established under shade (e.g., comp, B) it has grown markedly towards the light, elsewhere, however, it is generally straight and well formed. *Pinus oocarpa* appears to have suffered from wind exposure. The Caribbean Pine has grown better and near the valley bottom is as tall as the Leucaena where it is well formed. Mahogany was planted in a mixture at Louvet a year after the Leucaena was established. It appears to have grown well and has not markedly suffered from any shootborer damage. Most of the plantation was weeded i 1987 to encourage a more uniform establishment of the younger Leucaena.

Mabouya Valley (Forestry and Fuelwood)

Area: 6.2 hectares — planting year: 1987

Leucaena work in the Mabouya Valley has involved three main activities. These comprise:
(a) establishing a woodlot at La Ressource;
(b) enrichment planting at Fond D'or; and
(c) agro-forestry at Glavier and La Ressource.

La Ressource

A two hectares site was planted with Leucaena to provide a sustainable charcoal supply for the community in the La Ressource area. The site is situated on flat land close to the La Ressource community on an access road (see map). The site has varied soil and drainage, and supports several mango trees. Work involved: fencing the site, establishing the Leucaena, and maintaining the established crop. The site was fenced to demarcate the site and protect the seedlings from animal and human damage. Establishment involved manually clearing the site of woody seeds and tall grass, leaving the mango trees standing and planting the Leucaena. Containerised Leucaena seedlings were planted at a 180 cm x 180 cm spacing by locally employed workers. A border of Honduras Mahogany and Blue Mahoe were planted close to the fence to deter grazing animals. Maintenance of the established Leucaena involved three weeding and one fertilization and beating operation. The first operation comprised circle weeding, an 11% beating up (supply), and the staking of seedling against wind damage. The second operation involved applying two ounces of 15:10:21 fertilizer to each seedling directly following a circle weeding. The third operation involved another circle weeding of the seedlings. The Leucaena reached an average height of 2.7 meters after these operation.

Fond D'or

Area: 4 hectares—planting year: 1988

A four hectare area of the Fond D'or hillside was planted with Leucaena, West Indian Mahogany, Caribbean Pine, Honduras Mohagany, Albizi, *Gmelina arborea*, and Cordia. Leucaena accounted for over half the species used. The site was planted to protect and enrich the scrub covered hillside. One and two tenths metre wide lines were cleared along the contours 2.7 meters apart. Keeping the lines to the contours and 1.2 meters apart required constant supervision and recommended a more complete site clearance. Initial findings also suggested that the Leucaena and White Cedar had the best survival rate.

Agro-Forestry

Investigations into the agro-forestry potential of Leucaena centred around banana and Leucaena trial at Fond D'or and a Taungya trial at Glavier. The fond D'or investigation involved field trials of unfertilised bananas, interplanted with Leucaena. It is too early to identify the characteristics of such system. The Taungya trial involved employing farmers to planted a 1.2 hectare site with Leucaena, Blue Mahoe and Honduras Mahogany. Leucaena was planted on the steeper slopes, Blue Mahoe on the Borders, and Mahogany on the remaining areas. The common problems of poor tree care associated with the Taungya system was evident on this site.

TRIAL PLOTS

Dennery Manele

Area: 0.1 hectares—planting year: 1980

This site is situated on a flat sandy area close to the east coast road. The site was previously a dump and has a correspondingly varied soil and growth rates. Because the site has been burnt twice the growth rates are not comparable to that on other sites. Though the growth rate is moderate, charcoal production may still be the best land use for this site.

Parisoe

Area 0.012 hectare—planting year 1980

This clay site is situated along the rain forest walk track. It is the wettest of the site receiving approximately 375 cm of rain annually. The trees were established under partial shade and have not grown straight. However, the growth has been good with an average dbh value of 8.75 cm and the largest tree reaching approximately 12 meters in height. This good performance under partial shade and an acidic clayey soil may be due to good drainage the sites' fertile and intact topsoil.

Union

Area 0.012 hectares—planting year 1979

This flat site has a fertile alluvial soil and has supported very good growth rates. This site is situated in the north of the Island and consists of two small plots. One was left to grow and the other was coppiced after five years to produce charcoal. The 0.012 hectares (17 trees) charcoal plot yielded 1.65 cubic meters of wood which made 17, 10.09 kg bags of charcoal. The coppiced stumps were singled to two shoots, and have grown very fast reaching an average height of nine meters after two years and a dbh of 12.5 cm. The trees left uncut have grown to a height of approximately 16.5 meters These have a dbh of approximately 25 cms and a straight stem measuring some eight feet to the spring of the crown. Fertile soil, drainage and modest rainfall may partially account for this site's excellent performance.

Choiseul

Area 0.01 hectares—planting year 1979.

The site is of a flat area covered with a thin top soil and exposed to the prevailing winds. The site was planted to protect the soil. The Leucaena appears to have grown very well on this site though measurements have not been recorded.

FINDINGS

Forestry and fuelwood pilot trial involved the monitoring of Leucaena growth to identify a workable silvicultural and utilisation system. Methods of integrating these pilot trials with the local communities and extension programmes have also been investigated (Romulus 1987). Leucaena has been planted in mixtures with timber species such as Mahogany, Pine and Teak. It is anticipated that such a system will provide rapid returns from the Leucaena with medium term, high value returns from the timber. Soil conservation and erosion control has centred around extension work and the protection of hillsides. Communities and private individuals have already started to ask the Forest and Lands Department for Leucaena for soil conservation and improvement. The St. Lucian Banana Growers Association has also recognised the importance of Leucaena in windbreaks and boundary fences.

The pilot projects has been successful in identifing technical and social questions that require further research. Initial results from the pilot projects have shown that whilst Leucaena grows fast under certain conditions, there is high variation in growth from one site to another and plantations on degraded soils appear to require a longer period of rotation to provide sufficient biomass for charcoal production. Growth has been best at Union with a mean annual volume increment of 38 m^3/ha (Andrew, 1986) but disappointing in St. Urbain with an average height growth about half the rate found at Union (Tonnet, 1987). The cause of the variation has not been identified but may be factors such as soil acidity or seed provenance. A St. Lucian soil survey (Stark, 1966) indicated that while 25% of the island has soils that will support Leucaena. Only 15% of the soils ore optimal for Leucaena growth as suggested by Pond and Cairo (1983). Selecting the right Leucaena provenance or fuelwood species may be especially important on less suitable soils.

In order to demonstrate the usefulness of Leucaena to participating communities pilot project research has been directed towards solving technical and practical problems. Continued funding will be necessary to identify a workable harvesting system, and to integrate the adjusted pilot system with rural communities. Integration may continue to involve establishing the woodlots and paying for labour until the system becomes productive.

Since Leucaena was introduced in St. Lucia, the Forestry Department together with OAS has played an active role in promoting Leucaena. The woodlots established have shown interesting results that are worth pursuing. Small communities and private farmers are showing interest and the Forest and Lands Department is fully committed to expand this project once the problems identified in the pilot trials have been researched and resolved.

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Engineering

Drying of Leucaena

C.K. Sankat and D.R. McGaw

INTRODUCTION

Leucaena leucocephala, commonly called "Leucaena" or "Ipil-Ipil" is a leguminous plant with considerable potential for use in the tropics. Leucaena holds great promise as a constituent of animal feed. Dwarf varieties that are regularly mowed can yield large quantities of forage, production levels as high as 20 tonnes dry matter/ha/annum having been reported, with a crude protein content of 25-30%. It is for this reason that Leucaena has sometimes been called "the alfalfa" of the tropics (Farinas). If Leucaena forage is to be more widely used in the feed manufacturing industry however, its moisture content should be reduced from the high initial level, of up to 80% (wet basis), to a suitably low level (12-14%), which will allow for its storage and subsequent processing. It is clear therefore that Leucaena must be dried immediately after harvesting if it is to be incorporated into an animal feed which is to be utilised at some future time. Drying will also facilitate grinding of the forage, prior to feed compounding. This being so, it is necessary to evaluate the drying characteristics of the material so that the most appropriate drying methods can be used. A programme of work has therefore been carried out using a thin layer drying apparatus to investigate the drying characteristics of Leucaena over ranges of drying air velocity and temperature, these being the main system variables.

A particular problem in the use of Leucaena as an animal feed is the presence of the amino acid mimosine, a chemical known to cause hair loss and affect foetal development in non ruminants. As a general rule mimosine comprises 3-5% of dry matter and fear of its effects have been a barrier to its wider use as animal feed. The work reported in this paper therefore also payed particular attention to the effect of drying on mimosine content of the dried Leucaena.

APPARATUS, MATERIALS AND METHODS.

Raw Material

The raw materials used in the experimental drying work were leaves of *Leucaena leucocephala* obtained from the CARDI feed stand at the St. Augustine Campus, of the University of the West Indies, Trinidad, while samples for drying and subsequent mimosine analysis were obtained from the University Field Station, Valsayn.

Drying Experiments

The experiments to determine the drying characteristics of the Leucaena were carried out in a single layer drying apparatus, the flowsheet for which is shown in Figure 1. In this apparatus, the drying air was blown through the equipment by use of a centrifugal fan, the air flow rate being controlled by a gate valve and measured using a rotameter. An electrical air heater was used, the air temperature being controlled by a variac on the electrical supply to the heater. Pipework was of 5.2 cm bore.

The drying chamber, shown in Figure 2, was 15 cm diameter the air velocity distribution being straightened by use of a bed of glass beads. The material to be dried was placed in a single layer on a basket hung in the drying air stream just above the bed of glass beads. The basket was hung from the bottom loading attachment of a Mettler PK 4800 top loading balance. The drying characteristics were determined from sample weight against time measurements, the sample weight being taken from the Mettler PK 4800 balance at predetermined time intervals during drying. The temperature of the drying air was recorded from a thermocouple located directly underneath the basket. The initial moisture content of the material to be dried was determined in each case by drying to constant weight in an oven at 110°C. The range of air temperatures investigated in the experimental programme was 35 to 90°C and the range of superficial air velocities in the drying chamber was from 0.22 to 1.23 ms^{-1}.

Determination of Mimosine Levels

In order to determine the effect of drying temperature on the mimosine level in the dried Leucaena, a series of samples were dried at different temperatures to constant weight in a natural convection oven and then subjected to mimosine analysis. Mimosine was determined by a Colorimetric method which involved the extraction of mimosine with dilute hydrochloric acid. The extract was clarified with activated carbon and intense violet colour. The colour intensity of the samples, mimosine standards and blank were measured at 530 nm on a Variac 634 UV-Visible Spectrophotometer. The range of temperatures investigated was 30 to 90°C similar to the range used in the drying characteristics experiments.

RESULTS

Drying Characteristics

In most experiments the Leucaena was dried to less than 15% moisture The effect of drying air temperature on the rate of drying was investigated at five different air flow rates. A typical set of drying curves at varying temperature, those carried out at the lowest air velocity used, 0.22ms^{-1}, are shown in Figure 3 over the range 30° to 90°C. Reference to Figure 3 shows that the drying air temperature had a considerable effect on the rate of drying, drying rates increasing significantly with increasing temperature.

The effect of varying the air flow rate on the rate of drying is demonstrated in Figure 4 which contains drying curves at 75°C for superficial air velocities in the range 0.22 to 1.23ms^{1}. Reference to Figure 4 demonstrates that air flow rate is also an important variable in Leucaena drying, the effect not being as marked however as in the case of air temperature.

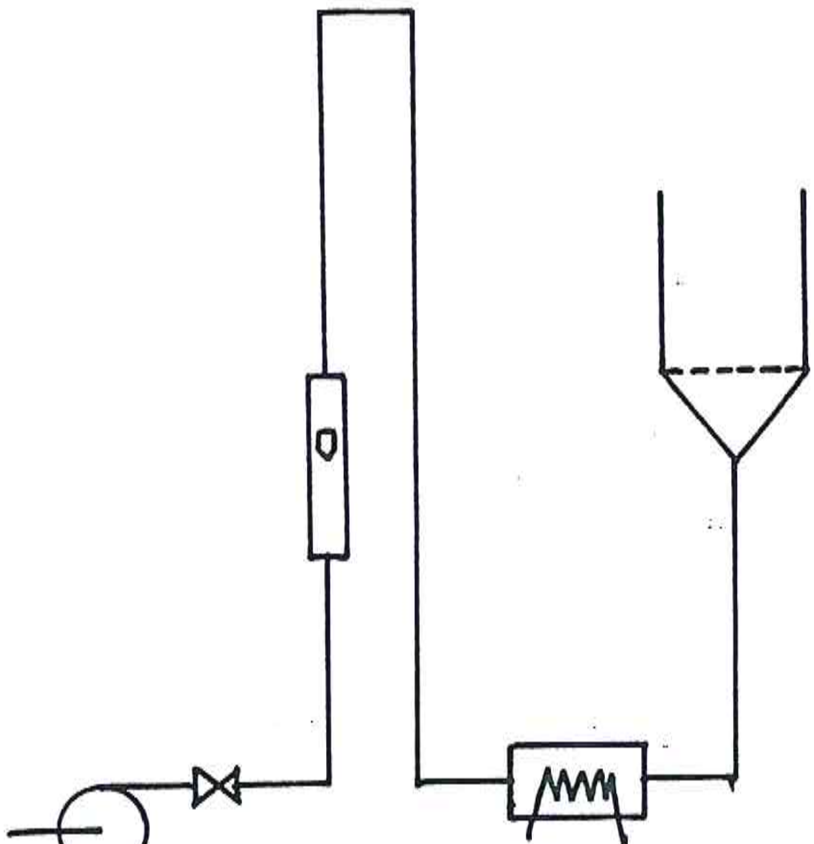

Figure 1
Drying Rig Flowsheet

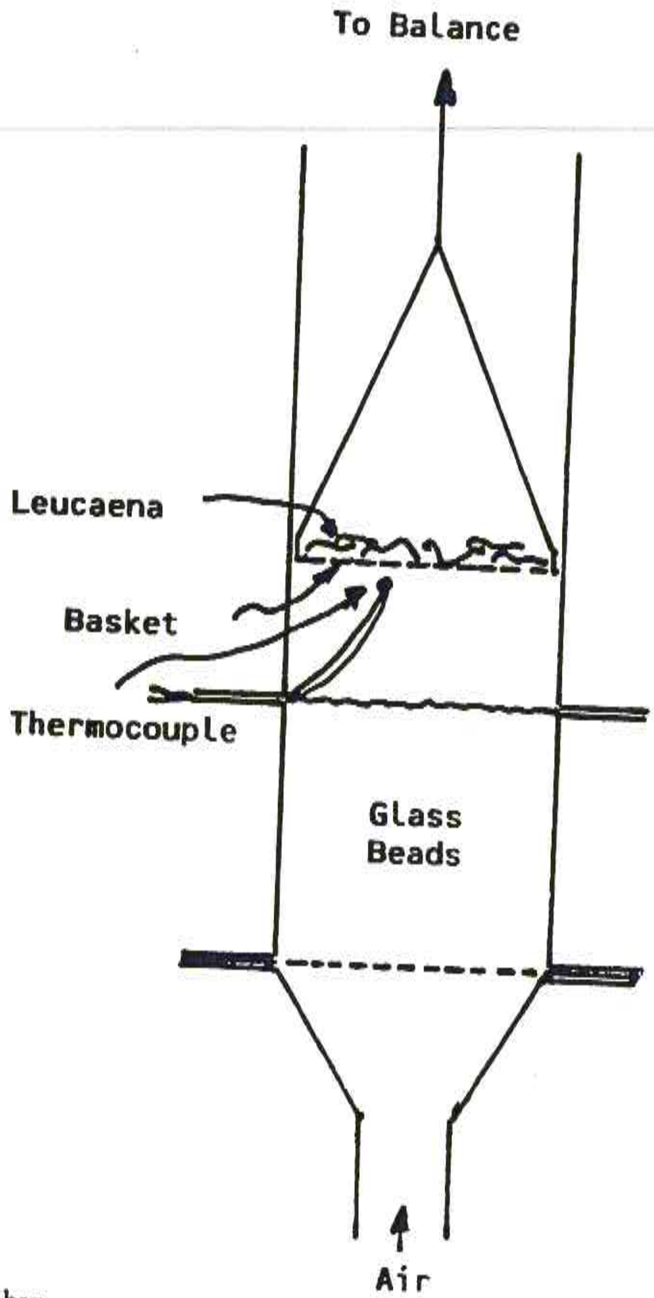

Figure 2
Drying Chamber

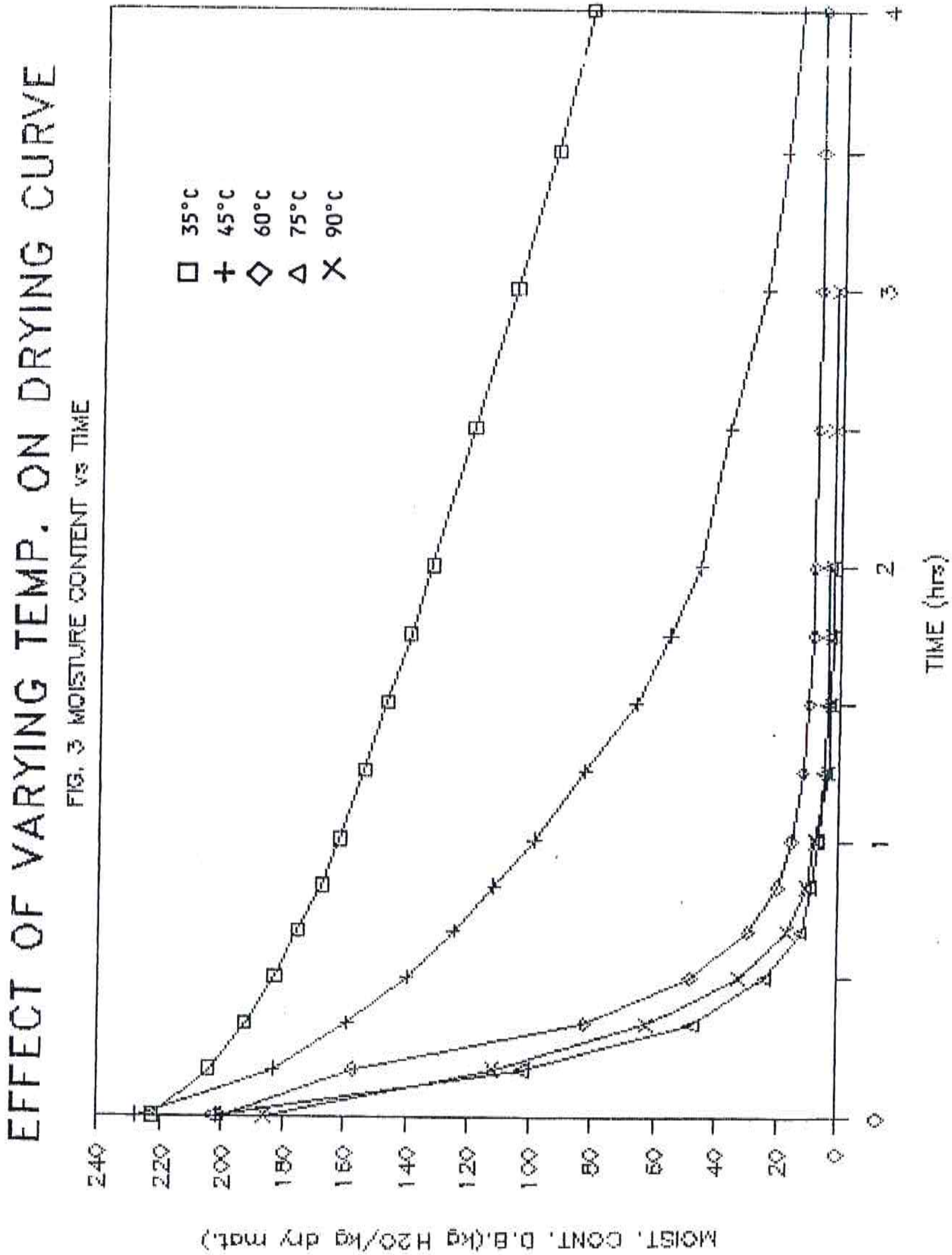

Figure 3
Moisture Content vs Time

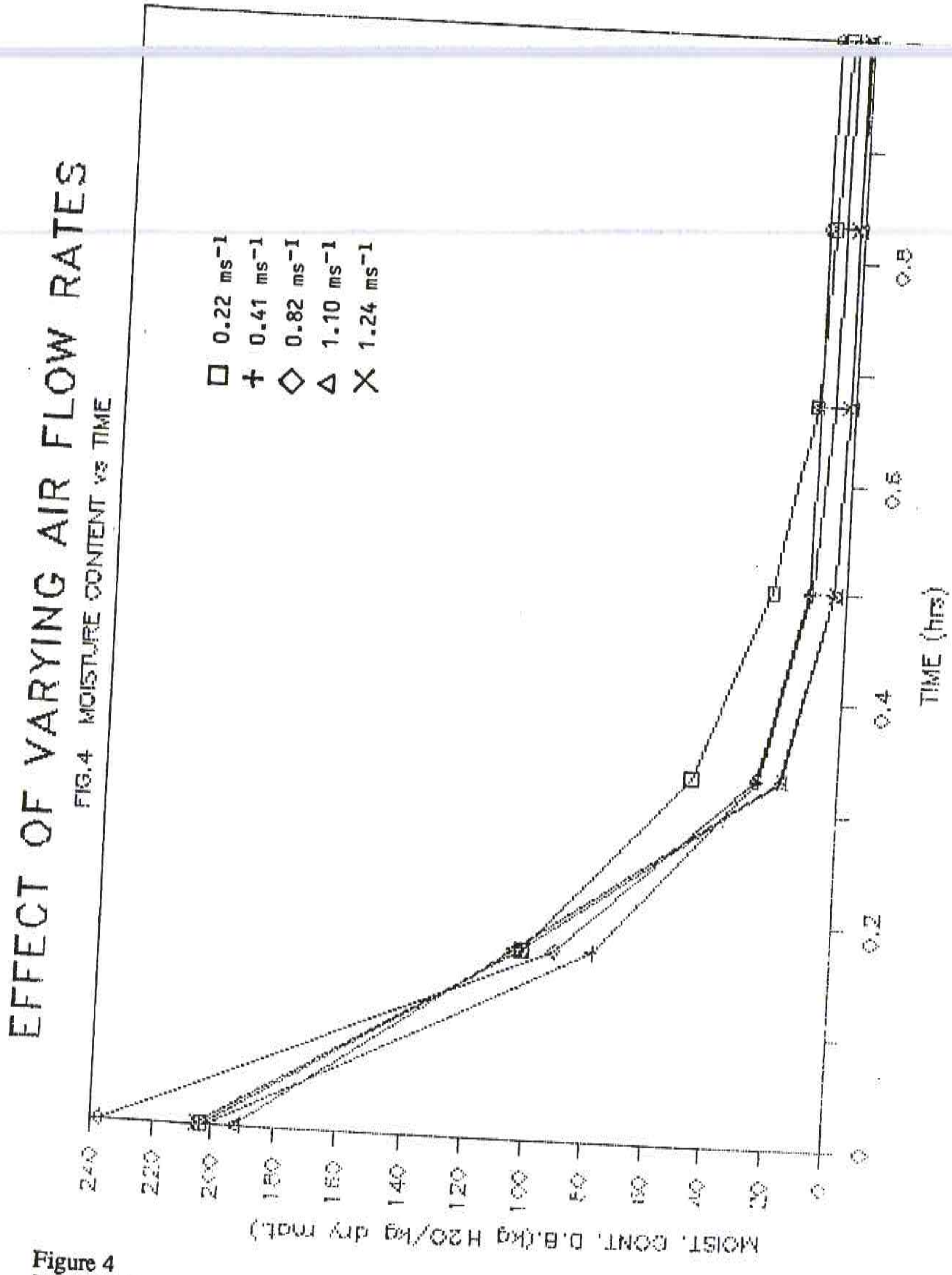

Figure 4
Moisture Content vs Time

Mimosine Levels

Five samples were dried to constant weight at different temperatures and subjected to mimosine analysis in accordance with the method described in Determination of Mimosine Levels. Table 1 shows a gradual reduction in the mimosine content with increasing drying temperature.

Table 1
Effect of Drying Temperature on Mimosine Content

Temperature	% Moisture	%Mimosine (as is)	% Mimosine (dry weight basis)
30	5.88	1.98	2.10
45	4.56	1.79	1.88
60	3.33	1.59	1.65
75	3.41	1.58	1.64
90	2.30	1.35	1.38

DISCUSSION

The significant effect of increasing the rate of drying by increasing drying temperature is a normal phenomenon in the drying of crops. It could take place as a result of increased external heat and mass transfer driving forces or by increased rates of internal diffusion of moisture to the surface of the material. It is more likely to be a combination of both of these, although with leafy material such as Leucaena external effects will probably predominate. A general rule in the drying of crops is that high moisture content crops are air flow rate dependent, but low moisture content crops, such as cereal grains, tend to be much less air flow rate dependent. Leucaena, has a fairly high initial moisture content and its demonstrated air flow rate dependence (Figure 4) conforms with that rule.

The reduction in the mimosine content at the higher drying temperature is quite marked and is an important observation for the choice of process. It confirms previous findings, where it has been suggested that the mimosine breaks down to DHP (3, 4-dihydroxy pyridine) which is not harmful to either ruminants or non-ruminants.

The results indicate that if drying times are to be minimised, the material should be dried at high temperatures using a reasonably high air flow rate. Use of high temperatures will also reduce the toxicity of the product. Some mimosine reduction will however be effected even by drying at temperatures as low as 45°C. An on-farm drying operation in the tropics is most likely to use the sun as the drying medium. If sun drying is to be practised it should be carried out in such a way that the material is well ventilated. If a solar drying system is to be used then it is important that a well ventilated drier be used, especially in the initial stages. In the case of the small farmer for instance the wire basket drier could be used for the initial drying and a hot box type unit for the later stages. Use of the hot box will increase the material temperature and hence reduce the mimosine content of the product. An alternative approach would be for the feed mill to carry out the drying in a commercial drier prior to mixing with the other ingredients. In this case drier choice would be such as to provide the preferred operating conditions, especially high temperature to reduce mimosine levels.

ACKNOWLEDGEMENT

The authors wish to acknowledge the contribution of Miss J. Felmine in carrying out the mimosine analyses and Mr. E. Lovell in carrying out the drying experiments.

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First International Conference on Leucaena "Leucaena in Agricultural Development" Design of Leucaena Harvester

L. Monplaisir and C.V. Narayan

CROP CHARACTERISTICS INFLUENCING MECHANIZATION

Mechanical harvesting of Leucaena requires careful consideration of the salient factors which would influence forage quality and yield. These factors are as follows:

(a) Harvesting frequency or cutting interval.

(b) Cutting height.

(c) Crop spacing.

(d) Protein and dry matter content.

Based on experimental data obtained mainly from the Sugar Cane Feed Centre SFC, 1982), the above variables were used to formulate a mathematical model with the objective of maximising yield and providing a suitable balance of the crop characteristics. The solution of this optimization problem provides the main design parameters for the harvester. The results are summarised below:

(a) The Leucaena harvester is designed to cut two months regrowth plants with a crop height of approximately 785 cm. The crude protein content is 22.7% for this stage of regrowth.

(b) The cutting height is 20 cm above ground level.

(c) A crop spacing of 50 cm by 12 cm will produce optimum yields of 7-8 tonnes per hectare. A schematic of the cropping system satisfying the design parameters is shown in Figure 1.

All experimental work was conducted on the "Cunningham" variety which proved to grow well Caribbean and Guyana.

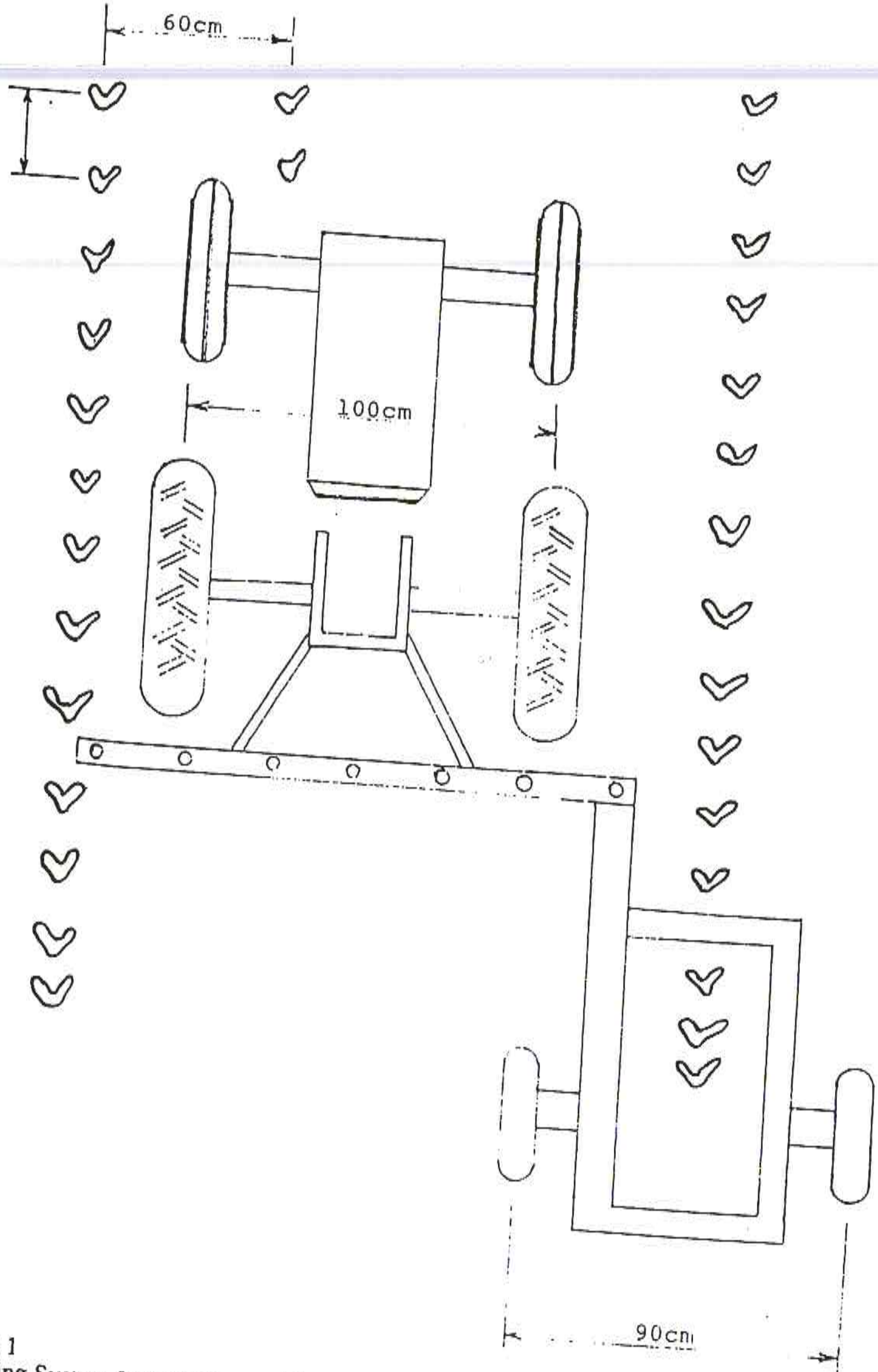

Figure 1
Cropping System for Leucaena and Positioning of Tractor and Harvester Wheels

FORAGE HARVESTER DESIGN

Flail Blades and Housing Design and Operating Principles

Figure 2 presents a schematic diagram illustrating the basic operating principle of a flail harvester. The flail drum housing is made of 1/4" sheet metal (mild steel) and is connected at its top with a 1/16" sheet metal duct of rectangular cross-section tapering towards the outlet.

The flails are made of mild steel sheet metal of thickness 1/2". The dimensions of each flail are 10 cm wide and 42.4 cm long. The diameter of the path described by the flails is 100 cm long. The diameter of the path described by the flails is 100 cm. The flail blades are attached to a rotor at one end, allowing the free sharpened end to swing with a flailing motion. The flails, numbering 10, are distributed in dextro-rotatory helices on the rotor. The rotor runs at 750 rpm in the opposite direction to the land wheels, severing the crop from the sward. The cut material leaves the flails with a peripheral speed of 32 m/s and is transported through the discharge duct designed at an inclination angle of 30° to vertical axis.

The flails are connected to the rotor shaft via a chain linkage. The chain is used to achieve the free swinging ability of the flail. The centrifugal force of each flail depends on:

(a) The angular velocity

(b) The mass density

(c) The flail cross-sectional area

(d) Distance of the tip of flail from one axis of rotation.

The absolute value of this force is 1,334 N which the linkage mechanism is designed to overcome.

The flail shaft is designed to be powered from the top of a 12 hp farm tractor via a 1:1 right angle gear box and belt pulley. figure 3 displays a schematic representation of the rotor drive system.

Power Requirements

The power consumption of the flail harvester can be broken down into five distinct categories viz:

(a) Power required to cut forage.

(b) Power required to accelerate forage.

(c) Power required to move air (Ventilating action of flail).

(d) Power required to overcome friction of cut forage against the harvester is housing.

(e) Power required to overcome mechanical friction in moving parts and other components of the machine.

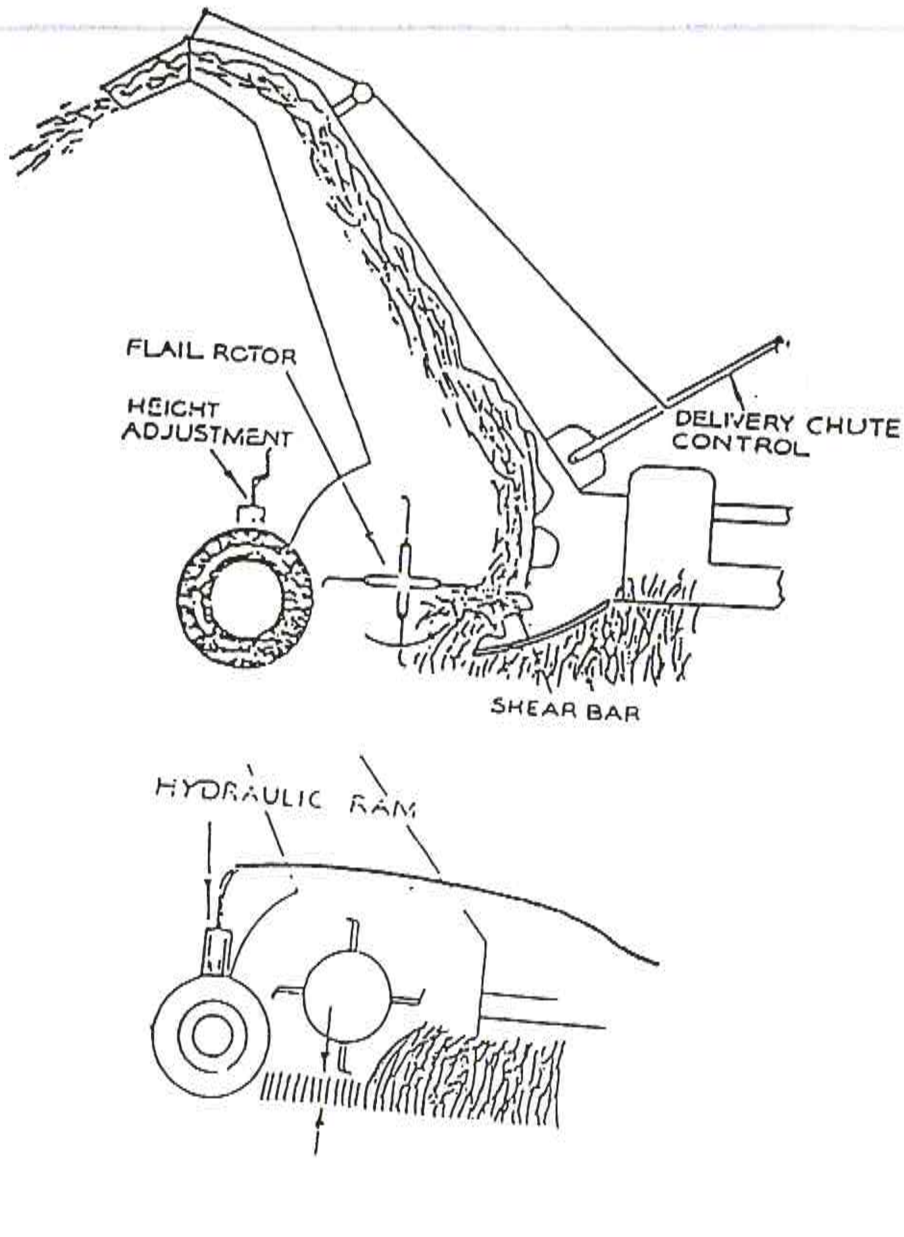

Figure 2
Principle of Operation of a Flail-Type Harvester

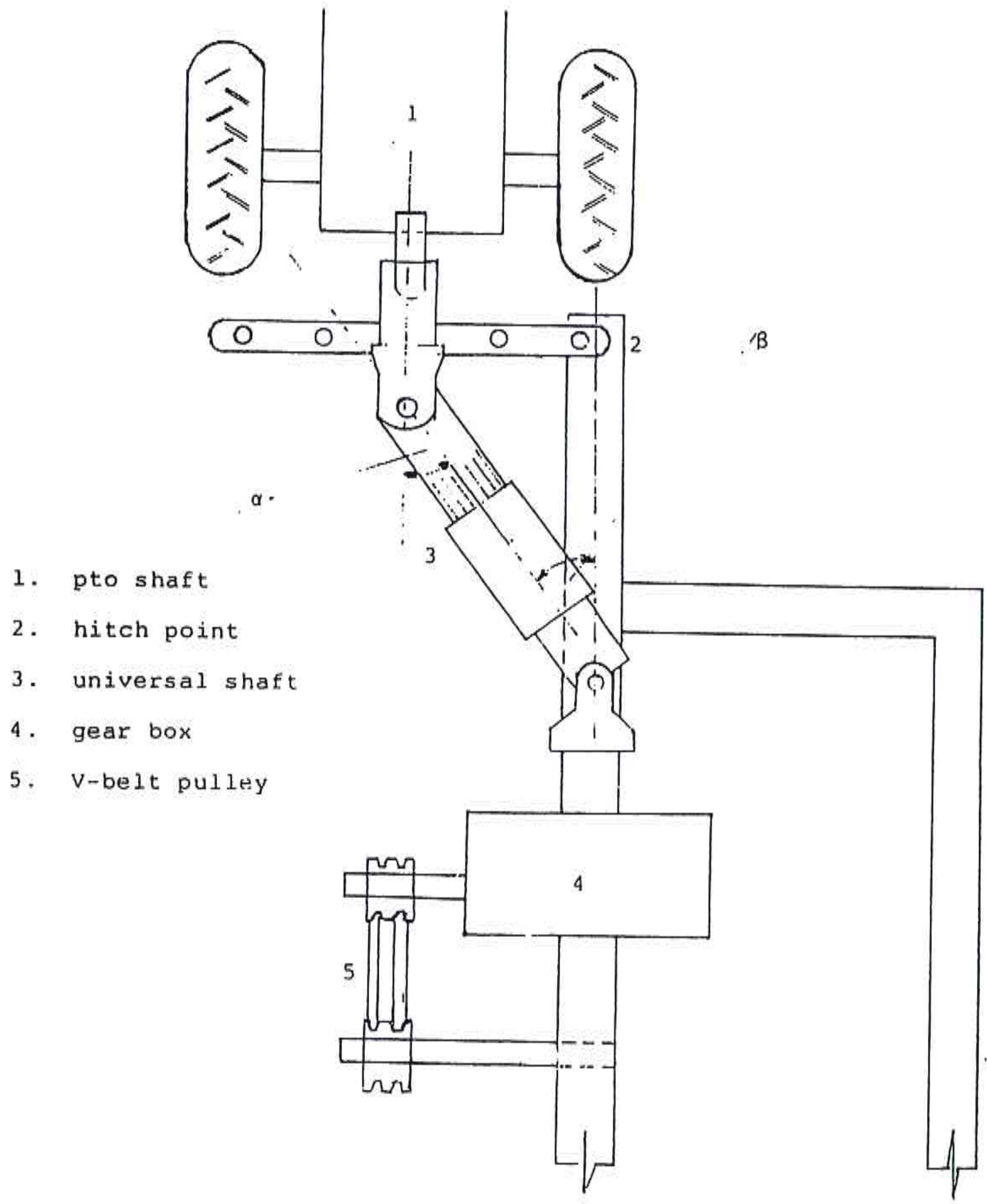

Figure 3
Mechanical Drive for Leucaena Harvester

The total power required to operate this harvester is 8.31 kW. A detailed breakdown of this is shown in Table 1.

The cutting power is almost 2 kW—the single largest component of the total power requirement. Its value was determined in the laboratory using an impact testing machine to simulate the cutting motion of a single flail with incisive investigation of blade sharpness, aggregate thickness of material, moisture content and blade velocity. The total cutting force per flail for two months regrowth is 10.5 N.

The other major component that is worth mentioning is ventilation resistance which accounts for 40% of the total power consumed. The power required is of decisive importance since rotating flails generate considerable draft and its absolute value is approximately proportional to the cube of the peripheral speed of the flail.

A small farm tractor with an output power take off (pto) shaft of 12 kW is adequate to meet the power requirement of this harvester.

Table 1
Summary of Power Requirements for Leucaena Harvester

Components	Power Required in kW
Cut Forage	1.93
Accelerate Forage	0.23
Overcome friction of forage against housing	0.31
Move air	3.86
Crop pressure	0.17
	6.50 kW
Slip and traction	0.24
Drawbar pull	0.81
	1.05 kW
TOTAL	7.55 kW
Add 10% (LOAD FACTOR)	0.76 kW
TOTAL	8.31 kW

N.B. A 10% LOAD FACTOR is used to offset miscellaneous power requirements which could not be calculated directly (e.g. friction in bearing etc.).

Structural Design

The chasis of carrying frame is designed to fully support the rotor shaft and housing along the principal members (See Figures 4 and 5). All members are made of mild steel rectangular hollow sections of 2" by 4" and thickness 1/8".

The flail housing is attached to the carrying frame by means of a length of angle section spanning the long dimension of the housing as shown in Figure 5. One arm of the angle section is welded to the housing while the other is bolted to the frame.

The vertical members, each of length 80 cm, are designed to provide the requisite cutting height. The effect of buckling in these members is obviated with the use of reinforcing gussets.

Having established the load distribution on the carrying frame and chassis, it became necessary to analyse the entire structure to determine bending moment, torsion, shear force, rotation and deflection at the critical sections. This monumental task was simplified through the use of suitable computer software. The largest bending moment 108 kN/cm, is evident along the principal member (alluded to earlier). The principal stresses are computed. The results are summarised below:

Bending Moment	1 kN/cm^2
Principal Stresses	5.5 kN/cm^2; 0.15 kN/cm^2
Bending Stress	5 kN/cm^2
Allowable Stress	8 kN/cm^2

St. Venant's Maximum Strain Energy Theory was applied to verify that the maximum bending stresses of all critical points are within tolerable limits.

Wheels

The carrying frame is supported on two rubber-tyred wheels. Each wheel is complete with rim, tube, rubber tyre and stub axle. The wheëls are coupled to the carrying frame via rigid flange coupling.

Assembly

The assembled unit shown isometrically in Figure 4. Photographs illustrate details of flail housing attachment, wheel arrangement, drive transmissions and hitching to Kubota tractor in an offset configuration (Monplaisir, 1987).

Field Testing

Even though detailed field testing did not form part of this development work, it is necessary that further test should be concentrated in the following areas:

(a) The variation of the length of cut with the speed of travel of the harvester.

(b) The variation of cutting height with rotor speed.

(c) The throwing distance of cut material.

(d) The power requirement for various stages of regrowth.

(e) The general manoeuvrability of the harvester.

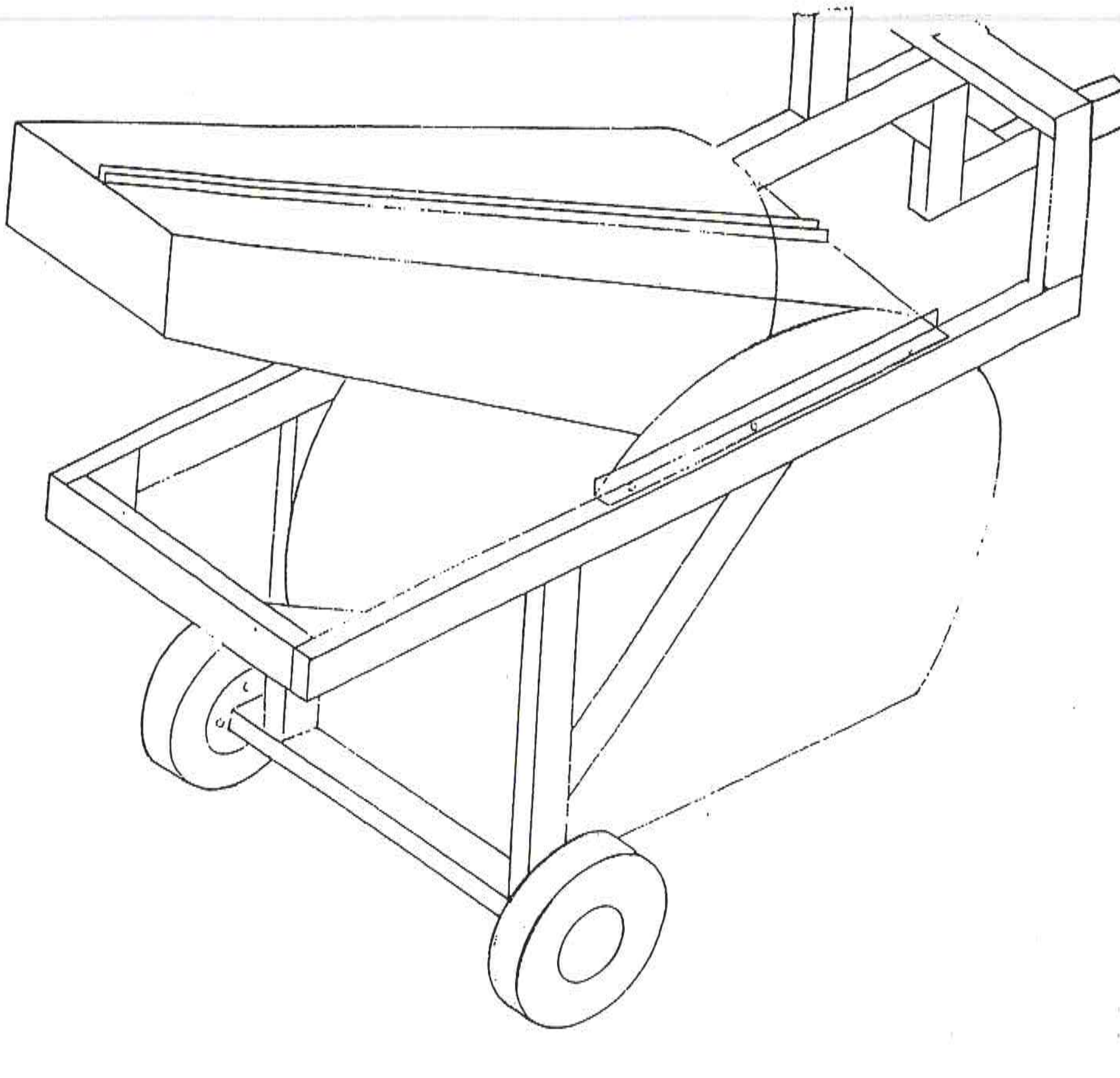

Figure 4
The Assembly Unit

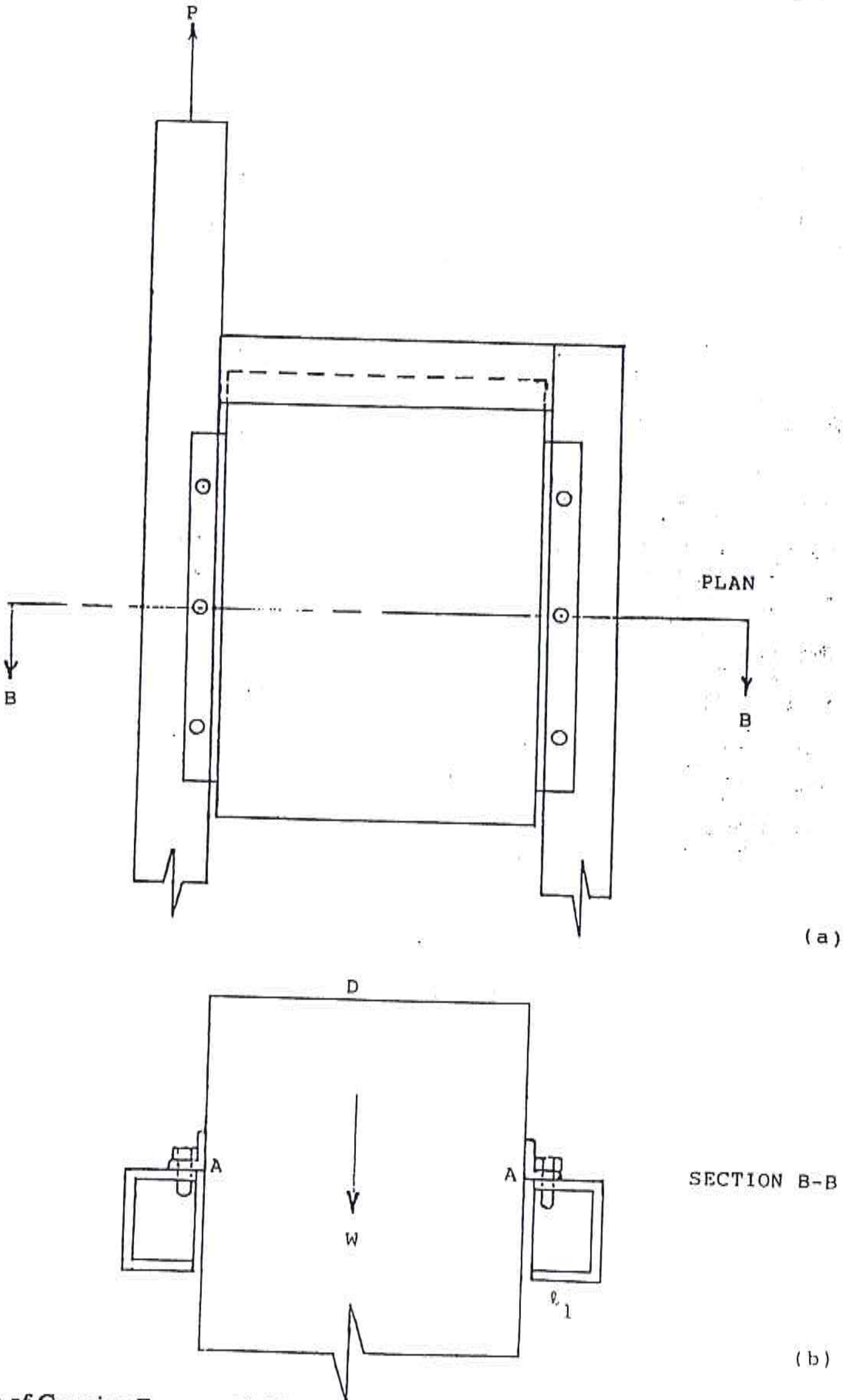

Figure 5
Connection of Carrying Frame to Flail Housing

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Leucaena As Animal Food

Leucaena leucocephala as a Feed For Ruminants: Nutritive Value, Forage Productivity and Some Considerations for More Widespread Use in Trinidad and Tobago.

G.W. Garcia, F.A. Neckles, T.U. Ferguson and K.A.E. Archibald

INTRODUCTION

Leucaena leucocephala (leucaena) is native to neutral and alkaline soils of Southern Mexico and Central America (Brewbaker, 1976 a, b). This plant is now naturalised throughout the tropics between 30°N and 30°S latitudes on the less acid soils and at elevations up to 1500 metres (m) above sea level (Hill, 1971; Brewbaker and Hutton, 1979). Leucaena shows wide genetic variation in growth habit and the National Research Council (NRC 1984) has indicated that there are more than 800 known varieties which are broadly classified into three types. The first type is the "Hawaiian", consisting of small highly branched trees and growing up to 6 metres (m) in height and normally flowering within six months of growth. Secondly, there is the " Salvador" or the" Giant" type. These are fast growing trees which attain up to to 20m in height. "Peru" is the third type, and it combines the vegetative vigor of the Salvador with extensive low branching and reduced relative woodiness of the Hawaiian types (Brewbaker and Hutton, 1979). Batson (1987) confirmed that all types are now present in the Caribbean.

NUTRITIVE VALUE

The chemical composition of leucaena forage and leucaena leaf meal as reported in the literature is summarised in Table 1. Leucaena leaf is higher in crude protein (CP) than leucaena forage [leaf (petiole and blade) and stem]. The leaf meal has an average CP value of 29.2% and the forage 22.03%. This is comparable to Alfalfa meal, and leucaena has about 40% the CP value of soyabean meal. Leucaena forage is however high in fibre, with Acid Detergent Fibre (ADF) values ranging from 34.1% to 36.1%. The literature also indicates that leucaena forage has a average value of 0.22% sulphur (S), 1.80% calcium (Ca), 0.26% phosphorus (P), 0.33% magnesium (Mg), 0.06% sodium (Na), and 1.45% potassium (K) . This mineral composition indicates that the forage is a good source of minerals for ruminants, except that it is low in P. The leaf meal is high in carotene, which makes the plant a good source of Vitamin A for ruminants. Leucaena forage contains in tannin, 0.51-1.60% of total DM (Jones, 1979, and Akbar and Gupta, 1984b). This characteristic may be of value with regard to providing protein with protection from degradation in the rumen, thus making it more available in the small intestine (Van Soest, 1982).

Table 1
The Chemical Composition of Leucaena Forage [leaf (petiole and blade) and stem] and Leaf Meal

	Forage		Leaf Meal	
Chemical Fraction Dry Matter Basis % Dry Matter (DM)	Range 27.00 - 34.00	Average 30.50	Range	Average
	% DM Basis (g/100g DM)			
Nitrogen (N)	2.24 - 4.80	3.52	4.00 - 4.30	4.15
Crude Protein (CP)	10.00 - 30.05	22.03	24.00 - 34.40	29.20
Mimosine	0.70 - 3.59	2.14	1.40 - 7.19	4.30
Crude Fibre (CF)	32.00 - 28.00	35.00	18.00 - 20.40	19.20
Neutral Detergent Fibre (NDF)	34.00 - 42.00	39.50		
Acid Detergent Fibre (ADF)	34.10 - 36.10	35.10		
Hemicellulose	2.01 - 7.40	4.71		
Cellulose	11.00 - 25.70	18.30		
Lignin	4.20 - 11.70	7.90		
Ash	6.62 - 9.46	8.04	10.00 - 11.00	10.50
Tannin	0.51 - 1.60	1.05		1.01
Sulphur	0.14 - 0.29	0.22		
Calcium	0.80 - 2.90	1.80		1.90
Phosphorus	0.14 - 0.38	0.26		0.23
Magnesium	0.17 - 0.48	0.33		0.34
Sodium	0.02 - 0.10	0.06		0.02
Potassium	0.79 - 2.11	1.45		1.70
	(g/1000000)			
Copper	2.00 - 32.00	26.00	8.00 - 11.40	9.70
Iron	250.00 - 575.00	412.50		907.40
Zinc	30.00 - 150.00	90.00	19.20 - 32.80	26.00
Manganese	75.00 - 875.00	475.00		59.90
Iodine	33.00 - 90.00	61.50		
Chloride	0.15 - 0.09	0.17		
Xanthrophyll			741.00 - 766.00	
	753.00			
Leutein			529.00 - 557.00	543.00
Zeaxanthin			110.00 - 146.00	128.00
Carotene			227.00 - 248.00	237.50

Source: Jones (1979); D'Mello and Taplin (1978); Brewbaker and Hutton (1979); Pillot, Leclesio and Wong Yon Cheong (1976); Meulen, Struck, Schulke and El-Marith (1979); Hulman, Owen and Preston (1978); Alvarez, Wilson and Preston (1978a) ; and Akbar and Gupta (1984a and b)]

Table 2 indicates that the total apparently digestible CP (TADCP) of leucaena forage ranges from 64.7 to 78.0% (Kharat, Prasad, Sobale, Sane, Joshi and Rangnekar, 1980 and Upadhyay, Rekib and Pathak, 1974) respectively. Garcia (1988) reported a rumen degradable protein value (RDP) of 42%. In addition the digestible energy (DE) value is estimated to range from 11.6 to 12.9 MJ/ kg dry matter (Sobale, Kharat, Prasad, Joshi, Rangnekar, and Deshmukh , 1978). Garcia (1988) reported that the estimated DE and the%CP of the forage declines with age, (Tables 3 and 4 respectively). Takahashi and Ripperton (1949) reported that as the havesting interval went from 60 to 90 to 120 days the % CP on a DM basis declined from 22.2 to 17.6 to 14.6%, respectively (Table 4). Pizarro and Sousa Costa (1983) in the Cerrados region of Brazil, which like Trinidad has a five to six month dry season, reported a mean annual forage CP composition of 18 to 19%.

Upadhyay *et al* (1974) indicated that the digestibility for DM, CP, ether extract (EE), crude fibre (CF), and nitrogen free extract (NFE) were 71, 78, 48, 57, and 81%, respectively. These coefficients indicated that good quality leucaena had a TDN value of 70% or an approximate DE value of 12.9 MJ/kg DM. Rosas, Quintero and Gomez (1980) reported a DE value of 10.13 MJ/kg DM for leucaena leaf meal fed to cattle. Yerena, Ferreiro, Elliott, Godoy, and Preston (1978) have reported a 59% DM digestibility with a 46.9% nitrogen retention which is high in contrast to that of 27% reported by Sobale *et al* (1978). *In vitro* DM digestibility of leucaena of 49.5 and 61.9% reported by Hulman, Owen and Preston (1978) appear low in comparison to the *in vivo* reports of Upadhyay *et al* (1974).

Table 2
Digestibility of Protein and Energy (DE) for Leucaena Forage

Fraction	Digestibility Coefficient as a %	Notes	Source
Rumen Degradable Protein (RDP)	42.0	The model proposed by this author suggests that only 48% of the UDP is digested post ruminally	Garcia(1988)
Undegraded Protein (UDP)	58.0		
Total Apparently Digested Crude Protein (TADCP)	70.0		
TADCP (1974)	78.0		Upadhyaya *et al*
TADCP	74.0		Work (1946)
TADCP	73.3		Sobale *et al* (1978)
TADCP	64.7		Kharat *et al* (1980)
Digestible Energy (DE) MJ/kg DM	11.6	Estimated from TDN of 63%	Sobale *et al* (1978)
DE (MJ/ kg DM) (1974)	12.9	Estimated from a TDN of 70.2%	Upadhyaya *et al*

Table 3
The Chemical Composition % Dry Matter Of Leucaena Forage Harvested at Different Ages Grown on an Acid Ultisol

Chemical Composition	February (3)	March (4)	April (5)	May (6)	June (7)	Average
	Month of Harvest/Age (Months)					
DM	33.2	24.3	34.3	35.5	28.7	31.2
CP	34.2	25.8	20.5	19.4	20.5	24.1
NDF	56.8	49.3	58.2	60.0	64.4	57.8
Ash	8.6	7.6	6.3	5.5	6.1	6.8
Estimated DE (MJ/kg DM)	10.6	10.4	6.3	6.0	7.1	8.1

Source: Garcia (1988)

Table 4
Effect of Time (months) between Regrowth Harvests of Leucaena on %CP of the Forage DM (SFC and Takahashi and Ripperton, 1949)

	%CP of Leucaena Forage					
Months of Regrowth Season	3 months 1st Harvest	4 months 1st Harvest	Takahashi and Ripperton (1949)[1]	Average[2] Wet & Dry	Wet Season	Dry
1	27.90	26.10	--	--	--	--
2	23.70	19.70	22.21	18.72	18.25	19.18
3	18.10	21.10	17.58	18.05	18.83	
17.28						
4	--	--	14.60	--	13.26	--
4.5	--	--	--	--	--	15.79

[1]Averages of repeated harvests over three (3) years
[2]Material harvested in a wet and dry season of the same year at the SFC Longdenville with the leucaena fully established
Source: Garcia (1988)

There is the presence of a toxic amino acid, mimosine [ß-N-(3-hydroxy-4-pyridone)], which constitutes about 1.40 to 7.19% of the DM in the leucaena leaves and 0.70 to 3.59% of the DM in the leucaena forage (Meulen *et al*, 1979). Brewbaker and Hutton (1979) reported a content of 2.0 to 6.0% on a DM basis in the leaf meal. Mimosine has been responsible for some animal disorders. Mimosine toxicity from leucaena has been reviewed by Jones (1979), Brewbaker and Hutton (1979), and Meulen *et al* (1979). In ruminants, the major effects of mimosine toxicity are alopecia (hair loss), loss of appetite, excessive salivation, incoordination of gait, enlarged thyroid glands, poor reproductive performance and the production of goitrous calves that may die soon after birth. The degree of each of these effects has varied. Jones (1979) suggested that this may be as a result of different amounts of mimosine intakes. The mimosine concentration of the diets fed has not been measured in many of the experiments reported, and although leucaena may provide toxic levels of mimosine, there have been no known reports of death caused from leucaena feeding

(Jones, 1979; and Meulen *et al*, 1979). Jones and Megarrity (1981) suggested differences in mimosine metabolism in animals from different geographic locations. Their findings suggest that ruminal metabolism of mimosine and its derivate 3-hydroxy-4 (1H) pyridone, (DHP) in Hawaii differs from that in Australia. Low DHP levels of the urine were found in goats fed leucaena in Hawaii, India, West Timor, Brazil, and the Phillippines. The Hawaiian fed goats had DHP levels of 0.08% in the urine, while the Australian samples had 1.10%. Badve, Joshi, Rangnekar and Waghmare (1985) suggested that the mimosine and DHP are broken down to non-toxic compounds, thus preventing toxicity. No reports on mimosine toxicity have been reported in the Caribbean. In Barbados, Quintyne (1987) fed fresh or dehydrated leucaena to Barbados Blackbelly sheep for extended periods of time and reported gains between 22.7 and 68.1 g/day. No marked evidence of mimosine toxicity was reported.

The mimosine content of the fresh leucaena forage can be decreased when it is heated to temperatures greater than 70°C, and the addition of ferrous sulphate to rations containing unheated leucaena leaf meal reduces mimosine toxicity [National Academy of Sciences (NAS) 1977]. Meulen *et al* (1979) reported that water-soaking of the leucaena leaf meal for 36 hours reduced the mimosine content.

The amino acid composition of leucaena seeds, leaves, and forage is compared with that of soyabean meal, fish meal, and alfalfa in Table 5. There is the indication that the sulphur-containing amino acids are limiting. If sulphur is not a limiting factor in the ruminant's diet, microbial protein production can adequately supplement these amino acids. It is therefore essential that leucaena diets be supplemented with a source of sulphur.

Leucaena needs the addition of 5% molasses for proper ensiling (Table 6 and Alli, Baker and Garcia, 1983). The leucaena can be best harvested at flowering (at about 8 weeks regrowth). In addition leucaena silage has been successfully fed to growing steers in mixed diets and the ADG obtained reported was 0.571 kg/day (Quintyne,1987).

Table 5
Comparative Amino Acids Composition of Soybean Meal, Fish Meal, Alfalfa and Leucaena (mg/gN)

	mg/g Nitrogen					
					Leucaena	
Amino Acid	Soybean Meal	Fish Meal	Alfalfa*	Seeds	Leaves	Pods
Cystine	106	69	77	79	42-88	21
Aspartic Acid	756	625	1	643	864	432
Methionine	88	175	96	64	88-100	42
Threonine	244	269	290	138	266	133
Serine	331	256	--	206	279	139
Glutamic Acid	1138	813	--	911	640	320
Proline	300	244	--	222	305	152
Glycine	275	400	--	285	278	139
Alanine	275	394	--	205	311	155
Valine	300	325	356	204	255-338	127
Isoleucine	294	256	290	148	244-653	122
Leucine	488	475	494	283	444	222
Tyrosine	238	--	232	162	208-263	104
Mimosine	0	0	0	763	343	172
Phenylalanine	319	256	307	197	250-294	125
Lysine	388	500	368	324	313-349	157
Histidine	181	--	139	158	112-135	56
Arginine	463	375	357	493	294-349	147

[Adapted from Meulen *et al* (1979), and Brewbaker and Hutton (1979)]

Table 6
Chemical Composition of the Silages of Leucaena Forage

Forage	Lactic Treatment	DM %	pH	CP %	Ethanol %	Acetic Acid %	Acid %
Leucaena	Fresh	34.5	6.3	20.7			
at flowering	* Control	33.2	5.2	21.0	0.5	0.4	0.7
(CF 95)	5% molasses	33.4	4.4	18.6	0.9	0.6	1.0
	10% molasses	33.7	4.4	26.0	1.7	0.7	1.8

Source: Pouchette (1988) (unpublished)
* The control silos contained the chopped forage ensiled on its own.

ANIMAL PRODUCTION

Animal performance data (live-weight gains and milk production) reported in the literature have varied from observations of traditional farming systems (Jones, 1979) to leucaena forage with molasses-urea [Pillot, Leclesio and Wong Yon Cheong (1976); Teeluck, Hulman and Preston (1982); Hulman, Owen and Preston (1978); Alvarez, Wilson, and Preston (1977); Salias, Sutherland, and Wilson (1977)]; or leucaena forage with freshly chopped sugar-cane [Alvarez and Preston (1976); Alvarez, Wilson and Preston, (1978a and 1978b); Siebert, Hunter and Jones (1976) and Garcia (1988)] or with leucaena/grass pastures [Hill (1971); Jones (1973) as cited by Jones (1979); Flores-Ramos (1979); Partridge and Ranacou (1974); and Stobbs (1972)]. High daily live-weight gains observed in animal performance studies with leucaena have been 0.85 kilogram per day (kg/d) with leucaena in molasses-urea-based diets (Hulman *et al*, 1978); 0.93 kg/d with leucaena and *Setaria anceps* pasture (Jones,1973, as cited by Jones, 1979); and 1.7 kg/d with leucaena leaf meal, maize stovers and maize bran [Jones (1979) citing Thomas and Addy (1977)]. Alvarez and Preston (1976) and Alvarez, Wilson, and Preston (1978a) reported that leucaena (restricted grazing) supplemented with rice polishings fed with freshly chopped sugarcane resulted in milk yields in the dry season of 6.19 to 6.90 kg/d with no loss in liveweight by the cow and positive calf live-weight gains with restricted suckling. Leucaena planted as hedge rows in pasture with about 2 to 3 metres of grass between the hedges, improved the performance of grazing animals because the protein content of the diet increased (Hill, 1971). Jones (1979) have found that leucaena should first be grazed when about 1.5m in height; the grazing should be light and only to about 0.75m in order to stimulate lateral branching.

When leucaena was fed alone, voluntary intakes were reported to be low to moderate (1.7 to 2.7% DM as a percentage of body weight). Intake was also variable, depending on the other dietary components with which the leucaena was fed [Alvarez *et al* (1978a & b)]. The literature suggests that leucaena should not be used as the only source of feed for ruminants, and this may in part be due to the toxic effects of the mimosine present, the high dietary fibre content (and thus moderate level of DE), and the low content of the sulphur containing amino acids present in leucaena. Leucaena's high % ADF makes it unfavourable as the sole protein source in diets containing high levels of sugarcane, > 70% sugarcane in the diet DM) as the sugarcane is already high in ADF, (Garcia 1988).

FORAGE PRODUCTIVITY

Leucaena was described by Brewbaker and Hutton (1979) as being the highest producer of forage protein among tropical legumes. There is however, still awealth of Tropical forage legume germplasm to be evaluated. Work done outside of the Caribbean indicated that leucaena has demonstrated an annual forage DM production ranging from 10 to 19.5 tonnes per hectare (t/ha) (Brewbaker, Plucknett, and Gonzalez, 1972; Takahashi and Ripperton, 1949; and Guevarra, Whitney, and Thompson, 1978). The upper level of DM production indicates a potential annual CP production in excess of 3 t/ha as reported by Takahashi and Ripperton(1949) and Guevarra *et al* (1978) in Hawaii where the soils are alkaline and leucaena is native. Work done in the Caribbean and Latin America have supported all of the above (Ruiz and Febles, 1987 and Menendez, Tang and Vega, 1988 in Cuba; Sanchez, Carrete and Eguiarte, 1988 in Mexico). There is however great variability in forage yield due to genetic, environmental, and agronomic factors (Brewbaker and Hutton, 1979).

Genetic effects on forage production have been reported by Guevarra *et al* (1978), Brewbaker *et al* (1972), Oakes and Skov (1967) and Batson (1987) who have all reported higher forage yields by the Salvador type. Brewbaker *et al* (1972) reported 19.5 and 10.5 t/ha/annum forage DM yield for the K8 (Salvador) and K63 (Peru), respectively, in Hawaii.

The most important environmental factors affecting leucaena establishment and production are soil pH and level of Aluminium (Al) saturation or Ca availability (Takahashi and Ripperton, 1949; Hutton, 1980; Halliday, 1981). Hutton (1980) reported that evidence to date indicated that it is very difficult to find ecotypes of *L. leucocephala* tolerant to highly acid Oxysoils and Ultisols (pH 4.0-4.5) with a high Al saturation (70-90%). Hutton (1984) has reported that Ca absorotion is more important than Al toxicity for leucaena growth in acid soils. Hutton and de Sousa (1985) reported that the Cunningham (Peru type) leucaena responded to the application of 200 kg/ha single superphosphate and Ca as dolomite (200 kg/ha).

Agronomic factors affecting the production of leucaena forage are plant population density, cutting interval and height of cut (Brewbaker, 1976b). Guevarra *et al* (1978) citing Guevarra (1976), have reported that an increase in plant population density from 44,000 plants/ha to 133,000 plants/ha increased annual forage yield from 17.1 t/ha to 19.6 t/ha. Increasing the cutting height for the K341 and K8 cultivars from 55cm to 155cm increased the annual forage CP yield from 2813 to 3975 kg/ha/annum (Guevara *et al*, 1978). Krishnamurthy and Gowda (1983) reported that maximum yield of herbage for the Hawaiian Giant K8 was obtained with a cutting frequency of 70 days and a cutting height of 150cm. The frequency of harvesting or grazing must be adjusted to suit the variety in order to maximise protein production (Brewbaker and Hutton, 1979).

In the dry season in Trinidad, Garcia, Neckles and Archibald (1987 and Garcia (1988) reported that the yield (kg/ha) of whole plant CP and DM, increased between the second harvest made at one and three months, regardless of the age at first harvest. This trend in whole plant or forage CP yield (kg/ha) with increasing age of the regrowth was in agreement with the report by Takahashi and Ripperton (1949), though the yields reported by the former were generally lower (Table 7). The yields from the former were from repeated harvesting over three years on Hawaiian neutral to alkaline soils as compared with the acid and moisture limited soils at the SFC during the dry season. The results obtained for three months of regrowth fall within the range reported by Logan (1979) and Devers and Keoghan (1978), in Jamaica and Antigua, respectively, on neutral to alkaline soils. Studies on forage production at three months of regrowth by Logan (1979) in Jamaica, and Devers and Keoghan (1978) in Antigua have indicated 250 and 458 kg/ha of forage CP, respectively, which were lower than the value reported by Takahashi and Ripperton (1949) in Hawaii (Table 6). There is room therefore for improving the performance of leucaena for forage CP production in the Caribbean. Other reports on Leucaena forage production in the Caribbean have been by Oakes and Skov (1967) in the US Virgin Islands; Devers and Keoghan (1978) in Antigua; Logan (1979) in Jamaica; Proverbs (1984); and Quintine (Personal communication) in Barbados and Garcia (1988) in Trinidad. The work has centred on agronomic evaluations with leucaena giving yields greater than most of the other introduced forage species. Batson, Ferguson, and Archibald (1984) summarised the status of leucaena research in the Caribbean, and suggested that leucaena had not been fully exploited under farm conditions. They further suggested ways in which leucaena could be utilised in livestock production systems in the Caribbean. Batson (1987) evaluated the leucaena germplasm available in the English speaking Caribbean. Pound and Martinex Cairo (1983) have done a comprehensive review on Leucaena cultivation, and Batson, Ferguson and Archibald (1987) has done the same special reference to the Caribbean.

Table 7
Effect of Time (months) between Regrowth Harvests of Leucaena on the Forage Yield (kg/ha) of Crude Protein

Harvesting Interval (months)	Age at First Harvest 3 month 1st Harvest	4 months 1st Harvest	Takahashi & Ripperton (1949) Hawaii	Logan (1979) Jamaica	Devers & Keoghan (1978) Antigua	SFC Dry Season
1	142.37	116.93	--	--	--	--
2	135.64	373.50	640.0	--	--	432.75
3	371.19	797.77	972.5	250.00	458.00	371.36
4	--	--	986.7	--	--	--
4.5	--	--	--	--	--	955.19

Source: Garcia (1988)

Some Considerations for More Widespread Use in Trinidad and Tobago

Garcia (1988) reported on simulated forage production models based on work done on an acid Ultisol in Trinidad and concluded the following:

(a) Potential annual forage CP production from leucaena grown in central Trinidad rainfall conditions on an acid Ultisol is calculated to range between 2.3 and 5 tonnes /ha/annum.

(b) Leucaena's animal carrying capacity is limited by it's low DE content.

(c) It will be necessary in the future to give attention to some of the agronomic and management problems which could arise with leucaena under systems of monoculture for forage protein production.

In actual practice these high levels of CP and indirectly DM production are very difficult to achieve on acid soils using the existing varieties available without irrigation in the dry season and without timely harvesting and management. Takahashi and Ripperton (1949) have reported that forage CP yields per annum of the Hawaiian type leucaena tended to decrease with increasing the days to harvest from 60 to 120 days; 3.84 and 2.96 kg/ha/annum, respectively. In the absence of irrigation in the dry season capitalization on the seasonal surpluses must be done. Data calculated from Garcia (1988) indicated that leucaena forage under a one or two month harvesting regime under rain fed conditions in central Trinidad could produce about 80% of its protein and dry matter during the wet season months from May to December. Conrad (1978) reported in a review of literature on forage production under Trinidad soil conditions that pangola grass (*Digitaria decumbens*) production during the wet season was 60% of the potential annual production. The experiences in Trinidad and Tobago suggest that very much less than 40% of the annual forage is available during the dry season, as some farmers had almost no pasture from March to May during the last two years.

Some important considerations arise if leucaena forage is to be harvested and managed for maximum/optimum production of CP/ha/annum. The method of harvesting has to be selected to minimise problems due to wet season inundated soil conditions, and therefore some engineering solutions would be required. Additionally, with leucaena having stems which increase in diameter with age, a different harvesting sequence may be required. Furthermore, the plant nutrient requirements of leucaena under a repeated harvesting regime are unknown under the ecological conditions of Trinidad and Tobago or anywhere else in the world. However, leucaena plots have been harvested at the SFC at a two to three month interval over the last six to eight years with only one application of calcium containing quarry waste and there has been good survival of the plants.

Another important consideration is the method of forage utilisation. It could be fed fresh along with other feed ingredients to promote an acceptable level of animal performance. However, if the material is to be ensiled, the high CP requires that it be ensiled either with a soluble carbohydrates or by direct acidification.

In Trinidad leucaena experiences weed competetion at establishment, and demonstrates very slow early growth. Establishment can therefore be costly and this makes leucaena a somewhat unattractive forage proposition to the ruminant livestock farmer whose holding tend to be small and are low investment systems. Varieties tolerant to acid soils would have to be introduced and seed made easily available to all farmers. To speedup establishment direct seeding could be done if the leucaena is planted with a companion crop which would not compete directly with the leucaena, e.g. maize and leucaena. Limited success with this have been achieved at the SFC. The immediate promotion of leucaena and other nitrogen fixing trees with potential for forage utilization in Trinidad and Tobago would require widespread establishment efforts for the propagation of seedlings in large quantities which could be made availabe to farmers at an affordable price. In this respect propagation units of the Forestry and Horticulture divisions within the Ministry of the Environment and National Service and the Ministry of Food Production and Marine Exploitation could be of assistance. This approach would be useful as it would afford the widespread introduction of multipurpose plants on farms which would be of both ecological and economic benefit to the farmer.

Future Work

1. The evaluation of leucaena forage harvesting and processing methods for use in intensive animal production systems.

2. The evaluation and management of leucaena varieties for acid soil tolerance .

3. The integration of leucaena forage production with animal production systems initally involving small ruminants.

4. Widespread propagation and distribution of leucaena planting material.

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Production and Utilization of *Leucaena leucocephala* in Barbados

R.C. Quintyne and G. Proverbs

INTRODUCTION

Barbados is the most easterly of the Caribbean islands being located at 13° north 59° west. It is a small (430 sq km) relatively flat island with the highest point being approximately 370 m above sea level. Barbados has a humid tropical climate. There are two seasons with a wet season running from June to mid-January. The average annual rainfall is approximately 1530 mm with a range of 635 mm to 2030 mm. The soils of Barbados are predominantly calcareous, formed mostly from coral limestone. The vegetation is typically tropical, covering a wide range of species, with a large number of the Leguminosae family.

Leucaena leucocephala grows profusely in Barbados on all soil types and in all the rainfall zones. The Leucaena is predominantly the Hawaii type (Shrubby dwaft). It may be found in road cuttings in uncultivated land, and as a coloniser on land that has gone out of cultivation. Leucaena in Barbados is relatively free from pests and disease. The most important pests are *Melipotis famelica*, *Spodoptera* sp., *Semiothisa* sp. and a psyllid bug (Quintyne, 1983; Proverbs, 1985 a, b). Leucaena has traditionally been browsed by animals of small farmers who obviously recognised its value as a livestock feed. It has also been cut and fed to all classes of animals, including poultry and pigs. Leucaena has been said to "stop pigs from getting too fat" and to keep them "healthy." It has even reported that when preparing horses for shows some owners fed them Leucaena which causes hair to fall out with a subsequent regrowth of a beautiful shiny coat. Leucaena has also found use in the fishing industry. Some fishermen have used some of the finer branches up to 2.5cm in diameter in making strong traps. In spite of the fact that it has been used so widely, it was only in 1976 that any studies on its utilization as a livestock feed were started (Quintyne, 1976). This paper seeks to review this development of the utilization of Leucaena in Barbados.

FORAGE PRODUCTION AND UTILIZATION

Seed of cv. Peru in 1976 and cv Cunningham in 1979 were received from Australia. The giant varieties K8, K28 and K67 were introduced in 1983 from the CARDI Forage Legume Project in Antigua. The first attempts at cultivation were carried out in 1980 when seeds of cv Cunningham were sown into newly planted elephant grass (*Pennesitum purpureum*) this field was later grazed by dairy cows on a six to eight week cycle (Quintyne, Chase and Millington, 1987).

Production

Two methods of Leucaena establishment have been used, direct seeding and transplanting pre-germinated seedling.

Direct Seeding

In a cultivated field with shallow furrows 1m apart seed was dropped by hand into the furrows at approximately 30 cm intervals creating a continuous row, and covered. This direct seeding was also accomplished by the use of a Stanhay Seed Planter with belts specially prepared for Leucaena seed. After cultivation, the field was levelled and then planted by the planter in continuous row 1 cm apart. In both cases the seed was soaked in water over night and then allowed to air dry prior to planting. A good germination of more than 80% was obtained in each case.

Transplanting

The method by which most of the Leucaena has been established has been by transplanting pre-germinated seedling. Small plastic pots 7.5 x 7.5 x 15 cm are filled with a potting mix of sand, peat moss and soil in a 1:1:1 ratio (Proverbs, 1985b). Seeds were planted at a depth not exceeding 2.5 cm and covered lightly with soil and placed in 3/4 shade. Germination occured in three to 14 days. At the beginning of the rainy season the seedlings were transplanted into the field six to eight weeks after germination.

Utilization

In Barbados Leucaena established in pure stands has been used in the following ways:

(a) Protein Banks

The value of Leucaena established and used as a protein bank is well recognised. There is much in the literature that suggests that the nutritive value of tropical grasslands can be improved by the use of Leucaena in this way (Brewbaker and Hutton, 1979). In Barbados protein banks have been established on beef, dairy and sheep farms where animals are allowed access to them for limited periods of time, thus increasing their daily protein intake. The use of hedge-rows has also been employed with Leucaena established on the perimeter of paddocks. By using the giant K8 variety, live fence posts are also established at the same time.

(b) Cut-and-Carry

Leucaena may be utilized in a cut-and-carry system. Stems are cut back and these are fed to animals along with grass and other feed ingredients. In this way Leucaena may also be included in the diets of other classes of animals such as rabbits and pigs.

(c) Leaf Meal

Leucaena has been conserved as a leaf meal which permitted storage for prolonged periods. Leafy stems are cut and placed in the sun to dry. This process takes from as little as three hours to two days depending on the amount of material. After drying, the leaves are shaken or stripped off the stem by hand and stored in bags. An improvement on this method involves the use of simple drying shed with a concrete floor and a roof of a clear rigid plastic material that allows the sun's ray to enter. The shed must be enclosed to prevent the rain from entering but yet allow the air to circulate. Leucaena stems cut and placed in this shed for two to three days are than stripped of dried leaves which are bagged and stored.

The keeping quality of the dried Leucaena leaf is influenced by the type of bag and by the form in which it is stored. Dried leaf stored in a woven plastic bag often turns dark grey in colour as a result of the development of fungus. Dried leaf stored in a bog that does not allow moisture to enter remained green and free of fungal contamination. It was also found that dried leaf that is first milled in a hammer mill store well in either type of bag.

(d) Silage

Leucaena has been ensiled to conserve some of the surplus wet season production. Preliminary studies using small plastic containers holding 30 kg of chopped material indicated that Leucaena ensiled well (Quintyne *et al.*, 1987). Subsequently it has been ensiled in 208 litre steel drums and in a trench silo. The quality of the silage depended on the method used in harvesting the material. When harvested by hand and leaves stripped from stems and chopped in a forage chopper and ensiled with molasses, whether in drums or trench silo, the quality of silage was very good with very little spoilage. This method of harvesting and chopping however, is quite labour intensive. An alternative method of harvesting was by use of a New Holland forage harvester. A stand of cv Cunningham was cut back almost to ground level and the chopped material blown into a forage wagon. This was ensiled in a trench silo. Although the quality of silage made was good, the high proportion of woody material had a negative effect on the feeding value of the silage. This problem could be overcome by developing a system that allows adjustment of height of cut and a frequency of cut that would ensure that only soft non-woody twigs would be harvested.

Nutritive Value

The high feeding value has been well recognised. This has been substantiated by many reports published on its feeding value (Oakes, 1968). This has also been seen as a result of work done in Barbados.

(a) Leaf Meal

There has been much interest generated internationally in Leucaena leaf meal as a substitute for alfafa meal (Brewbaker and Hutton, 1979). Leucaena leaf meal has been incorporated into rations for poultry as a source of protein and carotene and has been known to be of value as a source of vitamin K (Brewbaker, 1976). Table 1 shows the chemical composition of leaf meal from two sources.

The Crude Protein (C.P.) content and the NVI of the leaflet were higher than that of either the leaf or the petiole. The C.P. content of the leaf meal obtained in Barbados was similar to that reported elsewhere (Brewbaker, 1976).

Table 1
Chemical Composition of Leucaena Leaf Meal from Barbados and Antigua

	Source	CP	ADF	NDF	ASH	NVI
Leaflet	Barbados	33.4	19.0	32.0	12.4	89.3
Petiole	"	20.8	44.1	62.7	10.3	46.8
Whole Leaf	"	31.8	21.6	36.8	10.9	80.7
Whole Leaf	Antigua	26.2	21.1	33.4	13.0	75.9
Whole Leaf	"	27.4	18.5	31.0	13.6	84.3

Note: N.V.I - Nutritive Value Index = Digestible Energy Intake Potential
Source: Quintyne *et al.*, 1987.

(b) Mimosine Toxicity

Mimosine toxicity in non-ruminants is well known. It's effect in ruminants has also been widely reported. There have been reports of shedding of wool in sheep feeding on Leucaena for prolonged period and their subsequent death (Hegarty, Schinckel and Court, 1964; Reis, Tunks and Hegarty, 1975) and of hair loss in goats. Other clinical signs such as unco-ordination of gait, enlarged thyroid glances, loss of appetite and excessive salivation have been reported. It has been suggested that diets containing more than 30% Leucaena are likely to cause toxicity problems (Jones, 1979).

In Barbados, there have never been any reports of clinical signs of mimosine toxicity. Even when weaning lambs were placed on a diet of fresh or dried Leucaena supplemented with mineral salts only, for a period of five months, the only suggestion of an adverse effect was the enlargement of one thyroid gland in one sheep (Quintyne *et al.*, 1987). In a study prior to this in mineral salt was not offered, there was some indication of unco-ordination of gait in sheep after five months. A study in which Leucaena replaced up to 50% of their diets, rabbits showed signs of hair loss. This however was not severe (Yard, Thomas, King and Webster, 1989).

(c) Nutritive Value of Silage

There are few reports on the digestibility of Leucaena when fed to ruminants. Values of 50 to 71% dry matter digestibility have been reported (Singh and Mudgal, 1967; Joshi and Upadhyaya, 1976; Upadhyaya, Rekib and Pathak, 1974; Jones, 1979). Dry matter digestibility of 64.4% for Leucaena Silage with a Voluntary Intake of 68.8 g/kg liveweight obtained in Barbados (Quintyne *et al.*, 1987) compared favourable with these reports of Voluntary Intakes of 58 to 85 g/kg liveweight (Upadhyaya *et al.*, 1974; Jones, Blunt and Nurnburg, 1978).

Barbados Blackbelly lambs on a pure diet of Leucaena supplemented with mineral salts had average gains of 22.7 to 68.1 g per day (Quintyne *et al.*, 1987). This compares with the limited amount of data available which suggest that animals fed a pure diet of Leucaena either maintain or lose weight throughout the experimental period or that they gain and subsequently lose weight (Singh and Mungal, 1967;

Upadhyaya *et al.*, 1974; Jones *et. al.*, 1978). Holstein steers on a diet of Leucaena silage and cassava silage for 196 day gained 571 per day (Quintyne *et al.*, 1987).

(d) Animal Performance on Leucaena/Grass Pasture

Leucaena pastures are some of the most productive in the tropics, offering protein levels as high as 21.6%. When it is incorporated into various livestock production systems, high yields of quality forage are obtained. Such pastures have demonstrated some of the highest carrying capacities of beef in the tropics. In Australia such pasture have carried five to seven animals per hectare and produced liveweight gains of up to 1 kg per day when rotationally grazed (Proverbs, 1985b). In Fiji, when Nadi blue grass (*Dicanthium caricosum*) pastures with 0, 10 or 20% of the area planted with Leucaena were grazed at 1.5 steers per hectare, daily liveweight gains of 215, 300 and 500 g respectively were obtained (Partridge and Ranacou, 1974).

In Barbados, with Leucaena producing 20 to 25% of total forage dry matter from pasture in which it was mixed with four different grasses, Coast Cross 1 (*Cynodon* sp.), *C. plectostachyus*, *Panicum maximum* (Guinea grass) and *Digitaria* sp. (Transvala). Jamaica Red calves, during a seven month pre-weaning period registered liveweight gains of 1.0 to 1.04 kg per day when pastures were rotationally grazed. These same calves gained at 1.12 kg per day after weaning (Proverbs, 1985a). These pastures were supplemented with mineral salt and, during the dry season only, molasses. During the 1982 to 1988 seasons, the calving rate of the cattle on these pastures was 88 to 93%.

(e) Effect of Leucaena on the Performance of Rabbits

Leucaena has always been used by backyard rabbit producers in Barbados as a source of greed feed for rabbits. This is often fed along with other green material, such as other legumes and grasses. Yard *et al.*, (1989) at the Central Livestock Station looked at the effect of including Leucaena in the diet of rabbits weaned at four weeks as a replacement of commercial pelleted feed at 0, 25 and 50% of the diet. The results of the study are summarised in table 2.

Table 2
Performance of Rabbits Fed 0, 25 and 50% Leucaena Forage in the Diet

Leucaena Level (%)	0	25	50
Initial Wt. (kg)	0.4667	0.6389	0.5778
Final Wt. (kg)	2.425	2.306	1.839
A.D.G (g/day)	34.36	29.25	22.12
Carcass Wt. (kg)	1.220	1.087	0.757
Dressing %	49.78	46.72	40.85

There is very little information available on the effect of Leucaena on the performance of rabbits. Harris, Cheeke, Patton and Brewbaker (1983) reported that the crude protein digestibility of a ration containing 40% Leucaena fed to rabbits was 67.7%, digestibility of cell wall was 12.5% and of acid detergent fibre was 16%. Owen (1981) cited work in which up to 60% of a commercial rabbit pellet was replaced by Leucaena without a reduction in the average daily gain (ADG). Yard *et al.* (1989) found that the ADG of animals on the 25% Leucaena was significantly higher than on the 50% level. The ADG of the animals on the commercial ration was significantly higher than the 25% Leucaena, however, on examining the cost of production, they reported that the greatest profit per rabbit was obtained at the 25% Leucaena level. They also reported that hair loss was noticed, particularly in the case of rabbits fed 50% Leucaena with minor instances observed in the group receiving 25% Leucaena. This supports the observation by Cheeke, Patton, Lukerfaken and Mc Nitt (1978) that mimosine causes hair loss in rabbits. These workers also suggested that Leucaena should not make up more than 10% of the total diet dry matter.

Conclusion

Work being done on Leucaena world-wide indicates that it is a valuable source of livestock feed. Experience in Barbados has supported these reports. Leucaena is of particular value in pasture systems and as such should be more widely used on farms. The possibility of conserving and utilizing either as leaf meal or silage needs to be further explored. However production systems and harvesting methods for these purposes need to be developed. Because of the high protein and mineral content of the leaves of this plant and because of its adaptability, Leucaena has a great future in livestock production in Barbados.

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Leucaena: A Simple Production System for the Small Farmers

N. R. Gibson

INTRODUCTION

The propagation system discussed in this paper is based in part on work done in Barbados by CARDI, and described in the publication "Leucaena, A versatile Plant" (Proverbs, 1985). The main body of this paper is based on further work done on Leucaena between 1986 and 1988.

Leucaena leucocephala (Lam.) de wit is a tropical, leguminous tree or shrub of the sub-family mimosoideae. It is best known for its use as animal feed, in erosion control and making fence posts. In Barbados, CARDI has for many years been involved in Leucaena research, in association with the Ministry of Agriculture. In 1980s, seeds of the varieties Cunningham (dwarf-type used primarily for forage) and K8 (giant-type used mainly as fence posts and for erosion control) were imported from the CARDI forage legume project in Antigua. These varieties have since been established on several livestock farms and form the basis of most of the Leucaena research done in Barbados. In many parts of the country wild-types can be seen growing on abandoned land, and in many places have become a noxious weed. Farmers have traditionally used these wild varieties to feed almost all classes of livestock, including cattle, pigs, poultry and small ruminants. However, since the introduction of cultivated varieties, the scope of Leucaena production and utilization has widened considerably. Over the last eight years the demand for these varieties, especially Cunningham, has continued to grow. This has resulted largely from vigorous promotional activities by CARDI and the Ministry of Agriculture, projecting Cunningham Leucaena as a highly productive forage legume that is ideally suited to the establishment of protein, and protein-energy banks. This has had tremendous impact especially during severe dry seasons. During the height of the dry season farmers were taken to demonstration farms where Leucaena protein banks had been established. The visual impact of green succulent Leucaena leaves and stems standing out from parched, brown grass has proven to be the most effective means of impressing upon farmers, the importance of incorporating legumes into their pasture systems.

The high costs of imported fence posts and the scarcity of local trees suitable for timber (Barbados has no forests) have prompted farmers to seek other means of fencing their pastures. K8 Leucaena has found increasing use in this regard, as farmers have begun to use this variety more and more for fencing, as well as erosion control on steep slopes. As the demand for both varieties continued to grow, the need to develop a simple propagation system for Leucaena because more apparent.

MATERIALS AND METHODS

Seed Availability

Seeds of the two varieties Cunningham and K8 were originally obtained from the CARDI Forage Legume Project in Antigua. This under-utilized project, can meet the present demand for Leucaena seeds in the Eastern Caribbean. Over the last few years however, there has been no need to import seeds for Antigua, and instead seeds have been collected from existing Leucaena stands. Seeds are normally collected between January and May and stored.

Scarification

Leucaena seeds possess an impervious, waxy seed coat which acts as a germination inhibitor. Because of this only 2 to 12% of harvested seeds will germinate. Scarification is therefore necessary, in order to obtain a more acceptable germination percentage. Three methods of scarification have been suggested for Leucaena:

1. Hot water
2. Acid treatment using concentrated sulphuric acid
3. Mechanical

At CARDI the simplest and most effective treatment has been that of hot water. All that is needed is a heat-resistant container, and a mercury thermometer with a maximum temperature of 1100C. Boiling water is poured into a beaker or any other suitable container, and a thermometer is used to measure the temperature. When the water cools to 800C the Leucaena seeds are then poured in, and the "mixture" is allowed to cool, and stand for three days. The volume of water used should be twice that of the seeds, so as to avoid excessive imbibition. After three days, the excess water is poured off and the seeds are then treated with a fungicide. Any suitable fungicide that gives protection against common seedling fungal diseases can be used. After treatment, the seeds are spread out on a suitable surface and allowed to air-dry. This last step is not absolutely necessary, but it facilitates handling.

The Potting Mixture

Experiments have shown that a potting mixture of soil, peat moss and sand in a 1:1:1 ratio, is the best medium for the healthy growth and development of Leucaena seedlings. This mixture remains porous and is fast draining while retaining sufficient moisture for healthy growth. The mixture works well, but requires thorough watering at least twice per day. Where there are no automatic watering systems and where there is a shortage of labour, a potting mixture of soil, peat moss and sand in a 3:2:1 ratio may be used. This mixture reduces the need for frequent watering but stays sufficiently porous to ensure adequate aeration of the root system. Best results were obtained when the soil, peat moss and sand were sieved. The holes in the sieve need not be smaller then $0.75cm^2$. Fumigation has never been necessary at CARDI, but it is recommended for large scale production.

Containers

Black polythene bags or small pots can be used. At CARDI, small plastic pots 7.5 x 7.5 x 15cm with a drainage hole were used. These pots are lightweight and durable and can be used repeatedly. There were ideal for Barbados conditions, and propagation system. In St. Lucia, CARDI has also used polythene bags with equal success.

Racks

Racks were built to hold the pots. They constructed basically of wood and wire. All that is needed for the construction of one rack, is four sturdy posts about 1.6m long and 10-15cm in diameter, eight laths to construct the frame, and a length of BRC wire measuring 1.6 x 5.0 m, with 58cm² partitions. Four holes are dug, and the posts are concreted into the ground to form a rectangle 1.6 x 5 m. The laths are then nailed onto the posts to form a frame upon which the BRC wire will rest. The BRC wire is then stretched over the frame and fastened with nails. The pots fit precisely into the partitions of the BRC wire, and are thus supported.

Procedure

The potting mixture is placed in the pots, and the treated seeds are sown at a depth not exceeding 2.5cm. The pots are then thoroughly watered to ensure uniform moisture distribution. At the start of the project, the seeds were sown in pots in the nursery under shade. They were transferred to the racks outside about two weeks. This method proved to be a major constraint to throughput, and was soon abandoned. Presently, the pots are filled with potting mixture and placed directly in the racks outside. The seeds are then sown in the pots, and a 40% Saran netting frame is then placed over the racks. This gives the germinating seedlings some protection from the elements, especially heavy rainfall. Approximately two weeks after, the Saran netting can be removed.

RESULTS AND DISCUSSION

Germination is usually around 85-90% from Cunningham, and between 90-95% for K8. Seedlings start to emerge between 24-72 hours after sowing, and grow very slowly over the next eight weeks. The seedlings are watered and periodically treated with Formaldehyde mixed with animal feed, to control slugs. These are the only pests which attack the young seedlings to any significant degree at this stage. The treatment is effective and can be discontinued after four to five weeks. Since at least two seeds are sown per pot, it is necessary to thin out the seedlings to allow a single seedling per pot to develop. The extra seedlings can be put into pots where the seeds may have failed to germinate. This ensures that no pots are wasted. After eight weeks, the seedlings are ready for transplanting. They are about 20-30cm high and at this stage, have well developed tap-roots. They can now be pulled out of their pots without damaging the root system, since the soil forms a compact, cylindrically-shaped mass around the roots. This is very sturdy and facilitates the transplanting operation.

Pots containing mature seedlings (at least eight weeks old) are normally packed into a truck and delivered to small farmers. Farmers who have their own transportation are encouraged to collect their seedlings from the CARDI nursery. As soon as pots are removed from the racks, they are replaced with fresh pots and seeds are sown immediately.

This system ensured a near-continuous supply to seedlings throughout the rainy season. The major bottleneck of this method, is the length of time it takes for successive batches of seedlings to be distributed. This period is approximately equal to the length of time it takes for the seedlings to mature, which is about eight weeks. Even when the planting dates of the seeds were staggered, it still resulted in a relatively low throughput, although there was greater continuity. To overcome this problem, CARDI decided to encourage farmers to take a more active role in the seedling propagation process. Since the demand for the seedlings greatly outstripped our ability to supply them, we encouraged farmers to collect the seedlings before they were fully mature. Seedlings were then distributed at four weeks of age. This meant that the farmers were now responsible for the care and development of the seedlings for the next four weeks. As a result the time that one batch of seedlings remained in the nursery was reduced by half, leading to almost double the throughput. Even with this system, it was still not possible to meet the growing demand. At this stage CARDI started distributing seeds to interested farmers. Some of the farmer s sowed the seeds in a nursery, either in plastic bags or in pots, while others preferred direct sowing into prepared fields. Whatever the system, the farmer got involved in the whole business of Leucaena seedling propagation principally because of the application of simple extension practices.

In Barbados, livestock farms range in size from 2-80 ha. The success of this Leucaena propagation system is largely constrained by farm size. It is inconceivable that such a system could adequately service farms larger than 80 ha., even though CARDI has had some success with farms of around 75 ha. in size. The emphasis has not so much been on the actual system of propagation since this will always be adapted to suit local conditions. The focus has been in two areas. The first was, making farmers aware that there were simple propagation method which they can use. Secondly, alerting them to the fact that agricultural institutions like CARDI, and the Ministry of Agriculture are willing to help farmers get started, and provide them with the necessary research and technical support. This has been done hand-in-hand with on-farm demonstrations of the diversified roles that Leucaena play in livestock production systems. These factors have played a vital part in demonstrating to farmers, that *Leucaena leucocephala* has the potential to transform their production systems, so that they could become better equipped to deal with the problems of low quality forage and to be able to provide adequate feed for their animals during the dry season. It is recognised that in the Caribbean, one of the cheapest ways of providing protein for ruminant animals, was by incorporating legumes into the pasture system (Paterson, Phillip and Maynard, 1986). Realizing too that they can save money by using Leucaena as fence posts has also helped to make the plant more attractive to farmers.

CONCLUSION

Whatever propagation system was used, it was necessary to have an adequate extension programme. The approach has to be fully integrated, and one of the aims should be to get farmers involved at an early stage. It will be necessary for an Institution like the Ministry of Agriculture or CARDI to be involved, in order to provide the thrust needed for the success of such a programme. This system was designed to suit the needs of small farmers and as such it would need a lot of modification if it were going to be used to service larger farms. It is recommended that in the early stages, mature seedlings should be made available to farmers. However, as farmers become more involved they should be encouraged to take immature seedlings and care for them until maturity. Ultimately, seeds should be distributed to farmers, either for seedling production in a nursery, or for direct sowing. Such a programme would have the potential for rapid growth, and it can be expected that in a few years adjustments would have to be made to meet the growing demand for *Leucaena leucocephala*, firstly as a highly productive forage legume and secondly an invaluable resource for fencing and erosion control.

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Leucaena for Livestock Production: The Grenada Experience

K.U. Buckmire

INTRODUCTION

Leucaena is found as dispersed trees throughout Grenada and Carriacou. However, this leguminous plant is more commonly seen in the drier north and south eastern parts of the Island of Grenada. The planting of Leucaena in rows as a crop began in 1982 when Grenada became actively involved in the sub-regional Leucaena project sponsored by the General Secretariat of the Organisation of American States, Department of Scientific Affairs. Other activity with Leucaena in Grenada are joint efforts of the Ministry of Agriculture Grenada and the Caribbean Agricultural Research and Development Institute (CARDI). Pure stand plantings of Leucaena is of primary interest to Grenada as it allows for the all year harvesting of a highly nutritious animal feed that can ultimately play a significant role in the animal production systems in the State.

A pilot plot of just over two hectares was established in 1985-86 on a Capital clay Loam soil at Marlmont in Grenada. The objectives of the pilot were as follows:

1. To obtain production and economic data,
2. To produce forage material suitable for animal feed,
3. To assess the nutritional levels of the dry meal, and
4. To evaluate the feasibility of producing a local protein source from Leucaena plants.

ESTABLISHMENT

Seeds of *Leucaena leucocephala* cv. Cunningham was obtained from CARDI. Scarification of the seeds was done by placing them in a container with water at 80ºC. The seeds were allowed to soak in this water for three days after which they were set out in a nursery bed. By the time the seeds were ready to be transferred to the nursery bed most of the radicles would have emerged. Approximately 6912 seedlings were obtained from 454 grams of seeds. In the nursery bed the seeds were covered with a thin layer of well rotted sawdust. The entire bed was protected by a thick layer of Kush-Kush grass, *Vetiveria zizanoides*. This enhanced germination. In three to four days germination occurred and the grass cover was removed. The young plants were kept moist and left undistributed until the first true leaves were formed.

With the bed well watered the seedlings were transferred to plastic pots and left in 3/4 shade. The seedlings were gradually expose to more light until by three to four weeks they were exposed to full sunlight. Young seedlings eight to ten weeks old were transplanted to the field. Plants were removed from the pots taking care not to damage the roots and keeping the entire mass of soil in contact with the roots. Spacing was 1m x 1m. Care was taken after planting to prevent waterlogging.

MANAGEMENT

In the pilot plot under investigation, the plants were allowed to grow for nine to twelve months before the first cutting. Gramoxone (Paraquat) was used to control weeds. On an average the field was sprayed with a weedicide three times per year. Spraying was done soon after cutting. In Grenada no significant pest and disease problem were observed, but some plants showed signs of cercospora leaf disease. Two application of Manzate 200 cleared the problem.

When the Leucaena field reached 50% flowering regime the plants were cut using either a cutlass or a motorised brush cutter. The Material was then transported to a galvanised covered shed and placed in trays. These were 245cm long by 88cm wide by 14cm deep with 7mm x 7mm wire mesh wire floors. The trays were stacked one above the other. In three days the leaves were shaken off the branches and stems and left in the trays for another 10 to 15 days by which time the moisture content was reduced to 10 to 11%. During the drying period the meal was turned every day. The leaf meal was then bagged and stored. Drying in he shade away from direct sunlight allows the drymeal to retain the green coloration. When exposed to direct sunligh for drying the leaves turned brown.

With the objective of obtaining information on the effects of size of plot on dry meal yield and on regrowth regime an experiment was laid out in randomised complete block design of four treatments and four replicates. The plants were spaced 1m x 1m.

RESULTS AND DISCUSSION

Observations confirmed the findings published by Gueverra (1976), Brewbaker (1976) and Wong and Devendra (1982). The cutting interval was selected at the time of 50% plant flower but before pod formation. All plants were cut back 45 to 60 cm above ground level (Table 1).

The cutting regime reported in Table 2 was for a plot of 750 square metres during 1987 and 1988. The dry season was between January and May. The plants took a relatively long time to recover from the dry spell.

Table 1
Effect of Cutting Intervals on Yield (kg/ha) of Leucaena Leaf Meal

Size of Plot (m^2)	Yield (kg/ha) Cuttings per Year	
	3	4
50	3400	4600
100	3350	4330
200	2425	3363

Table 2
Cutting Regime of Plot (750 m²) as Influenced by Rainfall

Month of Harvest	Total Rainfall for Period (mm)	Days of Harvest	Total Leaf Meal Harvested (kg/ha)
February	85	35	873
May	97	72	700
September	1259	123	903
November	292	87	840
January	256	39	820

LEAFMEAL YIELD

Table 3 represents the data obtained on leaf yield. The regrowth regime was shortest for the 50 m² plots with each replicate having four cuttings in one year. The other three treatments varied between three and four cuttings in a year. The extrapolated yield show that 400m plots gave the lowest drymeal yield. Rainfall affected the regrowth rate and hence the cutting regime. The intervals between cuttings was in Table 2. The rainfall figures are the mean for 1987 and 1988. Abundant light regime tend to shorten the cutting period between November and February.

Table 3
Mean Annual Yield (kg/ha) of Four Replicates per Stand for Leucaena Leaf meal from Four Plots Sizes—Grenada

Treatment (M²)	No. of Cuttings	Leafmeal (kg/ha)
50	4	4314
80	3 - 4	4383.75
100	3 - 4	3802.5
400	3 - 4	2537.5

FEEDING LEUCAENA TO BLACKBELLY SHEEP

In an observation trial lasting over 50 months six Barbados blackbelly sheep were fed on 100% Leucaena. The feed was either fed dry or freshly cut. During the period three mothers gave birth to a total of sixteen lambs, three of which died. The feed acceptance by the animals were excellent. They all remained healthy and produced adequate milk for the young. The lambs gained on an average 4 kg per month (143g/day) up to five months after birth. The animals experienced no ill effects in looks, shape of general behaviourial pattern.

ECONOMIC ANALYSIS

Cost of establishing one hectare of *Leucaena leucocephala* cv. Cunningham was EC $9,640.44 ($ 0.5 US = $1 EC). The highest component of cost was fencing. Once the field was established, in about nine months the first cutting was be made. In the first 12 months two cutting could be made and there-after generally four crops per year. The harvesting and processing cost are shown in Table 5.

Table 4
Cost of Establishing One Hectare of *Leucaena leucocephala* (Cunningham) in Grenada

	Man Hours	Unit Price (EC$)	Cost
Labour			
1. Land clearing	114	2.60	296.40
2. Land preparation	5 (tractor hours)		225.00
3. Scarification of Seeds	0.25	3.75	0.94
4. Nursery work	46	2.60	119.60
5. Transfer to pots	171	2.60	444.60
6. Transplanting	300	2.60	780.00
7. Weed control	26	2.95	76.70
8. Fencing	1370		3562.00
		Sub-Total	5505.24
Services			
1. *Transport*			
Seedlings		50	200.00
Fencing Material		50	50.00
		Sub-Total	250.00
Materials			
1. Seeds		100.00	150.00
2. Fence Posts		0.32	112.00
3. Wire Fencing		126.00	2646.00
4. Weedicide		11.20	100.80
		Sub-Total	3008.80
		Sub-Total Cost	8764.04
		10% contingencies	876.40
		Total	9640.44

Table 5
Cost of Producing Leucaena Leaf meal from One Hectare of *Leucaena leucocephala* (Cunningham)

	Man Hours	Unit Price (EC$)	Cost
Labour			
1. Weed control	26	2.95	76.70
2. Harvesting	150	2.60	390.00
3. Post Harvest Processing	119	2.60	309.40
5. Bagging	146	2.60	379.60
		Sub-Total	1155.70
Services			
1. Transport fresh produce		50	400.00
		Sub-Total	400.00
Materials			
1. Weedicide (grammoxone)		11.20	100.80
		Sub-Total	100.80
		Sub-Total Cost	1656.50
		10% contingencies	165.65
		Total	1822.15

CONCLUSION

Leucaena leucocephala cv. Cunningham is well adapted to the environmental conditions in Carriacou and Grenada. The plant produces good foliage which could be used both as a fresh forage and as dry leafmeal for the feeding of small ruminants.Using both manual and hand operated motorised cutters leucaena can be harvested three to four times per year giving drymeal yield of 3.3 to 4.6 tonnes per hectare. Observations indicated that the leafmeal when dried to 90% dry matter can be successfully stored for many months without any noticeable physical change. The stored dry leafmeal can be utilised to feed animals during the dry season when forage production is much reduced. Rainfall pattern affects not only the growth pattern and cutting regime of the crop but influences the dry leaf meal yields. The cost of establishing Leucaena fields is high, however if this figure is spread over a ten to twenty year period this would give a more realistic cost of production. Including the labour and material cost for fencing in the economic analysis may seem harsh but it is essential to have Leucaena fields fenced especially during the early years of growth. This prevents animal damage and possible complete destruction of the crop.

The maintenance of harvesting and processing costs of Leucaena dry leaf meal indicates that the crop can be economically grown by small farmers in Grenada. The potentials of Leucaena in the livestock production system in Grenada and Carriacou suggest the crop could an important component in the small stock feeding programme in dry small Caribbean islands.

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Leucaena as a Source of Renewable Energy, Feed Ingredients and Fertilizer

D. Minott and C. Lewis

INTRODUCTION

The paper summarises the results of industrial scale processing of Leucaena raw materials to produce fuel, feed and fertilizer using the ENERPLAN process. Yield figures on the production of fuel gas, protein ingredients and fertilizers are given for typical industrial fermentation parameters under anaerobic mesophilic conditions. A video tape presentation showing operations with fermented Leucaena products, including electrical power generation, animal feed production and broiler chicken farming concludes the presentation.

THE PRESENTATION

The raw materials available from Leucaena are wood, leaves, pods and bark. Under the intensive cultivation of the giant types of Leucaena for forage, Leucaena yields in Jamaica of eight tonnes of leaves and twelve tonnes of wood (bone dry) have been achieved under irrigation.

The patented ENERPLAN fermentation process is able to recover between 200 m³ and 580 m³ of Leucaena fermentation gas per tonne of dry leaves fermented. The optimum retention time depends on the method of "substrate contact" employed. At the ENERPLAN plant, using an 18 day retention time, a steady annual rate equivalent to 90,750 m³ of Leucaena fuel gas has been produced based on daily processing equivalent to one tonne of Leucaena leaves. When scrubbed of $C0_2$, the resulting product, ENERGAS®, is released at a rate of 67,000 m³ per year.

The typical analysis of ENERGAS® is 82% methane and 18% hydrogen by volume. This has an upper heating value equivalent to good "sweet" natural gas. The theoretical maximum production of Leucaena gas is 799 m³ per tonne of dry leaves. A one tonne per day plant will continuously generate 81 KW of thermal power or 24.2 KW of electrical power plus heat. The gas is delivered at pressures of 30 psi and over. For higher rates of "contact" the rate constants allow for higher levels of power production than herein stated. This is a fruitful area for future research.

For a plant processing one tonne per day of 25% protein leaves (LM 24) under the conditions of the ENERPLAN process, approximately 255 tonnes of 33% protein solids (LM 33) are also produced. The Amino Acid profile of LM33 compares well with that of soya bean meal (Lewis, 1987).

ENERPLAN Ltd., under contract to International Renewables Ltd., a sister company, has been able to produce broiler chickens commercially on feed mixes which substitute for up to 35% of the soya meal concentrate with LM33.

The Leucaena liquor by-product has a typical dry basis analysis of 13.5% Nitrogen, 3.5% Phosphorus and 35% Potassium.

Leucaena wood chips have a heating value of 1.942×10^4 KJ/kg so that each tonne of chips burnt per day produces 224 KW of thermal power of 67 KW of steady electrical power plus heat.

We now present a video-tape documentary of our work.

ACKNOWLEDGEMENTS

Our work is part of company activities in which Messrs Alwin Hales, Brian Silvera and Dwight Butterfield are major contributors. We thank all the members of our team at ENERPLAN.

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The Use of Leucaena with Grasses in Forage Banks in St. Kitts and Nevis

H. Patterson and O. Williams

INTRODUCTION

Leucaena has been used throughout the world for various purposes; erosion control, fence posts, windbreak and soil restoration, but by far the most important potential for the Leeward islands as its use as a source of forage for ruminant animals. The annual rainfall in Nevis varies between <1,000 mm in the semi-arid areas along the east and south coast to 2,500 mm on the humid slopes of Nevis peak. At present the availability of land for pasture establishment is limited. Most livestock are grazed on rough grazing of improved pastures. As a result animal productivity is low and carcass quality is poor. In general Leucaena and other protein-rich plants such as Gliricidia are used in an *ad hoc* manner to feed ruminants, especially during periods of drought.

Forage banks in St. Kitts and Nevis and elsewhere offer a more controlled and organised system of utilizing these protein-rich plants. Taking into account these inadequacies CARDI has been promoting in St. Kitts and Nevis, as well as other countries in the region, the greater use of forage banks especially for dry season feeding. To date, however, insufficient use is made of forage banks where they exist, either for short duration grazing prior to the animals being turned into grass pastures, or for cut and carry systems. During the wetter months there is generally sufficient feed available for livestock maintenance and production, but during the dry season farmers spend much time gathering feed, often of questionable quality just to maintain their stock. The establishment of forage banks is seen as a way to improve animal management and productivity.

MATERIAL AND METHODS

CARDI, in colaboration with the Nevis' Department of Agriculture and CARDATS and with the assistance of the farmers, established protein/energy banks (forage banks) at two demonstration sites in Agro-ecological Zone 1 in Nevis: At Cades Bay with an annual average rainfall of 1,150 mm (36 year average) and at New River with an annual average rainfall of 750mm (31 year average). The standard legume in the system was *Leucaena leucocephala*. At Cades Bay, with the higher rainfall level, elephant grass (*Pennisetum purpureum*) was used, while guinea grass (*Panicum maximum*) was used for the lower rainfall area (New River). The guinea grass *P. maximum* was planted between parallel rows of Leucaena leucocephala which was spaced at 0.91 x 1.83 m (1.67 m^2). The Leucaena was both direct seeded and transplanted. Once the Leucaena was established super phosphate was applied at a rate of 210 kg/ha. Pen manure was broadcasted over the entire area and 0.68 kg of Siratro (*Macroptylium atropuropureum*) was also broadcasted over the [illegible].

Vegetative clumps of *Panicum maximum* were dug and the tops removed. These were slotted into holes created by using a hoe. The spacing arrangement was 60 cm x 60 cm (0.36 m^2). *Leucaena leucocephala* was planted in November 1986. Elephant grass *Pennisetum purpureum* cuttings were planted at a 30 cm x 60 cm spacing between the Leucaena alleys. Guinea grass *Panicum maximum* was planted at 30 cm x 30 cm spacing between Leucaena alleys.

Twelve 1.67 m^2 plots were randomly allocated between the *Panicum maximum* and *Pennisetum purpureum*, from which forage yields were harvested. Both fresh weight and dry weight yields were recorded. Five randomly selected *L. leucocephala* plants were harvested every three months, from which both fresh and dry weights were recorded. Data on cost of establishment of forage banks and other variable cost of production were recorded for use in economic analysis. Monthly liveweight changes of ten two-week old Creole lambs (average initial liveweight of 3.29 kg) inside the protein/energy banks was also recorded.

RESULT/DISCUSSION

Establishment

The planting of guinea grass was very labour intensive, requiring several operations to prepare the vegetative material. Establishment costs represented 39% of the overall cost of producing guinea grass. Though the establishment of elephant grass was less labour intensive, this grass is more suited to areas with higher rainfall and deeper soils. The average cost of establishing forage banks in Nevis was EC$2242. Direct costs attributable to Leucaena were EC$318. To total area established was 0.20 hectares at Cades Bay and 0.3 hectares at New River. No costs for fencing were included in the production costs.

During late 1986 and mid 1987 when the establishment of the forage banks was undertaken, rainfall was adequate for rapid establishment of the grass setts and the Leucaena seedlings. The most serious setback to establishment of Leucaena was the attack by tow insect pests: *Spodoptera* Spp. and a psyllid bug *Heteropsylla cubana* (Crawford). Keoghan and Proverbs (1987) reported similar deleterious effects of insect damage to young Leucaena plants in CARDI, Antigua studies. These were controlled chemically. *Sida* spp. - a member of the Malvacea family was the most prevalent weed. This was rogued.

Forage Production

Forage yields are influenced by the variety, harvest interval and the climatic and environmental conditions. Generally the annual yield of dry matter (DM) from Leucaena is anywhere from two to twenty tonnes per hectare (Proverbs, 1985). In Nevis Leucaena yields were reasonably good considering the limitations in moisture. At New River with an average annual rainfall of 750 mm, dry matter yield from Leucaena of 4.093 tonnes over a nine month period (Table 1) was recorded. At the Cades Bay forage bank with higher annual rainfall (1,150 mm) DM yield from Leucaena was 8.175 tonnes over a ten month period (Table 1). Measurements in Antigua and Barbados have shown that under favourable or relatively favourable growing conditions the yield of Leucaena forage reaches a maximum of 4,000 to 5,000 kg DM/ha after two to three months of regrowth (Keoghan and Proverbs, 1987). Under Nevis conditions for a similar period, the production of Leucaena averaged only 1,364 to 2,452 kg DM/ha. Both elephant grass and Leucaena production at Cades Bay appear promising (Tables 1 & 2). This forage bank was under-utilised in the wet season. Data was not recorded beyond March 1988 because of overgrazing.

Table 1
Leucaena Production in Forage Banks in Nevis 1987/88 (kg/ha)

	New River					Cades Bay				
Forage Cut	June '87	Aug. '87	Nov. '87	Feb. '88	Total	June '87	Sept. '87	Dec. '87	Mar. '88	Total
Fresh Wt. (kg/ha)	3818	3518	2900	1281	11518	3923	4318	10573	7532	26346
Dry Wt. (kg/ha)	1335	1115	928	715	4093	1298	1415	3202	2260	8175

Table 2
Production of Elephant Grass of Cades Bay, Nevis 1987/88 (kg/ha)

Forage Cut	Sept. '87	Oct. '87	Dec. '87	Feb. '88	Total
Fresh Wt. (kg/ha)	6595	9449	7150	5398	28592
Dry Wt. (kg/ha)	2984	2362	1930	1475	8842

Protein/Energy Banks

Leucaena can be planted on its own to form a Protein bank or with tall grasses to form Protein/Energy banks (Keoghan, 1980). Protein banks, or solid Leucaena stands, probably constitute the best system of management, and the most efficient method of utilization is probably to allow animals short periods (30 to 60 minutes) daily to graze Leucaena before grazing grass pastures (Proverbs, 1987).

In Nevis, Guinea grass (*Panicum maximum*), Elephant grass (*Pennisetum purpureum*) and forage sorghum were used as the companion grasses to Leucaena in protein/energy banks. For small acreages as in Nevis or other small farmer situations in the Leeward Islands a cut and carry method of forage bank management is preferred. Sometimes the forage banks could be grazed but only in a restricted manner to avoid permanent damage to the grass/legume stands.

The mean dry matter yield of the protein/energy bank at New River, Nevis monitored over a ten month period was 30,696 kg based on a four to seven week cutting cycle (Table 3). This compares favourable with results obtained in St. Croix where yields were 8,000 kg/ha based on a six week cutting frequency. Rainfall in one period influenced forage production in the subsequent period. The high level of rainfall obtained during March to May shortened the cutting interval in the following period (26 days) and also resulted in a secondary peak in forage output (Figure I). As rainfall levels declined between June and September 1987 there was a fall off in forage output and a lengthening in the days to harvesting (70 days). Data was unavailable for the months of November and December 1987 due to plot damage caused by young animals (lambs). Only limited data was obtained during the first six months of 1988. This resulted from ewes and lambs being turned into the forage bank.

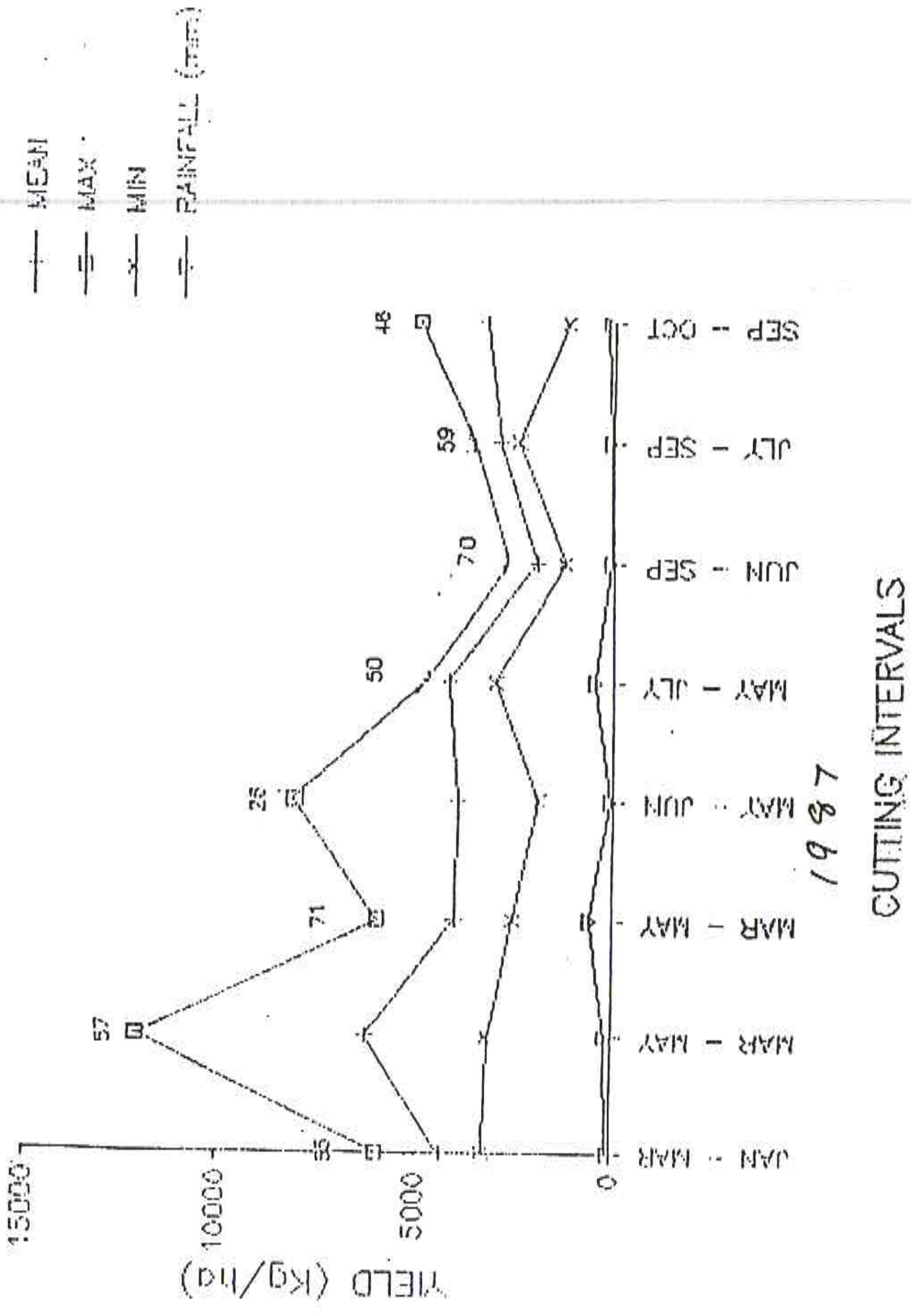

Figure 1
Forage Production : Dry Matter (Kg/ha)

Some attempts were made to conserve forage as silage in 55 gallon drums. However some 1.2 tonnes of silage made in February 1987 and two tones of chopped pangola grass was inadequate in meeting total flock requirements during the dry season. There is definitely a need to regulate flock size in relation to the productivity of the forage bank. Forage conservation during peak production periods should also be more systematic. In addition the construction of a simple pit silo would have been more appropriate for the farm in New River than using 55 gallon drums. The feasibility of offering supplementary concentrate feeding should also be studied in relation to returns from the farm.

Table 3
Productivity of Forage Banks at New River, Nevis (1987)

Harvesting Period	Jan-Mar	Mar-Mayu	Mar-May	May-Jun	May-Jul	Jun-Sept	Jul-Sept	Sept-Oct
Harvesting Intervals	55	57	71	26	50	79	59	46
Plot 1 (Dry Matter kg/ha)	6000	3550			2950		3550	2950
Plot 2 (Dry Matter kg/ha)	3750	12100			4750		2650	4900
Plot 3 (Dry Matter kg/ha)	3250	3150			4750		2400	4950
Plot 4 (Dry Matter kg/ha)			6000	4850		1950		2150
Plot 5 (Dry Matter kg/ha)			3550	3300		1200		1150
Plot 6 (Dry Matter kg/ha)			2500	2150		1950		
Plot 7 (Dry Matter kg/ha)				3300		2050		
Plot 8 (Dry Matter kg/ha)				8100		2600		
Plot 9 (Dry Matter kg/ha)				1850		1750		
Mean	4333	6267	4017	3925	4150	1917	2867	3220
Max.	6000	12100	6000	8100	4750	2600	3550	4950
Min.	3250	3150	2500	1850	2950	1200	2400	1150

Cost and Returns from Animals Fed on Protein/Energy Banks in Nevis

Returns from the sheep enterprise was negative for the period March to December 1987, and only slightly positive (EC$ 226.74) for the period January to June 1988 (Tables 4 & 5). Time spent tethering sheep was the largest component of labour inputs representing 66.9^ of the total labour costs and 62% of the total costs for the period March 1987 to June 1988 (Tables 4& 5). Time spend cleaning pens also contributed significantly to the cost of production (15.3% of total costs and 16.5% of total labour cost). together tethering and cleaning of pens accounted for 77.2% of the total costs of production and 83.4% of the total labour costs (Tables 4 & 5).

During the drier months time spent tethering was relatively high as animals stray widely in search of feed. Predators (dogs) also caused dispersal of animals. During the wetter months time spent tethering declined dramatically (Table 4). Time spent tethering animals can be significantly reduced if fewer animals were kept and also if total feed requirements could be met from within the intervention (forage bank) year round.

In comparison with the production costs inputs for sheep, those for goats reflected the fact that the goats were kept for the most part within the intervention, using the forage banks. Returns from the production of goats were also negative for the period March to December 1987 and only slightly positive for January to June 1988.

Table 6 and Figures 2 and 3, shown in the growth rate pattern, Average Daily Gain (ADG) for the ten sheep on the test. The two months at the beginning of growth period coincided with a period of high forage production so the ADG was high. Growth rate declined steadily except for a few slight increases in the 7th and 9th months of age.

Table 4
Cost and Returns Sheep Production March to December 1987

A.	Value of Opening Inventory (EC$)	6230
B.	Value of Sheep Sold During Period (EC$)	3360
C.	Value of Inventory at end of Period (EC$)	3990
D.	Value of Production During Period (EC$) = (B+C-A)	1120

Input Categories	Units	Cost/unit (EC$)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total Inputs	Total Co (EC$)
Labour Input*																
1. Watering	hrs.	2.5			10	10	8	10	10	10	8	10	10	10	96	240
2. Pen feeding	hrs.	2.5			10	10	10					3	4		37	97.
3. Cutting grass	hrs.	2.5			8	5	16					5	4		38	95
4. Cleaning pen	hrs.	2.5			23	23	31	23	23	23	23	23	23	23	238	595
5. Tethering	hrs.	2.5			140	142	108	61	70	67	69	76	51	79	863	2157.
6. Manure spreading	hrs	2.5			8	8	6	8	8	8	8	8	8	8	78	195
Sub-total (labour input)	hrs.		0	0	199	198	179	102	111	108	108	125	100	120	1350	3375
Other Inputs																
1. Nilverm	cc	.04													3000	120
2. Molasses	litres	.3													186	55.
3. Sulphate of Ammonia	kg	.92													75	69
4. Chopped Pangola	kg	.02													0	0
Sub-Total (others)																244.
Total Cost																3619.
Net Income																-2499.

* Family Labour was inputed at the Market rate of EC$ 2.50/hr. However, it is quite possible that the Opportunity Cost of Family Labour is Zero.

Table 5
Cost and Returns Sheep Production January to June 1988

A.	Value of Opening Inventory (EC$)	3990
B.	Value of Sheep Sold During Period (EC$)	3150
C.	Value of Inventory at end of Period (EC$)	3480
D.	Value of Production During Period (EC$) = (B+C-A)	2640

Input Categories	Units	Cost/unit (EC$)	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total Inputs	Total Cost (EC$)
Labour Input*																
1. Watering	hrs.	2.5	10	10	10	10	10	10							60	150
2. Pen feeding	hrs.	2.5	5				8								13	32.5
3. Cutting grass	hrs.	2.5	7												7	17.5
4. Cleaning pen	hrs.	2.5	16	23	23	23	23	23							131	327.5
5. Tethering	hrs.	2.5	89	118	125	133	61	106							632	1580
6. Manure spreading	hrs	2.5	6	6	6	8	8	8							42	105
Sub-total (labour input)	hrs.		133	157	164	174	110	147	0	0	0	0	0	0	885	2212.5
Other Inputs																
1. Nilverm	cc	.04													2000	80
2. Molasses	litres	.3													186	55.8
3. Sulphate of Ammonia	kg	.92													38	34.96
4. Chopped Pangola**	kg	.02													1500	30
Sub-Total (others)																200.76
Total Cost																2413.76
Net Income																226.74

* Family Labour was inputed at the Market rate of EC$ 2.50/hr. However, it is quite possible that the Opportunity Cost of Family Labour is Zero.

** Pangola grass purchased due to feed scarcity during the dry season.

Growing animals under these conditions without supplementary feed appears to be a very unsatisfactory method of animal production and simulates a subsistence-type of production suitable only to providing food security for the farm family.

CARDI-Antigua produced and tested in 1982 a dry season supplement for ruminants (CARDI Final Report, 1982). This has considerable relevance to the region since, Leucaena meal, a major ingredient of the supplement can be produced from Cunningham Leucaena protein banks and locally produced molasses.

On our two Nevis farms, sheep appeared to be relatively more prolific that goats with average littler size of 2.2 and 1.3 respectively. Despite the heavy infestation of unimproved pastures with eggs of internal parasites these small ruminant appear to be relatively hardy. Sheep continued to graze unimproved pastures and were occasionally fed fodder from the forage bank. Goats were fed mainly from the forage bank during 1987 as the flock size was much small (16 animals). Regular culling has been introduced to control flock size in relation to the productivity of the forage bank.

During the long dry season in 1988, the animals were turned into the forage bank, severely retarding the growth of forage and reducing the feed availability. The farmer in order to control indiscriminate breeding may have to maintain a smaller flock size and monitor females in heat more closely. Young animals born in the dry season face serious disadvantages under the prevailing harsh environmental conditions. Breeding females were often in poorer condition during lactation in the dry season.

In order to overcome the high incidence of internal parasites, the farmer may have to improve and enclose some unimproved pastures. Since the advent of the intervention, deworming of small ruminants has become more systematic. This treatment was done every three months against both roundworms and tapeworms. Pervent mortality for goats during the early phases of the intervention has high (47%), but as a regular deworming programme was introduced there was a 7% improvement, for sheep percent mortality fell from 16% which is still to high. The major limitations to a reduction in percent mortality have been the irregularity in supply of anthelmintics and also infection at pasture with eggs of internal parasites. Most farmers that make use of cummunal grazing do not practise deworming.

Table 6
Daily Weight Gain (kg) for Sheep During 1987

Animal ID	Starting Apr.* Weight	May*	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Animal 1	2.72	0.12	0.09	0.09	0.09	0.09	0.09	0.0	0.03
Animal 2	1.90	0.15	0.1	0.14	0.03	0.03	0.03	0.0	0.0
Animal 3	2.8	0.09	0.06	0.09	0.06	0.04	0.03	0.07	
Animal 4	3.20	0.09	0.1	0.05	0.07	0.06	0.08		
Animal 5	4.10	0.14	0.09	0.03	0.09	0.06	0.06		
Animal 6	2.73	0.14	0.1	0.06	0.09	0.04	0.08	0.06	0.0
Animal 7	3.13	0.12	0.1	0.06	0.09	0.04	0.08	0.03	0.0
Animal 8	3.64	0.12	0.1	0.06	0.01	0.03	0.03	0.0	0.03
Animal 9	5.00	0.08	0.1	0.06	0.04	0.03	0.02	0.0	0.02
Animal 10	3.65	0.12	0.06	0.03	0.04	0.04	0.05	0.0	0.11
Mean Wt. Gain	3.29	0.117	0.09	0.064	0.058	0.046	0.055	0.02	0.03
S.E.	0.16	0.005	0.005	0.013	0.007	0.003	0.002	0.008	0.008

* Denotes animals under improved system all other months represent traditional system.

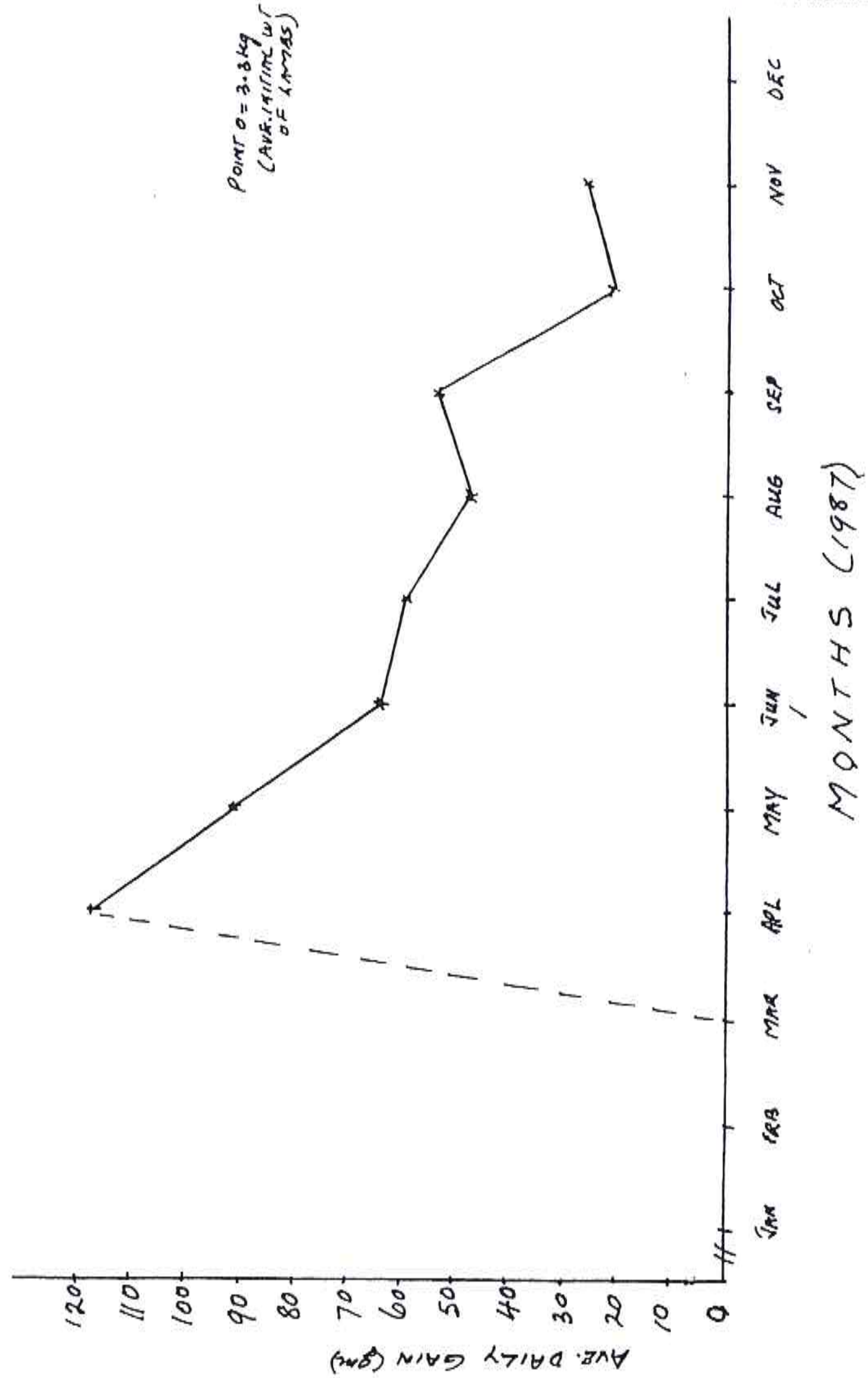

Figure 2
Average Daily Gain (ADG) of Ten Creole Lambs Fed on Protein/Energy Banks at New River, Nevis, March-November, 1987

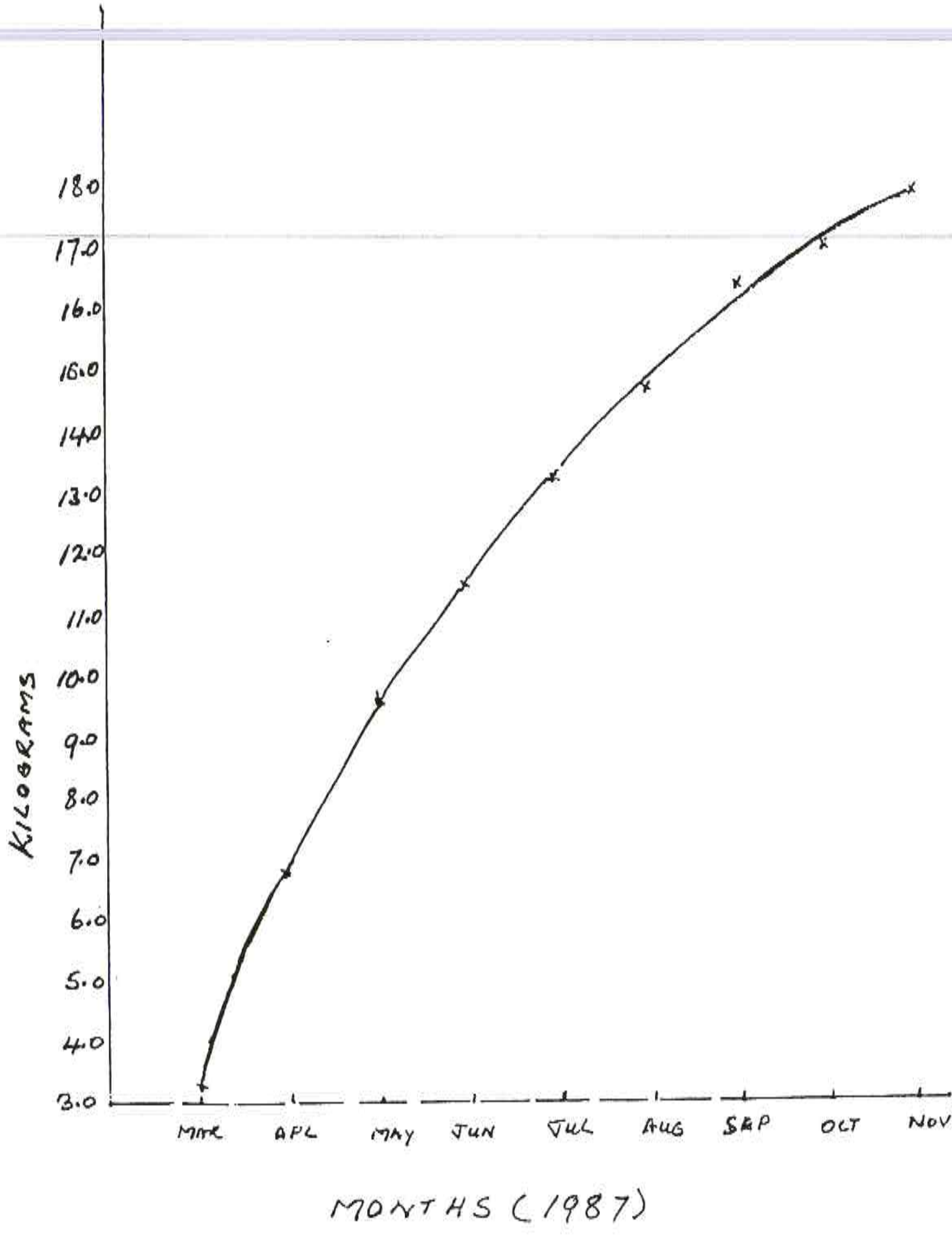

Figure 3
Growth curve for Ten Creole Lambs Fed on Protein/Energy Banks at New River. Nevis (March-November, 1989)

CONCLUSION

1. It is clear that the existing forage banks were inadequate in meeting the needs of the current flocks. These will have to expanded, in addition to a reduction in flock size as needed.

2. There is room for intensification of the current system of production in order to achieve even greater animal production and productivity. Already the managerial skills of the farmers have improved in the areas of animal hygiene, record keeping, regulation of flock size and forage conservation.

3. During the period under observation forage production was very high as seen in tables 1 to 3. However, insufficient feed was conserved during periods of peak forage production.

4. Although there are limitations in drawing too heavily on this study, the results indicate that there is a potential for improved animal production, by offering a better quality feed on a regular basis.

5. One of the major limitations to the further adoption of forage banks is the issue of land tenure. With insecurity of tenure most farmers are unwilling to engage any major capital investment such as fencing wire.

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Introduction of Leucaena into Small Ruminant Production Systems in St. Lucia

William C. Massiah

INTRODUCTION

Small ruminants, particularly sheep, play an important part in the production systems of small farmers in the district of Choiseul in the south-western corner of St. Lucia. However, forage availability and quality, particularly in the dry season, are major limiting factors to the development of an improved production system. Choiseul is a low-rainfall area with the annual rainfall in the La Pointe/Delcer/Industry sections of the district between 1,270mm to 1,400mm but three to five kilometres inland it can be as much as 2,500mm annually. The dry season commences usually in late December to early January, extending right through to May/June. Average Rainfall during this period is usually less than 50mm per month. The wettest months are usually July to September with an average of 250mm monthly while the period October to December averages about 125mm per month.

The soils in the area are poor, mainly acidic (pH 5.0 to 5.5) with gritty clays and clay loams containing silica hard pans at fairly shallow depths in most locations. These soils range from free to imperfectly drained and couple with the often steeply sloping terrain are very liable to erosion. Crops, primarily sweet potato and peanuts, are grown on the gentler slopes during the rainy season, and the land available for livestock is limited to the steeper, often rocky slopes. Pasture development is not a very practical proposition and the development of protein/energy banks of *Leucaena leucocephala* and grass has been an essential component of a CARDI project aimed at the development of an improved sheep production system.

METHODOLOGY

The activities under the CARDI sheep production system development project are being carried out on farms in the La pointe/Delcer/Industry areas of Choiseul. Demonstration/pilot units are being set up on seven farms strategically located around the district to facilitate the participation of neighbouring farmers. The activities on these units include stock improvement through the introduction of purebred Barbados Blackbelly rams, the introduction of housing, regular deworming, proper sanitation and disease control, and the establishment of protein/energy banks on lands unsuitable for crops.

The protein/energy banks were made up of Leucaena planted in rows 2.5m apart and spaced about 1.25m apart in the rows. The soil was well prepared and a small amount of limestone was added. Seedlings were transplanted into holes. Two to three weeks following the transplanting of the Leucaena, the grass component was planted. The grass used in the first banks was a dwarf elephant grass (Tift N76) but its poor performance led to the temporary use of ordinary elephant grass, with the continuing search for more drought tolerant species. CARDI provided and is continuing to provide barbed wire and stables for fencing the banks. The farmers were required to:

(i) cut Glyricidia fence posts and provide most of the labour for erecting the fence;
(ii) weed the plots at least twice during the establishment period usually the first two to three months: and
(iii) fertilize once during the late rainy season.

They were also required to record when harvesting starts, the dates of cutting and weights of materials harvested.

ESTABLISHMENT: MATERIALS AND ACTIVITIES

The planting material was produced at CARDI's Field Station at La Ressource, Dennery. The selected grasses were multiplied and seeds of Leucaena leucocephala var. Cunningham were planted at the Field Station. The Leucaena seeds were scarified using the hot water method and potted. The potting mix used was soil and soft-wood sawdust in a 1:1 ratio. Since the specific rhizobium -alkaline exuding rhizobium strain CB-81- was not available the soil used was taken, whenever possible, from wereas on the Field Station where there were exwasting stands of Leucaena. A small amount of limestone was also incorporated into the mix prior to potting. Black polythene bags with drain holes were used as pots, and these were kept under Sarn initially. Five days to a week after germination a soluble fertilizer (23-19-17 or 20-30-20) was applied with a watering can at the rate of 25gm to five litres of water. After three weeks the plants were taken out into full light and a second application of fertilizer was given. The seedlings were ready for planting out when they were about eight weeks old. Vegetative material - stems with several modes - was used in the establwashment of the grass component of the protein/energy banks two or three weeks after planting out the Leucaena.

INPUTS (BANKS: 2,000M^2)

4.5 x 220 m Roll Barbed Wire

9kg x 30mm Staples

60 x 2.5m Live Glyricidia Posts

600 Leucaena Seedlings

2 Bags Grass Cuttings

Labour - Erection of Fence: 2 men x 2 days

Labour - Planting: 2 men x 1 day

During the rainy months of May to September, 1987, ten small protein/energy banks of Leucaena and Dwarf Elephant grass were planted out on fenced plots on farms in the project area using the methodology described above. This was followed by the establishment of four more banks on new pilot units during July to September, 1988.

RESULTS

Visits to the plots during the period October to December, 1987, showed that establishment was good on eight of the ten, while two were lost due to the negligence of the farmers who did not carry out the necessary weeding and fertilizing of the plots and in one case allowed animals into the bank. Observations of these eight banks during the dry season – January to May/June, 1988 – indicated that, although establishment had been good, the growth of the Leucaena was way below anticipated levels in most cases. The dwarf elephant grass did not survive this dry season with no regrowth being seen in the following rainy season. Growth of the Leucaena during the rainy months of 1988 ranged from poor, to very good in one instance. Limited utilization of these plots was possible during the early weeks of the 1989 dry season but no records of yields were kept by the participating farmers. Elephant grass was used to replant the grass component of the eight original and the four new banks. Growth of both the Leucaena and elephant grass in the four new banks showed a similar pattern to that described of the eight original banks although rainfall was more favourable into the usually dry months. The factors influencing these developments could include:

(i) farmers not carrying out their required activities;
(ii) the pH level and mostly free-draining properties of the soils; and
(iii) the sloping and wind-swept terrain facilitating excessive moisture loss.

Related Field Station Activities

Two small protein-energy banks have been established at the Field Station in 1988 using two former alley-cropping areas. The Leucaena had been established in rows about 3.5 metres apart and was inter-planted with four rows of dwarf elephant grass. The forage from these banks is being utilized in the feeding of the animals of the CARDI sheep breeding unit set up at the Field Station in May, 1988, with one ram and ten ewes - all purebred Barbados Blackbelly. The flock at this unit now totals one ram, nine breeding ewes and 19 followers (nine males and ten females), Which were of varying ages. A few rams will be available for sale to farmers in late 1989, by which time the size of the unit should have doubled. This unit is also being used as a demonstration facility and one field day was held on 6th December, 1988, which was attended by farmers from the project area as well as by several others.

Although soil pH level at the station is about the same as that of the project area, establishment and growth were more rapid, probably due to the fact that during the dry months, the average rainfall is almost double that of the Choiseul district (and usually 100mm). The Leucaena in these banks has been cut several times in the past year – about every seven to eight weeks in the rainy season and about every ten to twelve weeks during the dry – but no yields were recorded. However, it is planned to cut back both the Leucaena and grass at the start of the 1989 rainy season and to collect data on the number of cuttings and yields over the following year. Work at the Field Station also will include the multiplication and evaluation of three new Pennisetum crosses which have been reported to be drought tolerant.

Planned Activities

It is planned that during the 1989 rainy season, two new protein-energy banks of Leucaena and two of the new Pennisetum crosses will be established on two new pilot farms. It is also planned that the CARDI team will undertake a completely manage at least three of the on-farm banks in the project area, ensuring that all the activities required for good production and plot maintenance are done properly and on time. Collection of yield data is also planned. This should aid in more effective demonstrating to the farmers the role that protein-energy banks can play in maintaining sheep-goat production on a profitable, year-round basis.

Feed Production of Leucaena leucocephala (Lam.) de Wit Cultivars on the Acid Sandy Loams of the Zanderij Formation in Suriname; Some Observations Concerning Chemical Composition.

P. Kerkhoff, M. Callebaut and Ch. Mehairjan-Kalpoe

INTRODUCTION

Within the framework of the Regional OAS-Leucaena Project (co-ordinator for Suriname, J. Ruinard), an experiment was laid out to determine the productivity and chemical composition of six cultivars (Surinam Lamtoro, K8, K28, K67, Cunningham and CF95) under the conditions of the lowland humid tropics and acid soils of Suriname. In a previous paper (Callebaut and Kerkhoff, 1989), figures of forage production of Leucaena cultivars were presented and discussed. In the present paper, the first results of chemical analysis of the forage of the same experiment are reported.

MATERIALS AND METHODS

For details on method of establishment, cultivars, experimental site and lay-out, the reader is referred to the earlier presentation of Callebaut and Kerkhoff (1989) at this conference. Chemical analyses were carried out in samples obtained by "boring" a metal pipe through a bundle of cut forage (method described in Callebaut and Kerkhoff, 1989). Incidentally, also top leaves of plants were analysed. For this the youngest fully expanded leaves on the highest twigs of the plants were used.

After drying during 24 hours at 70ºC, percentages of N, P, K, Na, Ca and Mg in the samples were determined, as well as crude ash - and crude fibre contents. These figures were then recalculated to obtain percentages of the components on a dry matter basis, after drying at 105ºC. For analyses the following methods were used. Digestion of the material according to Lindner-Harley (concentrated H_2SO_4) and H_2O_2). In the digests: determination of total N with the micro Kjehldahl method; P colorimetrically with Mo - blue coloring, K, Na, Ca and Mg by atomic absorption spectrometry; crude ash by means of a muffle furnace (600ºC) and crude fibre after boiling with H^2SO^4 and NaOH. Where possible, averages of elements in chemical composition have been calculated as weighed averages.

RESULTS

Tables 1, 2 and 3, all contain figures obtained from forage harvested at the same date (August 18th, 1988). In table 1 data of the chemical composition of material harvested after four weeks of regrowth are presented while in table 2 data of six week old material are given. Figures in these tables were obtained from random samples of the cut forage; figures in Table 3 on the contrary, were not from random samples taken from the harvested material but originated from samples of the youngest fully expanded leaves.

The data in tables 1 and 2 showed little difference in composition between four week old material and six week old material. Table 3 shows that there was also little distinction between top leaves of plants four weeks or six weeks after their last pruning.

Comparing table 3 with tables 1 and 2 shows a higher N percentage in the top leaves (5.1%) compared with the total mass of forage (3.7–3.8%), i.e. 31.9% crude protein (CP) in the top leaves and 23.1–23.8% (CP) in the bulk of the forage. The crude fibre contents in top leaves was much lower (12.6–13.3%) than in the total forage (22.4–23.3%).

Table 1
Chemical Composition of the Forage of Leucaena Cultivars, Harvest August 18th, 1988, Four Weeks of Regrowth

CV	N%	P%	K%	Na%	Ca%	Mg%	Crude Ash%	Crude Fibre%
K8	3.65	0.29	1.53	0.04	0.84	0.25	6.59	22.3
K28	3.81	0.28	1.81	0.04	0.81	0.26	6.55	23.5
K67	3.81	0.27	1.71	0.03	0.79	0.24	7.14	20.7
SL*	4.08	0.32	1.64	0.04	0.93	0.29	6.94	21.5
Cun**	3.75	0.31	1.82	0.04	0.85	0.29	7.33	22.5
CF95	3.75	0.33	1.54	0.05	1.37	0.25	6.83	23.9
Av.	3.80	0.30	1.68	0.04	0.90	0.26	6.87	22.4

* Surinam Lamtoro ** Cunningham

Table 2
Chemical Composition of the Forage of Leucaena Cultivars, Harvested August 18th, 1988, six Weeks of Regrowth

CV	N%	P%	K%	Na%	Ca%	Mg%	Crude Ash%	Crude Fibre%
K8	3.61	0.27	1.61	0.03	0.82	0.24	6.79	23.6
K28	3.71	0.27	1.48	0.03	0.80	0.24	6.64	21.6
K67	3.76	0.26	1.54	0.03	0.84	0.25	6.64	24.6
SL*	3.47	0.28	1.43	0.03	0.82	0.27	6.55	22.0
Cun**	3.88	0.30	1.62	0.03	0.91	0.29	6.95	24.0
CF95	3.70	0.29	1.57	0.03	0.80	0.25	6.89	23.5
Av.	3.69	0.28	1.54	0.03	0.83	0.26	6.70	23.3

* Surinam Lamtoro **Cunningham

Table 3
Average Chemical Composition of Youngest Fully Expanded Leaves of Leucaena Cultivars, Harvested August 18th, 1988

Regrowth Period	N%	P%	K%	Na%	Ca%	Mg%	Crude Ash%	Crude Fibre%
4 weeks	5.08	0.33	1.72	0.05	0.59	0.20	6.05	12.6
6 weeks	5.14	0.33	1.69	0.04	0.62	0.20	5.64	13.3

Table 4 contains N percentages in forage cut after harvest intervals of four, six and eight weeks. The figures displayed for four and six weeks were averages of three and four harvests respectively. No trend in N percentages can be detected from these data. Also the figures of crude fibre percentages (Table 5), obtained from the same harvests, do not indicate a trend in crude fibre contents with age of forage.

Table 4
Percentages of Nitrogen the Forage of Leucaena Cultivars After Regrowth Periods of Different Lengths

CV	4 Weeks*	6 Weeks**	8 Weeks***
K8	4.57	3.82	3.98
K28	4.08	4.01	4.20
K67	4.07	3.91	3.55
SL[1]	4.35	3.67	4.31
Cun[2]	4.09	4.05	4.36
CF95	4.08	4.06	4.02
Av.	4.22	3.92	4.04

* Average of 3 harvests
** Average of 4 harvests
*** 1 Harvest

[1]Surinam Lamtoro
[2]Cunningham

Table 5
Percentages of Crude Fibre in the Forage of Leucaena Cultivars After Regrowth Periods of Different Lengths

CV	4 Weeks*	6 Weeks**	8 Weeks***
K8	24.6	26.1	18.4
K28	25.5	27.6	23.0
K67	24.0	23.3	23.4
SL[1]	24.4	27.6	24.1
Cun[2]	24.0	25.3	21.3
CF95	24.2	24.6	25.8
Av.	24.5	25.8	22.2

* Average of 3 harvests
** Average of 4 harvests
*** 1 Harvest

[1] Surinam Lamtoro
[2] Cunningham

DISCUSSION

The chemical composition of the forage was not much unlike the composition of Leucaena forage found in other parts of the world. Pound and Martinez Cairo (1983) presented in their review several tables with comparable values for N, crude fibre and minerals.

Climatic conditions, cultivar and management, all may influence the chemical composition of the Leucaena forage in the experiment. Insufficient data have been collected as yet however, to detect a possible influence of the season, or to make a statement about differences in chemical composition between cultivars. If continuation of the experiment does not show large differences between cultivars, then the choice of cultivar to be planted for forage by farmers, largely depends on the yield that may be expected.

One aspect of management has been studied, namely the effect of the length of the interval between harvests. Twigs in older forage may become woody and therefore older foliage may contain more crude fibre and less protein than younger material. The available data from the present experiment do not indicate a marked reduction in CP contents or a substantial increase in CF percentage in older foliage within the range of harvest intervals investigated. If further research confirms this finding then longer intervals may be advantageous since there are indications (Callebaut and Kerkhoff, 1989) for higher annual yields with longer harvest intervals.

CONCLUSIONS

The preliminary results of the experiment show that the chemical composition of leucaena forage grown on the acid sandy loams in the experimental garden Coebiti is comparable with the chemical composition of leucaena elsewhere.

Within the range investigated (four to eight weeks) the length of the regrowth period does not show dramatic changes in either N% of crude%. Since longer intervals may result in higher annual yields, a tentative conclusion may be that there is little reason to choose intervals of a duration much shorter than eight weeks.

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Feed Production of Leucaena leucocephala (Lam.) de Wit Cultivars on the Acid Sandy Loams of the Zanderij Formation in Suriname: Some Observations Concerning Yields

M. Callebaut and P. Kerkhoff

INTRODUCTION

The importance of *Leucaena leucocephala* as a source of protein for ruminants and domestic animals has been well documented by numerous authors, Pound and Martinez Cairo (1983). Although Leucaena is well known in Suriname, it never played an important role as a feedstuff. The local Leucaena, known as "lamtoro", displays a slow, often stunted growth and has a small crown on a thin stem. With the introduction of seeds from cultivars which have shown high productivity in other parts of the tropics, renewed interest in Leucaena. The performance of Leucaena under the conditions of the humid tropical lowlands and acid soils of Suriname may be of wider than local importance. Within the framework of the Regional OAS-Leucaena Project, (co-ordinator for Suriname, J. Ruinard) and experiment was laid out to determine productivity and chemical composition of six cultivars (Surinam Lamtoro, K8, K28, K67, Cunningham and CF95). The first results on measurements of productivity are the subject of this paper. In a second paper (Kerkhoff, Callebaut and Mehairjan-Kolpoe (1989)) the initial results of chemical analysis of the foliage are presented.

MATERIALS AND METHODS

Preparations for the experiment started in a nursery where pregerminated seeds in plantbags were grown. The soil used in the plantbags was a mixture of soil from the trial field and a small percentage of soil obtained from the surface underneath old Leucaena shad trees. The experiment was established in April 1986 when three to four months old plants were transplanted to the field. Yield determinations were not carried out until March 1988. Pruning of the foliage has nevertheless taken place at several occasions prior to 1988. The cut branches were usually put between the plant rows during that time. The cultivars used are: local *Leucaena leucocephala* (Surinam Lamtoro, SL) and the introductions K8, K28, K67, Cunningham and CF95. In addition to liming with curacoa phosphate (533% Ca, 6% P) in an amount equivalent to 2 tons per ha prior to establishment, a gift of P and K (a mixture of patentkali and triplesuperphosphate, given in proportion to 80 kg patentkali and

20 kg triplesuperphosphate per ha) was applied in August 1988. The average annual rainfall is approximately 2250 mm. Monthly rainfall figures are presented in Figure 1.

The experiment was laid out in a randomized complete block design with six treatments (cultivars) in five replications (blocks). Each plot measured 7m x 4m = 28m²; there was 112 plants per plot (= 40,000 plants per ha) in four rows 1m apart; distance between plants in the rows was 25 cm. Every plot was surrounded by a 1 m wide path. There was a twin border row of Surinam Lamtoro, at 1m x 1m square spacing, on all sides of the randomized block experiment. The area of the trial was 0.16 ha. (53m x 30m) In May 1988 the 7m x 4m plots were split in two sub-plots, each measuring 3.5m x 4m. The soil chemical characteristics of the experimental site is presented in Table 1.

One half of the sub-plots (randomly assigned) was harvested after regrowth periods of six to seven weeks; while the other half was harvested after regrowth periods of various lengths. Cutting heights were about 55 cm.

Fresh yields were determined in the field. In case, during harvesting, it was noticed that the cut material contained a large quantity of woodified branches, the green twigs were slashed from the thick branches by means of cutlasses and both fractions were weighed separately. Dry matter yields were derived from dry matter percentages (70° C, 24 hours) found in samples bored out of a heap of cut foliage. Bore-samples were obtained as follows. A metal pipe, about 45 cm long with an inner diameter of 5.5 cm and sharpened rim on one end, was hammered several times at different places through a bundle of cut foliage until sufficient material was gathered in the pipe for a sample. Annual yields of the sub-plots harvested every six to seven weeks, were compared by means of analysis of variance. The Duncan Multiple Range Test (DMRT) was used to reveal statistical significance at 5% level.

Table 1
Soil Chemical Characteristics of the Experimental Site

Depth (cm)	0 -20	20-40
pH-H20*	5.3	5.2
pH-KCI*	4.4	4.3
Tot N (%)	0.10	0.08
ECEC (meg/100g)	1.61	1.62
Ca (meg/100g)	1.10	0.97
Al (% ECEC)	19	30
P (ppm)	44.3	28.0

*After application of curacao phosphate, pH-values (0-25 cm) were as follows: pH-H20 5.3 and pH-KCl 4.7.

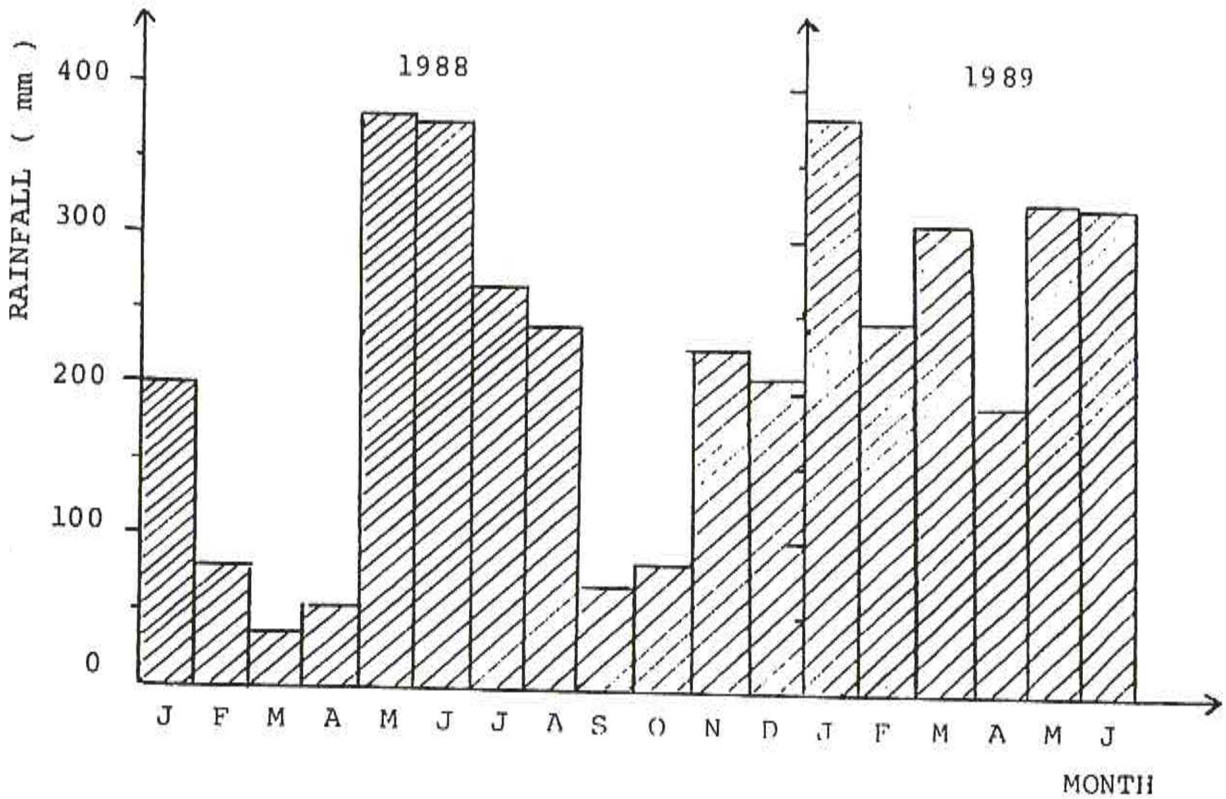

Figure 1
The Monthly Rainfall Total (mm) at Zanderij Airport During 1988 and the First Semester of 1989

RESULTS

In Table 2 dry matter yields of foliage from sub-plots harvested after intervals of six to seven weeks are presented, as well as the total yields of these sup-plots, during the first year of observations (May 1988-May 1989). The annual yields of all cultivars were below 10 tons D.M. per ha. D.M. percentages of the foliage harvested were usually between 22 – 28%. The K-types produced significantly more foliage than Surinam Lamtoro while the yields of the forage types Cunningham and CF95 were not significantly different from Surinam Lamtoro. There was no significant difference in annual yields among the K-types or among the forage types. Higher yields for K-types than for the forage types were also found where shorter or longer harvest intervals were used (data long intervals are not presented).

A marked variation in yields during the year was observed, the worst period producing 25 - 35% of the foliage produced in the best period.

Table 2
Dry Matter Production of Foliage (kg/ha) of Leucaena Cultivars of Coebiti after Regrowth Periods of Six to Seven Weeks (between brackets: number of days)

CV	Jul. 07 (42	Aug. 18 (42)	Oct. 03 (46)	Nov. 16 (44)	Jan. 05 (50)	Feb. 21 (47)	Apr. 07 (45)	May 25 (48)	Total (364)	Stat. Sign*
K8	1126.7	1081.4	1255.2	443.8	1206.8	1245.0	1057.8	1696.9	9113.6	a
K28	1035.7	938.8	1253.4	479.3	1357.8	1246.4	993.1	1782.8	9087.3	a
K67	968.5	981.1	1198.3	414.5	1232.9	1056.2	832.1	1558.0	8241.6	ab
SL**	693.7	774.5	942.2	238.1	617.2	540.2	454.5	776.0	5036.4	c
Cun***	783.4	942.5	921.1	258.4	665.3	562.8	569.2	940.6	5643.3	bc
CF95	570.6	606.4	755.2	260.9	474.4	585.4	429.9	793.0	44475.8	c

* Statistical significance; any two means having a common letter are not significantly different at 5% level
** Surinam Lamtoro
*** Cunningham

Table 3
Dry Matter Production of Foliage (kg/ha) of Leucaena Cultivars at Coebiti During a Three Months Period with Short and Long (four and six weeks respectively) Harvest Intervals

CV	Short Interval	Long Interval	%
K8	1544.3	2208.1	69.94
K28	1384.1	1974.5	70.10
K67	1364.7	1949.6	70.00
SL*	953.3	1468.2	64.93
Cun**	1173.0	1725.9	67.96
CF95	873.9	1177.0	74.25

Comparing long harvest intervals (six weeks) with short intervals (four weeks) shows that approximately 25% lower yields were obtained when the foliage was cut more frequently. Table 3 shows the results of two treatments in which, during a period of about three months, one half of the sub-plots was harvested three times after regrowth periods of four weeks while the other half was harvested two times after regrowth periods of six weeks. Foliage cut after regrowth periods of six to seven weeks contained flexible green twigs but no branches thicker than 10 mm. Regrowth periods of eight to nine weeks resulted in branches up to 12 mm in diameter. With a regrowth period of ten weeks, it was found that about 33% of the harvested material (fresh weight) consisted of woodified branches; for four months old regrowth this was nearly 50%. All Yield figures presented are derived directly from yields per plot. No correction has been applied for die-back of plants after establishment. Die-back of plants resulted in reduction to 88 - 55% of the number of plants originally planted at the time yield determinations started.

Discussion

At first sight, annual yields below ten tons per ha seem disappointing. In the literature much higher yields were reported. Pound and Martinez Cairo (1983) gave yields obtained in research in different parts of the world. These figures range from 5.3 to 33.1 tons D.M. per ha per year. Not known however, is whether all material of the high yields was edible. High yields were often obtained with long harvest intervals and the experience at Coebiti indicated a large amount of woody branches under those circumstances. NAS (1984), quoting sources from different tropical regions, gave annual yields of edible D.M. of 6-18 tons per ha. If material with stems up to 10 mm in diameter may be considered as edible, then the yields of foliage obtained at Coebiti with six to seven weeks harvest intervals, fall partly within that range. NAS (1984) it is stated that the giant varieties tend to produce most forage under infrequent cuttings (every 8-12 weeks) while the Peru types may be equally or more productive under more frequent harvests (four to six weeks). The (limited amount of) data obtained at Coebiti do not appear to be in accordance with this.

The seasonal variation in yields was likely to be a reflection of the availability of water. The seasonal distribution of rainfall is displayed in Figure 1. Data on woodyness were obtained from incidental observations; it is not known whether a seasonal trend may be expected. The authors are of the opinion, (based on the experience of a short period of observations) that the forage yields could be increased by modifying the planting system and improving management as follows:

- by reducing the distance between the rows;
- by harvesting;
- by fertilizing (but this still has to be determined and the control of leaf eating ants.

Conclusion and Recommendations

Harvest intervals of six to seven weeks resulted in relatively low annual foliage yields of about 4.5 - 9.0 tons D.M. per ha. K-type cultivars produced significantly more than Surinam Lamtoro or the forage types Cunningham and CF95.

Less frequent cutting yielded more D.M. than frequent cutting within a three months observation period. Regrowth periods up to eight weeks resulted in foliage with twigs up to 10 mm in diameter, though to be edible; longer regrowth periods resulted in an increasing percentage of branches thicker than 10 mm, thought to be inedible.

Thirty-three percent of the fresh weight of ten weeks old material and about 50% of the fresh weight of four months old material consisted of woodified branches.

Higher yields should be possible by reducing the distance between rows, thus reducing competition with weeds and improving light interception.

Higher yields may also be achieved by increasing the length of harvest intervals till eight weeks, better pest control and more fertilizer.

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Leucaena (Wild Tamarind) as a Feed for Ruminants (A Manual for Forage Production and Utilization)

A. Benn, C.H.O. Lallo, G.W. Garcia and F.A. Neckles

INTRODUCTION

The Caribbean is generally characterised by relatively low Ruminant (cattle, sheep, goats and buffalo) livestock populations and poor animal performances; one of the major reasons for this is the inadequate production and inefficient use of high quality forages. Most ruminant livestock feeding systems are based on forages of low quality combined with usually expensive concentrates for additional nutrients. Achieving satisfactory levels of animal performance through the use of high quality forages is also limited by the high cost of inputs such as fertilizers, chemicals and land. This results in high production costs. Frequently farmers do not have sufficient cash available to purchase these inputs. The cultivation and use of *Leucaena leucocephala* (wild tamarind) offers an option for improving the performance of ruminants in this part of the world. Leucaena is a legume capable of giving high yields of palatable forage rich in protein and other nutrients. This crop is a versatile tropical plant native to low-rainfall, alkaline soils. Leucaena can be used for the production of lumber and firewood, the re-afforestation of hillsides, the provision of windbreaks and shade, as a green manure crop and as food for man.

This document has attempted to add to the efforts of Proverbs (1984); Brewbaker, Hedge, Hutton, Hones, Lowry, Moog and Van de Beldt (1985); Pound and Martinez-Cairo (1983); and Batson, Ferguson and Archibald (1987). It has tried to cover both the establishment and nutritive value aspects of leucaena. The first two parts are generally written as a narrative which covers most of what has been dealt with by the above authors. The section on "Feeding of Leucaena Forage to Ruminants" takes the form of a review, highlighting the feeding of leucaena as a dehydrated forage meal at the Sugarcane Feed Centre (SFC). Aspects on mimosine toxicity of leucaena have been omitted as it has not been reported to be a problem in the Caribbean. It concludes with an effort at costing (or the provision of a costing mechanism for the Leucaena forage). It is hoped that this publication would be of the use to all in the tropical world who may be interested in leucaena feeding to ruminants, and that it could be used as a template for forage utilization manuals on the crop. Further it is hoped that both farmers and extension officers alike are provided with the comprehensive scientific facts so that the information could be used efficiently to meet their farming needs.

VARIETIES/TYPES OF LEUCAENA

There are three basic types:

a. *Hawaiian-Type*

The common types found growing in the Caribbean in areas such as Jamaica, Grenada, Barbados and the western end of Tobago are the short bushy varieties which grow to five meters in height and flower year-round except when moisture is limiting. Yield is usually low and cultivation of this type for forage production is not recommended. However, where it is found growing naturally, it can be harvested as a forage source and used as a livestock feed, and the general recommendations for forage management would apply.

b. *Giant or Salvador-Type*

These are tall plants which grow to 20 meters in height, having large leaves, pods and seeds and thick, branchless trunks. This type is cultivated for fuel, lumber and pulpwood. Varieties include K 8 and K 28 which were selected by workers at the University of Hawaii. This type has also been reported to produce high forage yields when cut or browsed to a height of one meter.

c. *Peru-Type*

These produce large amounts of forage for feeding to livestock. They are relatively tall plants growing to ten meters but with extensive branching even low down on the trunk. Varieties include "Cunningham", and " CF95". The former cultivar was bred in Australia and has shown itself to be useful for growing on acid soils but with careful management. The CF95 is the variety grown at the SFC on an acid (pH4) Ultisol in Trinidad.

ESTABLISHMENT

Land Preparation

Leucaena will grow under a wide variety of soils and under variable moisture conditions. However, best yields are obtained on well-drained, neutral to alkaline soils (pH 6 to 7). Where it is necessary to establish the crop on acid soils the land should be ploughed, harrowed with added manure and limestone applied at a rate of at least 2 tonnes per hectare (ha) where the soils are acid. When planted on soils with poor internal drainage, as is the case with a majority of the soils available in Trinidad for livestock production, ridge and furrows should be used to improve drainage, as Leucaena does not generally tolerate waterlogging. On hillsides where mechanical cultivation is not practical, holes may be dug and the soil mixed with manure and limestone before planting, with planting taking place along the contours. The plants may be planted as close as 15 cm. apart to form hedgerows.

Planting Materials

The crop can be established by seeds or transplanted seedlings or even by vegetative cuttings. Cuttings, however, root poorly and are not recommended. Seedlings grow slowly and have to be protected from weeds in the first three to four months of growth. Where small areas are to be planted or where control of weeds is difficult, it is advisable to establish seedlings in a nursery and then to transplant them into the field after about six to eight weeks. Where large acreages are to be established direct seeding can be done but weed control could be expensive. Seeds should be pre-soaked in water for 24 to 36 hours prior to planting. At planting, seeds should be lightly covered with soil or germination may be hindered.

Leucaena can also be established along with a nurse crop such as maize. This has several advantages:

1. Reduction in the cost of establishment as costs such as weed control can be shared between the nurse crop which has a high economic value and the Leucaena.
2. Increased revenue due to the production and sale of the cash crop along with the Leucaena.
3. Rapid, early growth of the Leucaena as it strives to compete with the much faster growing maize and the former tends to grow straight in an effort to compete for light.
4. By the time the maize or the companion is harvested the Leucaena crop could be well established and weeds no longer pose a serious threat.

Alley cropping can also be practised. Alley cropping is an integrated agro-forestry system in which food crops are grown in alleys between hedgerows of trees or shrubs such as Leucaena (Kang, Wilson and Sipkens, 1981; Kang, Wilson and Lawson, 1984). Crops such as corn are grown when the Leucaena trees are cut back. Material removed can be fed to livestock, used as green manure or as mulch.

Time of Planting

The crop should be established during a period when there is adequate rainfall such as early in the rainy season. Although Leucaena can withstand fairly long dry spells, it is critical that adequate moisture be available during and after establishment. In Trinidad for example, if the Leucaena is planted in early June or July at the beginning of the wet season it should be ready for harvesting for the first time in December, the last month of the wet season (i.e. six months later).

Spacing

Best forage production have been reported to occur with plant population densities of approximately 100,000 per hectare. This can be achieved with spacings of 75 cm. between rows and 15 cm. within the row. Where mechanical harvesting is being considered, inter-row spacing will need to be varied depending on the type of equipment to be used. In the final analysis however the spacing and the population density would depend on the practical consideration at each farm and the manner in which the forage is to be utilised.

Weed Control

Competition from weeds is a major cause of early crop failure. Effective weed control is essential during establishment. Regular hand weeding is one option but this is usually expensive, particularly on large holdings. Chemical weed control offers some scope but no entirely satisfactory herbicide for all soil and climatic conditions is available. However, where direct seeding is the chosen method of establishment, chemical weed control can be utilised to reduce the risk of competition on the emerging seedlings. "Dacthal" has been found to give good pre-emergent control in some instances.

For transplanted seedlings, grass weeds can be oversprayed with Fusilade (an emulsifiable concentrate containing 250g flauzifap-butyl/litre) a selective post emergent grass herbicide. Careful application of Atrazine will give control of some broadleaf weeds. When plants attain a height of 40 cm, Grammoxone (active ingredient–Paraquat), or Round-up (a.i. Glyphosate), can be applied between the rows using a shield. Manufacturer's recommendations should be observed. Alternatively, manual weeding or inter-row tilling can be done but care must be taken not to disturb the roots of young plants.

Pest Control

The most serious pests encountered under Trinidad conditions are mole crickets and leaf-cutting ants. The mole crickets cut the young seedlings roots and the parts of the stems below soil, damaging and killing seedlings up to three feet in height. The leaf cutting ants defoliates and cuts back the young stems which can lead to the death of the young seedlings. Control of the mole crickets, can be with the application of a soil-acting insecticide such as "Basudin" before or just after planting. The leaf eating ants can be controlled by the use of ant baits such as MIREX or by the searching out and the destruction of the nests. Aphids also pose a problem early in the wet season causing wilting and growing tip dieback. This can be controlled by the application of systemic insecticide such as Perfecthion (a.i. Dimethioate), or "Malathion" at the Manufacturers' recommendations. White ants also have been seen to attack the roots of older plants which are in poor condition and this leads to plant death. It is however not an establishment problem.

Diseases

At the SFC in Trinidad a leaf spotting occurs late in the dry season. It appears to be related to the problem of inadequate water supply at this time. The condition quickly disappears with the onset of the rains but if the dry spell is prolonged, there is leaf fall. A fungal infection has been seen to occur in the roots of older plants (more than five years old).

Fertilization

Leucaena is capable of fixing atmospheric nitrogen. Therefore, not as much fertilizer is needed for Leucaena as for a grass crop. However, to maintain high yields, fertilizers should be used. A recommended amount would be 100kg. Sulphate of Ammonia, 100kg Triple Superphosphate and 50 kg Muriate of Potash per ha. per annum. This could be applied in six equal applications per year beginning four weeks after direct seeding or two weeks after transplanting, and after each harvest (six times per year), however, so many small applications may prove to be impractical. One may choose to apply this in one or two applications. More may be required as at present the plant nutrient requirements of Leucaena under a system of continuous forage harvesting is still unknown.

Harvesting

Due to the distinct wet and dry seasons in Trinidad and Tobago which last approximately six months each, harvesting should be done at six-week interval in the wet season and less frequently in the dry season. The forage should be harvested just before the onset of flowering. In cut-and-carry systems, the plant should be cut one meter from the ground. Regrowth is better when this is done. Occasionally, the stumps will need to be cut closer to the ground to prevent them becoming too large. The crop may also be browsed by livestock. An example of an annual harvest schedule in Trinidad and Tobago would be first harvested in late June, then next harvest at Mid-August (six weeks), then Mid-September (six weeks), then Mid-November (six weeks), then Mid-January (eight weeks), then late March (ten weeks), then late June (ten weeks).

Yield

Yields are affected by several factors. These include soil type and fertility, plant population density, pest and disease control and the amount of water that the crop receives. With an annual rainfall of 1500mm as exists at the Sugarcane Feeds Centre, fresh weight yield in excess of 35 tonnes/ha/annum is achievable (ten tonnes dry matter). Assuming an average protein content of 18%, total protein yield per hectare is 1.8 tonnes equivalent to over 1100 kg. of a formulated 16% CP dairy ration or 250 bags (each weighing 45 kg) valued at approximately TT$9,000.00 at current Trinidad and Tobago prices.

NUTRITIONAL VALUE OF LEUCAENA

Leucaena forage contains on a dry matter basis about 22.03% crude protein (CP), 35.0% crude fibre (CF), 1.8% calcium (Ca), 0.26% phosphorous (P), 0.22% sulphur (S), 0.33% magnesium (Mg), 0.06% sodium (Na), and 1.45% potassium (K). Table 1 presents a comprehensive review of the chemical composition. The digestible energy content of the Leucaena forage is highly variable, and decreases as the forages increase with age. At the SFC it was estimated that at six, eight and twelve weeks of regrowth Leucaena forage had 12.0, 11.0, 10.0 MJ/kg dry matter of digestible energy (DE) respectively. It is therefore being suggested that the forage be harvested at an eight week or less interval, as the crop begins to flower at about eight weeks regrowth and with the onset of flowering the forage becomes stemmy and this lowers the DE content of the forage.

THE FEEDING OF LEUCAENA FORAGE TO RUMINANTS

Background

In Australia, ruminants fed solely on Leucaena developed toxicity symptoms such as hair loss from the tail. No such problems have been observed in the Caribbean. It has been determined that animals in Australia do not possess certain microbes in their rumen that are able to break down the toxic substance (mimosine) in the Leucaena into harmless compounds (Jones and Magarrity, 1981). Even though this is not a problem in the Caribbean it is not recommended that animals be fed a diet of 100% Leucaena as they would not intake sufficient DE for high levels of gowth.

Leucaena as a Cut Forage for Beef and Milk Production

Leucaena has been fed in cut-and-carry systems under the following conditions:

With Crop Residues

(a) Rice bran–Jones (1979) has reported that this is a traditional system in the phillippines for finishing cattle, where rice bran is force fed with a mixture of leucaena as a slurry in water.

(b) Banana pseudostems–Jones (1979) also reported that in Indonesia and Timor, cattle are fattened for about six months on a diet essentially made up of Leucaena and the pseudostems of banana.

(c) Rice straw and crop residues—Perez (1976) as cited by Jones (1979) have reported that 40% dried leucaena leaf gave 0.38 and 0.36 kg/day weight gains.

He also reported 50% concentrates plus 50% rice straw; and 35% rice straw plus 35% dried Leucaena leaf plus 30% concentrates gave 0.54 and 0.71 kg/day live weight gains; therefore Leucaena has been able to substitute for the low quality roughage plus the expensive supplement. This system would be of benefit during the dry season when high fibre low protein animal feed sources are available.

(d) As a supplement to pasture during the dry season—Sun-dried Leucaena leaf is used for this purpose in Malawi, with improved performance over those on pasture alone, and with equal performance as those supplemented with groundnut cake fed to provide the same level of protein as the Leucaena (Thomas and Addy as cited by Jones, 1979).

(e) Sorghum hay—The best results observed were 0.52 kg/day with 20% fresh leucaena forage and 80% sorghum hay, with a feed conversion efficiency of 7.62 kg feed per kilogram lightweight gain (Jones unpublished as cited by Jones, 1979).

(f) Maize stovers and maize bran—Another report from Malawi by Thomas and Addy (1977) (as cited by Jones, 1979) was 1.17 kg/head/day when one part of sundried leucaena leaf meal and four parts of maize stovers and maize bran were fed.

With Molasses-Urea

The utilization of leucaena forage in molasses based diets have been reported by Pillot, Leclesio and Wong Yon Cheong (1976); Alvarez, Wilson and Preston (1977); Salias, Sutherland and Wilson (1977) and Hulman, Owen and Preston (1978). The function of the Leucaena forage was twofold, firstly to act as a roughage source and secondly to provide some by-pass protein. One experiment in which leucaena forage was used as the sole source of forage and preformed protein was reported by Alvarez, Wilson and Preston (1977), and daily live weight gains of 0.481 kg were obtained, but this was less than the 0.615 kg per day gain obtained whent the roughage source was leucaena fed with rice polishings. Another report with leucaena forage *ad lib* with molasses-urea gave better results with weight gains of 0.85 kg/day/head (Hulman *et al.*, 1978). The intakes associated with this study was exceptionally high, in the order of 3.92 kg DM intake per 100 kg body weight. The other two experiments revealed a 0.618 kg/day and 0.588 kg/day weight gain when leucaena is used as one of three roughage ingredients (Salias *et al.*, 1977 and Pillot *et al.*, 1976). However it was concluded by Salias *et al.*, (1977) that under the mauritius conditions it was most economic to employ leucaena forage in a molasses-urea based diet instead of fish meal or maize grain.

In Sugarcane Forage Based Diets

Leucaena leucocephala forage has been reported to successfully substitute up to 75% of rice polishings, a good protein supplement for sugarcane based diets (Alvarez and Preston, 1976; Alvarez, Wilson and Preston, 1978a and 1978b). This statement is not quite accurate for on closer examination of the data in Alvarez, Wilson and Preston (1978b) it is revealed that the leucaena forage protein did not displace the protein from the rice polishings but in fact displaced the part of the protein contributed by the urea. The data presented by Alvarez and Preston (1976) and Alvarez, Wilson and Preston (1978a) also suggested that Leucaena (restricted grazing) and rice polishings both gave favourable milk yields in the dry season, 6.19 to 6.9 kg/day, with positive live weight changes in the cows and favourable calf live weight gains (with restricted sucklings) in the order of one half a kilogram per day.

Leucaena and meat meal have both been used with whole sugarcane based diets by Siebert, Hunter and Jones (1976) with both giving equal performance of 0.61 kg/day live weight gains; but the experience here as well as with Alvarez, Wilson and Preston, (1978a and b), and Alvarez and Preston (1977) was the reduction of sugarcane intake with the introduction of the fresh leucaena forage. With the introduction of the leucaena forage the crude protein content of the sugarcane diet was increased but at the expense of the sugarcane intake.

At the SFC, cows fed dehydrated Leuceana forage at 20% of the diet dried matter along with chopped sugarcane and a suppliment showed a more persistent lactation curve, higher total milk yield and higher butter fat yield than those that received no Leuceana (June Brown O'garro personal communication).With a yield of 35 tonnes per ha. as fed on a protein content of 18%, one hectare of leuceana is sufficent to meet the protein requirement of four cows producing ten litres of milk per day for the entire year. At the SFC under a zero grazing system a life cycle or phased feeding programme is practised according to the physiological state of the animal. An attempt would therefore be made to categorized leucaena-sugarcane based diets (both fed at the SFC and reported in the literature)

Leucaena Feeding to Early Weaned Dairy Calves

At the SFC replacement dairy calves were weaned at 35 days of age. Leucaena has been fed to these animals from the latter part of the milk feeding phase through to post weaning. The work involved the feeding of dehydrated chopped leucaena forage as the only source of forage. Table 2 presents some of the performances obtained. Table 3 describes a suggested system based on the SFC's experience. In stage I while the calf is still on milk leucaena can be introduced after the animal has been consuming about 0.4 to 0.5 kg/day of DM (Diet 1, Table 2). This works out to be leucaena being fed at about 10% of the diet DM intake, and this could be increased up to 29% of the diet DM intake post weaning (Diets 2 to 5, Table 2). The quality of the other feed ingredients however would be critical.

Leucaena Fed to Growing Beef and Dairy Cattle

It has been demonstrated by Siebert, Hunter and Jones (1976) that fresh chopped leucaena and sugarcane fed to beef cattle could make up 100% of the diet, however, the live weight gains were low (ADG 0.26 kg/day), table 4, diet 6. The work of Garcia (1988), diet 7 table 4 supports this. The work has further shown that dehydrated leucaena can be the sole forage source in molasses based diets aimed at ADG approaching 1kg/d; diets 11 and 13 table 4 and Diets 15 table 5. It can also be the sole forage source in sugarcane juice based diets in which up to 1kg/day ADG was reported (Durate, Elliott and Preston, 1982 Diets 21 and 22 Table 5). The analysis of Garcia (1988) suggested that animal performance with leucaena based diets is dependant on the intake of energy and protein by the animals, as the performance obtained reflected a consistent agreements with the National Research Council (NRC) (1978) protein and energy requirements for dairy cattle.

Table 2
Leucaena Feeding to Early Weaned Calves

Diets	1	2	3	4	5
	Milk Feeding Phase	Post Weaning Calves	Weaned Calves	Weaned Calves	Weaned Calves
Diet Composition (% DM Basis)					
Dehydrated Leucaena forage					
12 weeks regrowth	–	–	–	17	–
6 weeks regrowth	–	–	–	–	17
8 weeks regrowth	10	29	29	–	–
Soya bean meal	–	–	–	20	20
Cracked Maize	–	–	–	55	55
Molasses	–	–	–	7	7
Biophos	–	–	–	1	1
Commercial 16% CP Diary Ration	46.0	57	71	–	–
Milk Replacer	44.0	–	–	–	–
Rice Bran	–	14	–	–	–
Number of Days	19.9	26.3	27.9	16.5	35
Number of Animals	44	45	89	10	14
% Total Forage	20	29	29	17	17
Chemical Comp DM Basis % CP				19.8	19.8
% of total CP as NPN	0	0	0	0	0
% ADF estimated	5			10.4	10.4
Estimated DE (MJ/kg DM)				14.9	16.0
DM intake kg/day	0.87	1.51	1.40	0.89	1.51
% liveweight	2.20	3.10	2.80	1.90	2.80
Inital Lv. Wt. (kg)	37.3	42.4*	41.8*	44.2*	43.3*
Final Lv. Wt. (kg)	40.9*	56.3	57.0	50.3	66.1
Average Lv Wt. (kg)	39.1	49.3	49.4	47.3	54.7
ADG kg/day	0.27	0.59	0.58	0.41	0.65
F.C.E. kg DMJ/kg ADG	3.2	2.60	2.4	2.2	2.3

Source: Lallo Neckle and Garcia, 1988. * Weaning weight

Table 3
A Suggested Early Weaning Calf Rearing System Using Dehydrated Leucaena Forage

Stage	Discription	Feeding	ADG (kg/d)
I	Purchae to Weaning at 35 days age	(1) Arrival P.M. 1 litre electrolyte Day-1 and 1 litre milk replace (MR) A.M. and P.M. Day-2, A.M. previous day P.M. 2 litres MR (2) From day 3, 4 litre/day MR reduced to 2 litres 1 week prior to weaning (3) 16% CP Dairy Ration (DR) (4) Feeding Leucaena after calf consuming of 400-500 g/d of DM	0.27
II	Weaning to Transfer into community pens at (50-55 kg)	- 16% CP Dr - Leucaena or Leucaena/Rice/Bran	0.59
III	Community Pen Rearing	– Up to 100kg liveweight, it is suggested that leucaena 29%, Rice Bran 14%, Dairy Ration 40%, and Molasses 17% could be used for replacent heifers and bull calves	

Note: The possibility of using fresh leucaena forage exists.

Table 4
Feeding of Leucaena to Growing Cattle

Diets	6	7	8	9	10	11	12	13	14
Source Code	1	2	2	2	2	2	2	2	2
Sex	Male	Male	Male	Male	Male	Male	Male	Female	Female
Diet Composition (% DM Basis)									
Chopped Sugarcane	69.9	61.51	68.12	67.42	22.1	–	19.9	–	20.3
Leucaena	30.1	27.79	13.62	–	–	21.2*	–	19.6	–
Soya bean meal	–	–	6.81	13.48					
Molasses	–	4.26	4.93	12.18	26.6	26.9	26.8	26.7	26.6
Urea	–	1.90	1.85	1.94	0.8	0.9	0.8	1.2	0.9
Ammonium Sulphate	–	0.35	0.36	0.14	0.4	0.3	0.5	0.5	0.4
Trace Muriel Mix	–	0.95	0.96	0.95	–	–	–	–	–
Sodium Chloride	–	1.46	1.49	1.47	–	–	–	–	–
Calcium Carbonate	–	0.95	0.97	1.35	–	–	–	–	–
Dicalciumphosphate	–	0.85	0.88	1.06	1.0	0.8	0.7	0.8	0.7
Rice Bran	–	–	–	–	39.4	25.0	39.5	27.6	39.2
Cracked Maize	–	–	–	–	9.7	24.9	5.0	23.7	5.1
Poultry Rendering Meal	–	–	–	–	–	–	6.8	–	6.8
% Total Forage	100	89.30	81.74	67.42	22.1	21.2	19.9	19.6	20.3
Chemical Comp DM Base % CP	7.6	14.0	15.0	14.0	10	14	14	14	14
% of total CP as NPN	0	40	40	40	20	20	20	20	20
% ADF estimated	42	40	38	31	17	17	17	17	17
Estimated DE (MJ/kg DM)	10.7	11.0	11.1	11.3	13.2	13.2	13.2	13.2	13.2
DM intake kg/day	3.31	3.24	3.53	3.72	5.07	7.82	8.54	6.59	4.54
% liveweight	2.46	2.51	2.62	2.78	2.37	3.40	3.38	3.09	2.28
Inital Lv. Wt. (kg)	126.5	115.1	118.5	113.3	203.2	199.2	230.6	188.0	182.7
Final Lv. Wt. (kg)	141.8	138.6	150.5	160.3	222.5	261.3	274.3	239.2	215.8
Average Lv Wt. (kg)	134.2	128.9	134.5	136.8	212.9	230.3	252.5	213.5	199.3
ADG kg/day	0.26	0.28	0.38	0.55	0.35	1.14	0.76	0.91	0.59
F.C.E. kg DMJ/kg ADG	12.7	11.57	9.29	6.76	14.49	6.86	11.24	7.24	7.70

*Dehydrated Leucaena Forage
1 – Siebert, Hunter and Jones (1976); 2 – Garcia (1988)
DM – Dry Matter; NPN – Non-Protein Nitrogen; ADF – Acid Detergent Fibre; DE – Diestable Energy;
MJ – Mega Joules; ADG – Average Daily Grain; FCE – Feed Conversion Efficiency;
DMI – Dry Matter Intake

Leucaena/Grass Pastures

Animal performance on leucaena—grass pastures reported is given in Table 6. The live weight gain varied from 0.09 kg/day to 0.93 kg/day. The lower value was obtained when the leucaena was grown under a total annual rainfall of 510 mm (Henke as cited by Jones, 1979), and this was a good reflection of leucaenas' drought tolerance. Milk yields have also been acceptable (by developing tropical country's standards) in excess of 10 kg/day. The carrying capacity reported has been from 1.25 (in drought years) (Henke as cited by

Jones, 1979) to a height of 6.1 animals/ha., giving 12 kg milk/day in the latter case; (Plucknett, 1979).

Jones (1979) has suggsted that the variability in animal performance on leucaena-grass pastures are due to (i) environmental factors and (ii) the degree of leucaena intake and the development of toxicity symptoms. This may be overcome by limited grazing of the leucaena grass pastures, varying the stocking rate, as well as varying the ratio of leucaena to grass in the pasture along with the selection of low mimosine leucaena varieties (if this is a problem, which fortunately does not exist in the Caribbean).

Leucaena Feeding to Sheep

Leucaena forage has been fed alone either fresh, ensiled or dried to sheep for extended periods in Barbados (Quintyne, 1987). At the SFC dehydrated leucaena forage has been used as a source of fibre and protein in complete diets for sheep during lactation. Table 7 gives the formulation on a dry matter basis; this diet could also be used as a lamb starter; and it has been successfully forage to goats at similar physiological states. As leucaena forage contains about 20% CP it should best be fed in association with grasses or by-product feedstuffs which are low in protein.

Conservation of Leuceana

The whole freshly chopped forage may be dried (to 15% moisture) either by natural or artificial means, and storage has been found suitable in woven feed bags. Leucaena leaves could also be collected (as it falls off the freshly cut stems quite easily) dried and stored. In this way it could be used as a source of protein to a limited extent, but moreso as a source of calcium and vitamin A (Table 1), under circumstances which these may be limiting. Chopped leucaena forage has been found to ensile well with the addition of five to ten per cent molasses (Alli, Baker and Garcia, 1983 and Quintyne, Personal Communication).

COST OF PRODUCTION

The cost of producing Leucaena forage can vary widely. This financial outlay is dependant upon the system of production utilised (method of establishment, weed control and harvesting) and the yield obtained. Preliminary estimates based on data generated at the SFC and elsewhere indicated that under adequate management systems, cost of production and harvesting (manual) was TT$1.22 per kg dry matter or $0.37 per kilogramme as fed (Table 8). On a per kilogramme protein basis, this was comparable with the cost of supplementing the animals' diets with a purchased 16% CP dairy ration formulation which costs $0.90 to $1.00 per kg dry matter. The comparison was $6.78/kg CP for Leucaena versus $6.0/kg CP for purchased dairy ration concentrate (16% CP). Leucaena forage provides approximately 18% protein. A comparable figure for imported soya bean meal is $4.35/kg protein. It should however be noted that labour costs account for 75% of the total operating cost. On a farm where this labour was supplied by the farm family there was no direct cash outflow and therefore the cash flow situation was not as affected as if large quantities of concentrates were to be purchased. It can be predicted therefore that with expected increases in the cost of these purchased supplementary feeds, more farmers will turn towards the cultivation and use of Leucaena or other high quality forages to assist in meeting the nutrient needs of their Ruminant Livestock. If forage production could be increased by 50% then the cost of producing leucaena would be considerably reduced. In the computation on the cost of producing leucaena it was assumed that only 10 tonnes DM/ha/annum would be attained and this can be considered as the lowest production level.

Table 5
Feeding of Leucaena Forage to Growing Cattle

Diets	15	16	17	18	19	20	21	22	23	24	25	26	27
Source Code	3	3	3	3	3	3	4	4	4	5	5	5	5
Sex	Males	Males	Males	Females	Females	Females	Males	Males	Males				
Diet Composition (% DM Basic)													
% Leucaena Forage	47.0	28.6	–	46.8	29.3	–	32.2	31.1	35.0	28.9	27.5	20.8	20.3
% Napier Grass	–	20.3	48.9	–	20.7	49.1	–	–	–	–	–	–	–
% Cotton Seed Meal	7.0	6.9	6.9	7.2	6.6	6.6	–	–	–	–	–	–	–
% Chicken Litter										–	–	13.5	13.7
% Molasses/Urea	46.0	44.2	44.2	46.0	43.4	44.3	–	–	–	71.1	58.1	65.6	54.7
% Wheat Bran										–	14.4	–	11.4
% Fish Meal	–	–	–	–	–	–	8.8	7.4	–	–	–	–	–
% Sugarcane Juice	–	–	–	–	–	–	58.4	61.5	63.7	–	–	–	–
% Minerals	–	–	–	–	–	–	1.3	1.2	1.3	–	–	–	–
% Total Forage	47.0	48.9	48.9	46.8	50.0	49.1	32.2	31.1	35.0	28.9	27.5	20.8	20.3
Chemical Comp. DM Basis % CP	19	15	12				10.4	9.5	7.0				
% Total CP as NPN	20	24	30				0	0	0				
(%ADF estimated)	20	20	20				12	12	16				
Estimated DE (MJ/kg DM)	11.7	11.7	12.1										
DM intake kg/day	5.4	5.2	4.5	4.7	3.9	4.5	4.5	4.9	4.5	5.2	5.92	7.4	7.4
% Lv. Wt.	2.4	2.4	2.5	2.5	2.6	2.6	1.98	2.11	1.99				
Inital Lv Wt. (kg)	176	166	143	156	119	145							
Final Lv. Wt. (kg)	271	255	217	214	185	205							
Average Lv. Wt. (kg)	224	210	180	185	152	175	227	232	226				
ADG kg/day	0.8	0.7	0.6	0.5	0.5	0.5	1.05	1.02	0.85	0.585	0.722	0.787	0.89
F.C.E. Kg DMJ/kg ADG	6.75	7.47	7.53	9.40	7.84	9.04	4.28	4.83	5.57	8.96	8.14	9.29	7.93

Source Code:
3 - Teeluck, Hulman and Preston (1982); 4 - Durate, Elliott and Preston (1982); 5 - Meyreles, Pound and Preston (1982)

Table 6
Animal Performance on Grass-Leucaena Pastures Reported in the Literature

Location	Grass Species	Stocking Rate Animals/ha	Breed of Animal	Management Practice	lv. wt gain kg/day	kg/ha/year 1. wt. gain	Milk Yield Kg/ha/annum	Calf Growth Kg/day	References
Australia					.2 - .52				Hill (19 1)
Hawaii		1.25			.09 - .233				Henke a cited by Jones (1 79)
Hawaii	*Panicum-maximum*	6.1	Holstein Frasiar			400 kg	9,770 (12 kg/day/cow)		Pluckne (1970)
Mexico	Cynodon sp.	3.0	Holstein or brown swiss	No Leucaena			(9.19 kg/day/cow)	.563	Saucedo Alverez Juminez and Arriaga (1980)
			Swiss or Zebu	6 hrs Leucaena/day			(10.75 kg/day/cow)	.632	
Busbane Australia	Chloris-guyana cv Pioneer		Jersey	Control Control + 2 kg Leu. Control + 4 kg Leu.			(9.6 kg/day/cow) (10.3 kg/day/cow) (10.3 kg/day/cow)		Flores-Ramos (1979)
Australia	Cetariaanceps		Steers & calves		.93 - .88				Jones (1 73) As cited by Jones (1 79)
Fiji	Dichanthium sp.	1.5			.3 - .5				Partridge and Ranacou (1974)
Australia	Digitaria decumbens	6.2 4.9 0.6			.37 .33 .29	830			Blunt as cited by Jones (1 79)
Australia	Chloris guyana (Rhodes grass)	1.9 2.5		Continuous	.49	340 327			Jones (1 79)
Australia	*Panicum maximum* cv. Tricha-glume	4.78	Jersey				6290 kg/ha (for 9 mths)		Stobbs (1972)

Table 7
DM Composition a Diet Containing Leucaena Fed to Few Grazed Hair Type Tropical Sheep Dairy lactation

Premix	1
Ingredients % DM Basis	
Dried Leucaena	15.0
Wheat Middlings	20.0
Poultry By-product Meal	20.0
Maize (Cracked)	34.5
Molasses (sugarcane)	10.0
Mineral Mix	0.25
Salt	0.25
Analysis % DM Basis	
Crude Protein	22.0
Digestible Energy (MJ)	14.6
Ca	0.54
P	0.46
ADF	13.5

Source: Lallo, Neckes and Garcia, 1988b

Table 8
Estimated Cost of Production for Leucaena Forage in Trinidad and Tobago

			TT$*
Establishment Cost			
1.	Land preparation (brushcut, plough, rotovate and bed formation)	$	2000.00
2.	Limestone (2 tonnes per ha.)	$	1000.00
	labour for application (10 man-days per ha.).	$	500.00
3.	Planting material - 5 kg. seeds.		400.00
4.	Planting (10 man days / ha)	$	500.00
5.	Weed control:		
	Chemical- pre emergant: Dacthal @ 8 kg/ ha	$	256.00
	Labour (5 man days /ha @ $50.00/ manday)	$	250.00
5.	Pest controll:		
	Basudin-	$	200.00
	Labour @ 5 man days / ha	$	250.00
6.	Total	$	5356.00
7.	Interest:	$	3137.00
8.	Total Establishment Cost:	$	8493.00
	Annual Cost**	$	849.30
Operating Cost			
1.	*Fertilizer*:		
	100kg Sulphate of Ammonia/ ha	$	139.00
	100kg Triple Super Phosphate /ha	$	137.00
	50kg Muriate of Potash	$	91.00
	Mandays for application:60 (6 applications)	$	3000.00
2.	*Herbicide*		
	Roundup - 3 litres/ ha x 6 times / year	$	1425.00
	Labour- 5 mandays / ha x 6 times per year	$	1500.00
	Stumping and mannual weed control twice per year @10 mandays / ha	$	1000.00
3.	*Harvesting*		
	10 man/days/ha/harvest (with 6 harvests / year)	$	3000.00
4.	Interest	$	1029.00
5.	Total Operating Cost	$	11321.00
	Total Annual Cost	$	12170.30
Yield expected 10 tonnes dry matter (DM) / ha			
Cost / kg DM		$	1.22
Cost / kg as Fed		$	0.40

*Present Rate of Exchange 1 TT$ - $0.20 US
**The annual cost of establishment is spread over ten years

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Multipurpose Use and Farming Systems

Leucaena and Alley Cropping

G.F. Wilson

INTRODUCTION

Until the last decade modern science contributed little to the evolution of agriculture in the tropics. Due mainly to the belief that tropical agriculture was primitive and should be replaced, most efforts were directed to introducing techniques, methods and equipment developed in temperate regions. The significant break from that approach came with the establishment of International Agricultural Research Centres (IARC's) and their emphasis on farming systems approach to agricultural research. This approach brought attention to indigenous systems, but even here the tropical systems were regarded as something to replace rather than something to improve. Therefore in creating the research programmes at the International Institute of Tropical Agriculture (IITA) the founders created the Cereal Improvement Programme (CIP), the Grain Legumes Improvement Programme (GLIP), the Root and Tuber Improvement Programme (TRIP), and the Farming System Programme (FSP). Note the absence of the word improvement from the Farming Systems Programme that was mandated to develop alternate systems for the humid tropics. Yet, Alley Cropping one of the most striking development in tropical cropping system resulted from attempts to organise or improve bush fallow, a common system of the humid tropics (Wilson and Kang, 1981; Kang Wilson and Lawson, 1984).

EVOLUTION OF SHIFTING CULTIVATION

Before looking at Alley Cropping and the role of *Leucaena lecocephala* in its evolution, we should briefly discuss evolution of shifting cultivation, the system it was designed to improve. In its earliest stages, shifting cultivation is characterised by short, one to two years, cropping periods alternating with long, up to 15 to 20 years, naturally regenerated fallows in which trees are the climax vegetation. As the human population density increases so does the cultivation intensity (Ruthenberg, 1971; MacDonald, 1982), consequently the fallowing periods is shortened and the climax vegetation becomes bush or small trees and shrubs. In the drier tropics the fallow progression develops into grassland savannahs, while in the wetter tropics the progression moves to multistory cropping with economic trees in the top canopy story, economic shrubs in the middle story and annual food crops in the lower story (Weston, 1983). With intensification comes the realisation that fallows contributes to soil fertility restoration and that selected plant species are more efficient at this. These species (usually legumes) are therefore encouraged to dominate the following (Benneh, 1972; Wilson and Kang, 1981; Wilson Kang and Mulongy, 1986) and especially where they produce edible portions, retained in multistory systems (Getahum, Wilson and Kang, 1982). Note that unlike temperate regions where herbaceous species are used in soil fertility restoration, the tropics emphases trees. This difference will be discussed further. However, it should be mentioned that higher productivity or efficiency noticed for herbs in temperate systems may be due not to type of plants used but to climate and management intensity. While herbs in temperate regions are managed to ensure green mature at the beginning of the cropping season, the same is not feasible in the tropics where the dry season that normally proceed the planting season results in the drying and dying of most herbaceous legumes.

International interest in trees in tropical agriculture began in the early 1970s (Bene, Beall and Cote, 1977; Posulsen, 1978) just at the time when researchers in IITA, FSP were realising that managing the fallow was one likely method of improving some of the more popular tropical systems.

ALLEY CROPPING

Kang *et al.* (1984) used the term "alley cropping" to describe cultivation of food crops in alleys formed by hedge rows of leguminous trees or shrubs that are cut back at crop planting and kept trimmed during cropping to prevent adverse effects of hedge plants on crops. As the crop matures trimming or cutting is stopped and the land goes to fallow under the influence of selected tree or shrub species known for rapid soil fertility restoration. This same concept goes by other names for various reasons. The International Council for Research on Agroforestry (ICRAF) prefers to call it "Hedgerow Cropping" because it believes the hedges are outstanding features of the technique. Wijewardene and Waidyanatha (1984) use the inappropriate "Avenue Cropping" simply because "Alley" is an unsavoury connotation in their native Synalese language. On the whole alley cropping and its associated "alley farming" dominate the literature and seems more appropriate to the tropics. Therefore it will be used throughout this report.

The work with tropical legumes began as part of an overall desire to identify species that would enhance soil fertility restoration and had some potential for supporting livestock production. Thus, Leucaena well known as a livestock feed was included in the early trials. But because livestock is not an important component of agricultural system of the humid region of West Africa and other aspect such as rapid growth, stem size and length and soil fertility restoration that led to selection of Leucaena were more influential criteria. The tall stems, produced in relatively short time, were regarded as good replacement for institu stems of slower growing plants used for supporting yam vines. However, because the high nitrogen of the leaves were deleterious to yam yield and quality, it was found to be more feasible to use the stems, without leaves, as cut and carry stakes, leaving behind Leucaena fields with inter-row species (Alleys) covered with nutrient rich Leucaena leaves. These leaves could be retained on the surface as mulch or incorporated as green manure. Bio-assays with maize demonstrated that the nutrient use efficiency was higher when used as green manure than as mulch (Wilson *et al.*, 1986), but because of the soil conserving properties mulching was, in many cases, advantageous. These findings pointed to the potential of Leucaena and other tree legumes as nutrient sources and managed fallow within the concept of Alley Cropping.

LEUCAENA

Contribution of Alley Cropping

Although various trees have been used in tropical cropping, none has caught the attention or stimulated the imagination of the tropical agriculturalist as Leucaena. Its potential contributions, (Brewbaker, 1987) though not fully estimated were the main factors that led to alley cropping as a potential replacement for bush fallow. While many other trees can be used in alley cropping, rapid growth and high biomass to maintain soil fertility during cropping were additional plusses. As a well known animal feed it is easily adopted into "Alley Farming" (Sumberg and Okali, 1983; Atta-Krah and Francis, 1986) where its persistent foliage was an added advantage in dry season feeding. The many attributes of Leucaena are well documented (Brewbaker 1987; Ngambeki, 1985) and even in this meeting more will be brought forward. Therefore further discussion will be directed to its use in alley cropping for the Caribbean.

ALLEY CROPPING FOR THE CARIBBEAN

Leucaena remains a relatively new crop to the Caribbean. The species has been present and in some cases appears native to the region but interest in its cultivation is recent and not well developed. A few livestock farmers have established small plots and attempts are being made in fuel wood production in Haiti, but alley cropping and its associated management practices have not been introduced in the English speaking Caribbean. Yet there are indications that alley cropping and the principles it embodies cover many of the specific needs of Caribbean small farmers.Considering the terrain and the need for soil conservation practices, alley cropping offers a low cost alternative comparative with the low input and management expertise available. All it requires are viable seeds planted closely on the contours and a cutlass to cut back the biomass from which the stems can be laid at the base of the trees to reduce erosion and the leaves and twigs applied to the soil as mulch or green manure. While green manure produces better Nitrogen recovery and higher crop yield, mulch provides better soil protection. Therefore, alley cropping with mulching should be preferred for effective soil and water conservation. Although yields would be slightly lower, the conserved resources would facilitate sustainable production.

The resource poor farmers of the Caribbean are, by themselves, unable to construct conventional terraces and contour barriers needed for erosion control. Consequently most such conservation structure were installed with public funds. However, because public funds were not provided for maintenance they deteriorated rapidly. There were also no consideration for none crop uses of the field or the solid needs of the farmer. Therefore many terraces deteriorated from lack of maintenance, were destroyed by grazing animals that were part of the rotation or in some cases, the stones were removed by farmers who considered them cheap building materials. Leucaena and similar trees would not have these disadvantages and properly introduced the biological conservation provided by alley cropping should not only reduce erosion but should provide many benefits to the farmer and the environment.

So far alley cropping appears the most efficient method of exploiting the many attributes of leucaena. Not only will it aid conservation but can be a major renewable source of wood that can be used as stakes, poles and fuel, possibly the most attractive aspect in countries that can no longer afford fossil fuel energy. The high protein leaves are good animal feed which can be exploited in alley farming which is alley cropping with ruminant animals components.

The Caribbean, like most developing regions lacks the internal capacity to inject fossil fuel energy and introduction of the associated expensive technology put agriculture at a disadvantage on the international market that is so important to the region. While leucaena may not provide all the energy needed for agriculture it can reduce the fertilizer and fuel energy imported to the region.

As many of the papers presented at this workshop will show, the Caribbean is aware of the potential of Leucaena. However, its use in alley cropping and potential for small farmers of the region remains untested. The holding of this first International Workshop on Leucaena here in the Caribbean is a good omen that should set in motion a major effort to harness the potential in the local farming systems and to developing more efficient biological farming systems for the region.

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Fertilizer Effect of *Leucaena leucocephala*, *Cassia siamea* and *Cajanus cajan* in Alley Cropping with Maize

S.S. Chiyenda and S.A. Materechera

INTRODUCTION

Smallholder farmers in the tropics have historically practiced a system of bush fallow or shifting cultivation in which the land, rather than the crops, were rotated. In this type of system, the land was cleared and some trees felled. Quite often, however, some soil fertility restoring trees such as *Acacia albida, Acacia bateri, Gliricidia sepium, Anthonatha macrophylla, Leucaena leucocephala* and others were selectively retained (Wilson, 1981) mainly for their ameliorating effect on the soil. Crops were usually planted on a piece of land for two to four years. With repeated cropping and no measures being taken to return nutrients to the soil, fertility declined and, therefore, the land would be left under fallow in order for it to regain fertility. Meanwhile, the farmer moved to another piece of land and repeated the clearing, felling, burning and crop planting process on what was often new virgin land. But, as the human population grew, the ratio of fallow to cultivated period declined and with it the fertility and productivity of the land also declined.

Increases in world population have not only made the practice of bush fallow or shifting cultivation obsolete and impractical but have necessitated more intensive use of a dwindling land base for food production with a view of warding off widespread hunger and famine. It is noteworthy, however, that increased food production has been achieved in most developed and developing countries through use of large amounts of inorganic fertilizers and pesticides. Yet while the use of inorganic fertilizers is obviously attractive, the cost of most such fertilizers is escalating beyond the financial ability of many a smallholder farmer, the majority of whom live in the developing countries of the tropics. It is because of this escalating cost of inorganic fertilizers that agricultural scientists have turned to studying seriously the probable benefits of growing certain types of trees with crop plants, in the hope of cutting down on the amounts of inorganic fertilizers required to maintain current production levels. While empirical evidence is accumulating in support of the view that such trees contribute quite positively to the amelioration of the soil and to enhancing its fertility to a measurable degree, they may also serve as much-needed firewood for cooking and heating or as poles for construction. In view of the critical fuel problems now facing many developing countries, such a role for trees cannot be ignored.

Over the last ten years the cost of farm inputs, especially inorganic fertilizers, has more than doubled in Malawi (Manduwa, 1985). On the other hand, corresponding increases in prices paid to smallholder farmers for their crop products have significantly failed to keep pace with input cost increases. These increased input costs are attributed in part to local currency value fluctuations relative to the currencies of the developed countries from where these inputs are imported, increased transport costs and the removal of subsidies by

Government on critical agricultural inputs such as fertilizers. On the other hand, inadequate increases in producer prices are blamed in part on worsening international terms of trade. All this means that the smallholder farmer in Malawi, as in most other developing countries, is faced with declining fertility and productivity of his land in the face of fast-escalating input (fertilizer) prices.

In order to help redress the problem of declining soil productivity which is exacerbated by the smallholder farmer's inability to pay for inorganic fertilizers, a medium to long-term experiment on alley cropping was initiated at Bunda College of Agriculture in Lilongwe, Malawi, in October 1983. The objective here is, therefore, to describe some of the results obtained so far in this investigation and their implications for soil fertility and productivity. But before doing so, it is relevant to examine or review related work carried out in Malawi and elsewhere on this very important subject.

The recycling of nutrients to the surface soil is one of the basic assets of alley cropping and green manuring in general. This is because where nitrogen-fixing leguminous trees or shrubs are used, some of the nitrogen fixed is eventually released to the companion crops through decomposition of prunings (leaves and twigs). Kang, Spikens, Wilson and Nangju (1981) have observed that Leucaena prunings are a more effective nitrogen source when incorporated in the soil than when applied as mulch. They suggested that better results obtained with incorporation may be attributed to faster decomposition and mineralisation of prunings, while the lower efficiency of surface applied prunings may be due to high losses from nitrogen volatilisation during decomposition. Recent data (Anonymous, 1986) indicated, however, that crop utilisation of nitrogen derived from prunings is usually low and that supplementary commercial nitrogen is necessary for optimum food crop production under alley cropping. By using the inorganic nitrogen fertilizer equivalent method, nitrogen contribution of *Leucaena leucocephala, Gliricidia sepium, Cassia siamea and Flemingia congesta* was evaluated to be in the range of 38 to 78 kg/ha, representing no more than 30% of nitrogen from the prunings.

On a sandy Entisol at Ibadan, Nigeria, yield of maize alley cropped continuously for six years has been maintained at about 2000 kg/ha with the incorporation of Leucaena prunings only (Kang Wilson and Lawson, 1984). Plots receiving prunings contained twice the amount of soil organic matter as plots where prunings were not incorporated. Repeated application of sulphate of ammonia as nitrogen fertilizer increased soil acidity but the addition of Leucaena prunings did not affect soil pH.

Manduwa (1985) reported that incorporation of 20 tonnes/ha of Leucaena prunings as basal application on a Ferric Luvisol (FAO classification) at Bunda in Lilongwe, Malawi, produced 6,443 kg/ha of maize grain yield compared with 6,885 kg/ha when 200 kg/ha of 20:7:8:0 (basal) and 200 kg/ha of calcium ammonium nitrate (side dressing) were applied. In this study, single application/incorporation of Leucaena prunings generally gave higher grain yields than split incorporation of the same amounts of prunings.

Dry matter yield and the potential N, P and K contribution of some woody leguminous perennials (e.g. *Leucaena leucocephala* and *Gliricidia sepium*) as well as performance of maize were assessed in an alley cropping system at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Yomoah, Agboda and Wilson 1986). Dry matter yield was highest for Cassia, followed by Gliricidia and Flemingia. Whereas dry matter yield of Cassia varied significantly with pruning time, those of Gliricidia and Flemingia were relatively uniform. Gliricidia contributed the highest N from the prunings. Maize yields were generally higher in alley cropped than in control plots. The difference was attributed in part to poor soil physical properties and nutrient status, particularly in N content. It was thus concluded that the significance of alley cropping system should be viewed in light of its improvement in both the physical and chemical properties of the soil. However, the improvement in soil physical properties was deemed more important than the supply of nutrients because the nutrients released by the prunings become useless if the soil physical properties do not favour proper root development to tap these nutrients.

Kang, Wilson and Sipkens (1981) reported that an addition of Leucaena prunings from the full grown hedge rows of maize-leucaena alley cropping system on an N-defficient sandy Apomu soil series (Psammentic Usthorthent) at Ibadan, Nigeria, was able to sustain maize grain yields at about 3,800 kg ha^{-1} $year^{-1}$ for two consecutive years with no addition of inorganic nitrogen while yield declined with no addition of prunings. Higher maize yields were, however, obtained with supplementation with low N rates of 20 to 80 kg/ha depending upon maize variety and season. In the same long-term experiment, Kang *et al.* (1984) reported high organic matter and reduced acidity on plots which had received larger amounts of prunings than those where no prunings were incorporated.

Materials and Methods

An experiment was started at Bunda College of Agriculture, Lilongwe, Malawi (altitude 1,118 m, 33° 46' S, 14° 11' E) in 1983. Bunda College is located within the Lilongwe plain which is a greatly undulating landscape with almost flat and gentle slopes. The area has tropical continental climate characterised by a distinct wet and dry season. The mean annual rainfall ranges from 850 to 875 mm and is evenly distributed throughout the growing season (November to April) giving the years semi-arid conditions.

The aim of the work was to meet the following medium to long-term objectives:

(i) To assess soil fertility maintenance capabilities of *Cassia siamea*, *Leucaena Leucocephala* and *Cajanus cajan* under local environmental conditions;

(ii) To determine the growth rate and biomass production of the three tree species;

(iii) To determine the quality of nutrients accumulated by the three tree species and their contribution to the soil;

(iv) To assess the yield of maize grown with different tree species in alley cropping systems; and

(v) To determine suitable tree species for use in alley cropping systems in Malawi.

The results to be discussed in this paper will be relevant mainly to objectives (i), (ii), (iii) and (iv) above. The soil used in this study is classified as a Ferric Luvisol by the FAO soil classification system (Lowole, 1985). Some characteristics of the soil are presented in table 1. This soil is a sandy clay loam, slightly acid with low Cation Exchange Capacity (CEC) and exchangeable cations, except K.

Table 1
Some Characteristics of Lilongwe 2 (ferric luvisol) Surface soil used in the study

Mechanical Composition							Am Acclate Extr. (me $100g^{-1}$)				
Sandy	Silt	Clay	$pH-H_2O$	Org. C (%)	Total N (%)	Bray 1 P	K	Ca	Mg	Na	CEC (me $100g^{-1}$)
56	10	34	6.1	0.656	0.06	48.17	0.58	1.97	0.77	0.04	4.36

The experiment was laid out as a split-split-plot with three blocks. Main plot treatments consisted of three levels of nitrogen: 0kg/ha, 50kg/ha, and 100kg/ha. Sub-plot treatments consisted of associated tree species: that is, maize alone, *Leucaena Leucocephala* (with maize), *Cassia siamea* (with maize) and *Cajanus cajan* (with maize). Sub-sub-plot treatments were alley width for maize: 2.7m, 5.4m and 10.8m alley widths (3 ridges maize). Maize ridges were spaced 91 cm and maize and trees were planted on the ridge at a spacing of 91 cm between planting stations. Four maize seeds were planted per station initially and thinning to three plants per station was done a week after emergence. The maize variety Ukirigura Composite A (UCA) was used in this trial. The tree species were planted only at the beginning of the investigation in 1983 but maize was planted annually in November/December, at the beginning of the crop season.

At the time of planting, all maize plots, including the control, received 22kg/ha of phosphorus. Treatments with 50 and 100 kg N/ha received N in split application, the first dose of half the rate at time of planting while the remainder was applied when the plants were 45 to 50 cm tall. At both times, the fertilizer was applied using the dollop methods in which fertilizer is applied about 7.5 cm on both sides of a planting station at a depth of 5-7 cm. Tree species received no fertilizer.

Yield and yield components of maize were recorded as well as selected performance characteristics of the tree species. Data reported here relates to the second year (1984/1985) and third year (1985/1986) after establishment of the tree species because it was possible to assess the probable effects of incorporating prunings from the trees on maize yield. Some data on yield of maize is given for 1986/87 and 1987/88 seasons. Prunings were incorporated at least three weeks before maize was planted, at time of ridging, in October each year.

Soil sample were also taken each year at the beginning and end of the crop season. In addition, soil samples were taken before the experiment was established in 1983. This was intended to aid in assessing possible changes in soil characteristics due to incorporation of prunings. Samples of prunings were also taken with a view to determining nutrient composition. Since percentages do not generally follow a normal distribution, the percentabe value of organic carbon and total nitrogen were transformed using the arcsin transformation (Snedecor and Cochran, 1967) prior to carrying out analysis of variance.

RESULTS AND DISCUSSIONS

In order to assess the contribution to maize yield resulting from incorporation of tree prunings into the soil as a source of nitrogen, it is useful to discuss the establishment and performance of the tree species used in this study. Accordingly, results relating to establishment of the trees and their contribution to soil carbon and nitrogen from incorporation of prunings will be considered before discussing their probable influence on maize yield.

Establishment and Performance of Trees

As indicated earlier, the three tree species were planted by direct seeding in October/November 1983 and results relating to their survival during three successive growing seasons are presented in Table 2.

Table 2
Percentage Survival of Tree Species During Three Growing Seasons at Different Alley Widths at Bunda

Tree Species	Alley Width (m)	Survival (%)*		
		1983/84	1984/85	1985/86
L. Leucocephala	2.7	73.7	72.4	72.4
	5.4	71.2	70.6	69.7
	10.8	73.3	72.5	70.5
Cassia siamea	2.7	39.9	68.8	87.0
	5.4	39.1	71.1	86.1
	10.8	46.5	80.3	84.2
Cajanus cajan	2.7	95.1	90.3	92.6**
	5.4	95.1	93.7	87.1
	10.8	94.2	92.4	90.4

* Value for each season is a mean of three replicates
** All the *Cajanus cajan* was uprooted and replanted in 1985/86 because over 75% of the plants died from *Fusarium wilt.*

Survival records were taken at the end of each growing season and represent the proportion of trees alive relative to what was there at the end of the preceding season. As is evident from Table 2, the highest survival rate was observed in *Cajanus cajan,* followed by *L. leucocephala* and then *Cassia siamea.* It is noteworthy that considerable difficulty was experienced in getting *Cassia siamea* established as is clear from the very low survival rate of between 39.1% and 46.5% in the first season.This is reflected in negligible biomass production for incorporation in the soil during the first and second year of establishment for *Cassia siamea* and, to some extent also, for *L. leucocephala.* While *Cajanus cajan* was the easiest to get established, it suffered seriously from attack by *Fusarium wilt* after the second season so that it had to be replanted at the beginning of the third season (1985/86).

The performance of the tree species, in terms of canopy height and canopy width, was recorded after maize harvest during the 1984/85 and 1985/86 season (Table 3) while total biomass (dry weight basis) incorporated into the soil in the form of prunings is presented in Table 4 for three consecutive seasons. The results in Table 3 show that *Cajanus cajan* performed best among the three tree species, followed by *L. leucocephala* and then *Cassia siamea.* This is certainly consistent with the superior survival rate of *Cajanus cajan* observed earlier relative to that of the other two species. It is also significant that because of the slow rate of establishment of *L. leucocephala* and *Cassia siamea,* it was not possible to get enough biomass for incorporation into the soil until the third (1985/86) season. On the other hand, *Cajanus cajan* was able to produce enough biomass for incorporation by the end of the first season of its establishment.

Table 3
Canopy Height and Canopy Width (means) of Tree Species After Maize Harvest During the 1984/85 and 1985/86 Seasons

	Cajanus cajan		*L. leucocephala*		*Cassia siamea*	
	1984/85	1985/86	1984/85	1985/86	1984/85	1985/86
Canopy Height (cm)	152.9	160.2	73.9	78.4	65.4	68.3
Canopy Width (cm)	102.7	104.7	64.9	66.7	65.0	65.0

Table 4
Total Biomass (Kg/ha), dry weight) of Prunings incorporated from Different Tree Species Alley Cropped with Maize

Alley Width (m)	Tree Species	Total Biomass*		
		1983/84	1984/85	1985/86
2.7	*L. leucocephala*	–	–	1740
	Cassia siamea	–	–	5310
	Cajanus cajan	450	2250	1230
5.4	*L. leucocephala*	–	–	1980
	Cassia siamea	–	–	5520
	Cajanus cajan	390	1830	1590
10.8	*L. leucocephala*	–	–	1590
	Cassia siamea	–	–	6420
	Cajanus cajan	450	1800	1350

* Biomass entries are means of three replicates
- Biomass not available

Contribution to Soil Carbon and Nitrogen

Analysis of samples of prunings from the three tree species for different nutrients gave the results presented in Table 5. These results show that *L. leucocephala* consistently had more nutrient content compared with the other two species. *Cassia siamea* was second to Leucaena while *Cajanus cajan* was last. It might be expected from these results that for equal quantities of incorporated biomass, L. leucocephala would contribute more nutrients to the soil followed by *Cassia siamea* and then *Cajanus cajan*. Indeed, bearing in mind the slow establishment of Leucaena and Cassia, this situation might be expected to prevail in the long term. On the other hand, the higher carbon content of Cassia, followed by *Cajanus cajan* and then Leucaena would seem to suggest that improvement in the physical structure of the soil from incorporation would be greatest for Cassia followed by *Cajanus cajan* and then Leucaena.

Table 5
Nutrient Composition of Prunings of Tree Species Grown on a Lilongwe 2 Series (Ferric Luvisol) at Bunda*

Tree Species	C %	N %	P %	K %	Ca %	Mg %	C:N Ratio
L. leucocephala	22.80a	1.92a	0.24a	1.24a	1.13a	0.17a	12:1
Cassia siamea	58.48b	1.12b	0.18a	0.70b	1.22a	0.08b	52:1
Cajanus cajan	46.35b	1.03b	0.19a	0.17c	0.53b	0.11b	45:1

* Values for each nutrient element with different letters are significantly different ($P<0.05$);

By applying the results on nutrient composition presented in Table 5 to the quantities of biomass incorporated as given in Table 4 one arrives at the estimated amounts of incorporated carbon and nitrogen given in Table 6. As observed earlier, because of early establishment, it was possible to incorporate some prunings from *Cajanus cajan* in the first season but because of the relatively small quantity of the material, its contribution to soil carbon and nitrogen was small (Table 6). The largest estimated contribution to soil carbon and nitrogen from *Cajanus cajan* prunings was observed in 1984/85. The reduction in the level of estimated contribution to soil carbon and nitrogen from this species in the 1985/86 season is attributed to reduced biomass production due to attack by *Fusarium wilt*. In the 1985/86 season, the largest contribution to soil carbon and nitrogen is observed in *Cassia siamea* with *L. leucocephala* coming second and *Cajanus cajan* last. It is noteworthy that for each tree species, there are no significant differences in the estimated contribution to soil carbon and nitrogen among alley widths. This note withstanding, it is significant that in absolute terms the greatest estimated contribution to soil carbon and nitrogen is observed for an alley width of 5.4 m except in *Cassia siamea* where this is observed for an alley width of 10.8 m. This appears to suggest that an alley width of 5.4 m may be optimal for maximum contribution to soil carbon and nitrogen although there is no statistical evidence that this is necessarily superior to the other alley widths.

Determinations were made of total nitrogen and organic carbon from samples of surface soil of the Lilongwe 2 series (Ferric Luvisol) on which this investigation was conducted after three seasons of alley cropping with maize (Table 7)

Table 6
Estimated Total Carbon and Nitrogen (kg/ha) from Incorporation of Prunings from Different Tree Species Grown in Alley at Bunda

Alley Width (m)	Tree Species	1983/84 C	1983/84 N	1984/85 C	1984/85 N	1985/86 C	1985/86 N
2.7	*L. leucocephala*	–	–	–	–	397	33
	Cassia siamea	–	–	–	–	3105	59
	Cajanus cajan	209	5	1043	23	570	13
5.4	*L. leucocephala*	–	–	–	–	451	38
	Cassia siamea	–	–	–	–	3228	62
	Cajanus cajan	181	4	848	19	737	16
10.8	*L. leucocephala*	–	–	–	–	363	31
	Cassia siamea	–	–	–	–	3754	72
	Cajanus cajan	209	5	834	19	626	14

Table 7
Total Nitrogen and Organic Carbon of Surface Soil of Lilongwe 2 Series (Ferric Luvisol) after Three Seasons of Alley Cropping with Maize at Bunda

Alley Width (m)	Tree Species	Total N* %	Organic C %
2.7	Maize alone	0.05 a	0.66 a
	L. leucocephala + maize	0.08 a	0.91 b
	Cassia siamea + maize	0.08 a	0.87 b
	Cajanus cajan	0.13 b	1.12 c
5.4	Maize alone	0.04 a	0.65 a
	L. leucocephala + maize	0.08 b	0.83 ab
	Cassia siamea + maize	0.07 b	0.81 ab
	Cajanus cajan + maize	0.08 b	0.91 bc
10.8	Maize alone	0.05 a	0.64 a
	L. leucocephala + maize	0.07 b	0.72 ab
	Cassia siamea + maize	0.08 b	0.75 ab
	Cajanus cajan + maize	0.07 b	0.81 ab

* Values for N or C having a common letter are not significantly different at 5% using least significant difference (LSD)

Analysis of variance for total nitrogen for the surface soil after three growing seasons showed significant differences among tree species. There was significantly higher nitrogen in the treatments which had received 100 kg/ha N in the three years, the levels being 0.06%, 0.08% and 0.11% for 0, 50 and 100 kg/ha N, respectively.

This may be due to the effect of residual N from annual application of fertilizer. For the tree species, treatments with *Cajanus cajan* and maize had higher N contents of 0.06%, 0.07% and 0.98% for maize alone, Leucaena and maize, Cassia and maize and *Cajanus cajan* and maize in that order. The high N content in plots with *Cajanus cajan* and maize may be attributed to differentials in mineralisation of material from the three species resulting in more additional organic nitrogen in *Cajanus cajan* and maize plots, thus increasing total N levels. Without empirical evidence on levels of mineralisation, however, this is at best a conjecture.

Analysis of organic carbon showed significant differences among tree species and among alley widths. Again, *Cajanus cajan* and maize had significantly higher organic carbon than the other treatments while an alley width of 2.7 m generally gave the highest organic C content. The organic C content for maize alone, Leucaena and maize, Cassia and maize and *Cajanus cajan* and maize were 0.81%, 0.76%, 0.84% and 1.01% in that order. This could be explained by the fact that shorter alley widths had relatively more biomass added to them than was added to longer ones.

Influence on Maize Yield

Results relating to the yield of maize during the 1984/85, 1985/86 and 1986/87 seasons are presented in Table 8. No results are reported for the 1983/84 season because the main objective here is to assess the effect on yield due to incorporation of prunings into the soil. No material was available for incorporation at the beginning of the 1983/84 season.

Analysis of these results shows that average grain yield of maize was highest for the different treatments during the 1984/85 season compared to the other seasons and was relatively lowest during the 1986/87 and 1987/88 seasons. The reduced grain yields during the 1985/86 season are probably due to a higher incidence of cob rot prior to harvesting thought to have been induced by prolonged rains compared to the preceding season. Unpublished empirical evidence based upon work carried out at Bunda (MacColl, 1987: personal communication) showed that there was a high positive correlation between relative humidity during maize silking stage (80-100 days after planting) and per cent cob rot at harvesting. More specifically, MacColl's data showed that in addition to more prolonged rains during the 1985/86 season, average relatively humidity during silking of maize was highest during that season while the highest proportion of cob rot (up to 70%) was recorded in the same season. This may explain the reduced grain yields observed in maize during the 1985/86 season compared to those observed during the 1984/85 season.

Table 8
Effect of Alley Cropping and Fertilizer Application on Average Yield of Maize (kg/ha at 12.5% M.C.) for Four Seasons

		Nitrogen Rate (kg/ha)			Alley Width (m)			Mean
Season	Crop System	0	50	100	2.7	5.4	10.8	
1984/85	*Zea mais*	704	1954	3564	1683	2495	2043	2074
	L. Leucocephala	617	2459	2794	2412	2038	1420	1957
	Cassia siamea	467	1856	3287	1997	1827	1785	1870
	Cajanus cajan	468	1523	3054	1617	5121	1907	1682
1985/86	*Zea mais*	151	2317	3233	2111	1973	1618	1901
	L. Leucocephala	107	1665	2935	559	2394	1279	1411
	Cassia siamea	57	1049	1638	440	992	1382	915
	Cajanus cajan	255	1918	2870	1231	2237	1575	1681
1986/87	*Zea mais*	356	927	1279	1122	820	621	854
	L. Leucocephala	230	8852	968	536	769	744	683
	Cassia siamea	116	886	806	279	753	775	603
	Cajanus cajan	375	849	1098	828	811	684	774
1987/88	*Zea mais*	336	672	904	867	619	425	637
	L. Leucocephala	287	953	973	869	743	601	738
	Cassia siamea	347	856	925	738	576	814	709
	Cajanus cajan	349	862	1089	981	609	710	767

Note: Interactions are not significant

The relatively low yields for maize observed during the 1986/87 and 1987/88 seasons may be due to a number of reasons. Firstly, the 1986/87 season was characterized in Malawi by delayed on-set of the rains and a period of relative drought during the middle of the growing season which is likely to have affected grain yields for maize. While the rains were normal during the 1987/88 season, with some of the best maize yields being recorded at Bunda in 1987/88 over the last few years, it is not immediately clear from our analysis why yields from our experiment were so low during this season. It is hoped that soil analysis results for the season which were not ready at the time of writing this paper may help explain this apparent anomaly in maize yields.

It is significant to note from our data that, except for the 1984/85 season, average maize yields under alley cropping with *Cajanus cajan* were highest and comparable with those obtained from sole maize. However, the results indicated that, in terms of influence on maize yield over the four-year period, *Leucaena leucocephala* and *Cajanus cajan* appear to be the most promising tree species for use in alley cropping system with maize. It is significant to observe here that *Cajanus cajan* is native to Malawi and hence adapted to Malawi conditions. However, the effect of *Fusarium wilt* on two-year old *C. cajan* plants means that either the plants will need to be replanted every two years or a variety resistant to *Fusarium wilt* be used in a sustainable alley cropping system. It is also noteworthy that yields of maize from alley cropping with Leucaena across the seasons compared favourably with yields of maize to which 50 kg/ha inorganic N had been applied. Thus it would appear that incorporation of organic matter from these species into the soil may produce grain yields for maize equivalent to those resulting from application of 50 kg/ha inorganic N.

CONCLUDING REMARKS

On the basis of the four year post-establishment results presented in the foregoing analyses, there is evidence to suggest that the incorporation of prunings from *Leucaena leucocephala, Cassia siamea* and *Cajanus cajan* into the soil had a definite ameliorating effect on the soil which was reflected by the yields of maize grown in alley with the trees. Evidence from this study also suggests that incorporated material from such trees cannot be expected to provide the amounts of nitrogen that would be equivalent to those recommended when using inorganic fertilizers in order to get maximum yields of maize. This was clearly consistent with evidence from other studies (Anonymous, 1986). While this is so, however, there is evidence that incorporation of purnings from these trees into the soil has an ameliorating effect on the soil without N fertilizer application. In view of the escalating cost of inorganic fertilizers already cited elsewhere in this paper, such a role for trees as a supplementary source of nitrogen cannot be ignored, especially as it would enable a smallholder farmer to trim his budget for buying fertilizer inputs. It is also evident that, in addition to acting as a source of N for plant nutrition, material from these tree has a tendency to improve the physical properties of the soils in which it is incorporated, especially if the soils are sandy with a low organic matter content.

Results from this study appear to suggest the *Cajanus cajan* may be one of the more promising soil improving tree species especially as it is considerably easy to establish and produces relatively large quantities of biomass over short periods of time. Since *Cajanus cajan* is capable of producing woody stem within two years, it can also serve as a source of much-needed firewood for rural farmers. Again, in view of the critical fuelwood problems facing rural households in many developing countries, such a dual role for trees must be appreciated.

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Lamtoro in Nusa Tenggara Timur (NTT)—Indonesia : Its Ups and Downs

V. Parera

INTRODUCTION

The Province of NTT comprises the Eastern part of the Lesser Sunda Islands of Indonesia and it includes West Timor, Flores, Sumba, Alor and many other smaller islands and consists of twelve administrative regions called "kabupatens." The total land area is about 50,000 km² and the population is three million with the average density varying greatly from one kabupaten to another. The highest population density is Sikka on the Island of Flores with 150 people/km² and the lowest is Sumba-Timur on the island of Sumba with only 25 people. NTT has a rainfall of 2,000 mm for 125 days a year. The rainy season usually starts in the month of November/December and ends in April/May. Dryland agriculture, the predominant form of land use practiced, is seriously restricted by the long dry season, the marked fluctuation in rainfall, the strong relief of the landscape, and the low nutrient content of the soil. Shifting cultivation (slash and burn, faming) without soil conservation efforts, and with over-grazing, has caused the landscape of NTT to be marked by extensive savanas, with alang-alang (*Imperata cylindrica*) lands and eroded hilly areas. This covers 48% of the entire total land area of NTT. Low average productivity causes low incomes and seasonal food shortages. This has urged the government to introduce changes and improvements in the agricultural practices and farming systems. At the end of the last century, coconut was introduced, but vast areas of wild monoculture plantings of coconut from the sea shores up to the hilly mountain slopes with an altitude of 600 m in Sikka, Endo, Flore-Timur on the Island of Flores, have also helped in hastening the erosion. Cattle was introduced in the first decade with the intention of inducing the population to switch to commercial livestock rearing. Large numbers of cattle can be found on the Island of Timor and Sumba, and organized rearing has not been wholly achieved. The cattle adapted well to local condition but did little to solve the problem of feeding the people. Moreover, the heavy concentration of animals have led to overgrazings. The introduction of several intensive agricultural practices with high technological inputs, have mostly ended with failures.

It was then felt that the bottleneck could only be overcame by the introduction of a sound dryland farming systems well suited to the social and economic conditions of the peasant farmer and to the natural conditions of NTT. This is now evident in the Lamtoronisasi program of Sikka and the Paronisasi activity of Amarasi on the Island of Timor. This can be achieved with the help of the long known lamtoro plant.

DISCUSSION

1. The Lamtoro Plant

Lamtoro, the Indonesian name for *Leucaena leucecophala* a promising legume forage and tree crop for the tropics, is native to Latin America. Sometime during 1565 to 1825 a bushy type, the Hawaiian type, reached the Philippinas with the Spaniards (NRC: 1984). During the last century it was imported to Java/Indonesia to be planted as a shade tree for plantation crops. It appeared later on that this plant can also be used as green manure, forage and planted in rows along contour lines for erosion control. Lamtoro was introduced to NTT at the second decade of this century. From 1978, the Salvador type (Hawaiian Giants) and the Peru type (Peru and Cunningham) were also introduced. Only after the *Heteropsylla cubana* infestation in 1986, interest began to grow for other species and hybrids of Leucaena.

2. The Introduction of Lamtoro

For the rural farmers of NTT especially the shifting cultivators, the introduced lamtoro was a hard thing to be accepted. Its rapid growth and spreading, deep and strong root system, hard wood and fast regrowth after cutting, were real challenges for them. But although no spectacular progresses were then made, some small gains however were obtained. The plant adapts well to the dry and harsh condition of NTT and in limited ways can be used in some places. Some examples:

- Along the steep slopes of the mountainous Lio area of Central Flores, the first planted lamtoro in 1930 still can be seen. Growing wild, it expanded very rapidly. The shifting cultivators here at last have came to recognise that a lamtoro forest can well be suited to their traditional practice; the restoration of the soil fertility takes a shorter time.
- The planting of lamtoro in Amarasi on the Island of Timor was made on the order of raja (traditional local ruler) Koro in 1929 on abandoned fields infested with *Lantana camara* around Baun. The plant expanded rapidly and formed an even cover where it grows. In 1980, Metzner estimated that lamtoro covered two third of the Amarasi area, and lantana had been largely eliminated as a weed plant.
- Waingapu, the capital town of Sumba-timur and its suburbs is a striking example of the barrenness of NTT. But at the Isyak Daoriwu garden, three hectares of land planted with lamtoro in 1930, the condition there is very different. The fertile soil and favourable micro-climate created by the green foliage, stimulated healthy growth of many fruit trees and domestic animals.

3. The Lamtoronisasa and the Paronisasi

Two of the most widespread and positive roles of lamtoro in NTT are soil rehabilitation of forage production. Sikka and Amarasi are two well known examples of these developments. In Sikka, lamtoro was planted in contour hedgerows on hillsides that created indirect terraces in a system called Lamtoronisasi (Parera; 1980, 1982). Hedgerows were prunned periodically to prevent the plants from growing wild and becoming weeds. In Amarasi, lamtoro was planted in the 1930s to eliminated *Lantana camara*, which was destroying grazing lands. Once the lamtoro became established, farmers adopted a system called Paronisasi to use it (Metzner, 1980; NRC, 1984).

The Lamtoronisasi

> ... the result of this experiment in Central Sikka could decisively influence the development of agriculture in the whole south eastern part of Indonesia. (Metzner: 1976).

The fight against erosion in Sikka in fact was already started in 1966 with the setting up of bench-terraces. The hard work and no immediate pay offs, the local population being reluctant to adopt it. Father H. Bollen, a Catholic priest, who was impressed with the potential of the lamtoro plant in controlling erosion and rehabilitation of critical lands, then established a small trial plot of lamtoro planted along contour lines in front of his parochial church in the hilly area of Watublaqi. Influenced by this practice, Moa Kukur, a local farmer, made the same effort in one of his small gardens. The stable foodcrop production of this garden then over a period of three years from 1969 to 1971 promoted the IPP (Panca Sila Farmers Association) to create a demonstration plot planted with clove trees between the lamtoro hedgerows. The healthy growth of the clove trees then, became best proof of the ability of lamtoro as a pioneer plant to grow in harsh conditions, were valuable crops could be grown. The bupati (administrator of the kabupaten) of Sikka, stimulated by this success, then made a coorporation with the IPP to expand it to other areas of Sikka. An Erosion Control Team (Team Penanggulangan Erosi) was then founded in 1977 with members consisting of government officials and IPP members and charged with the extension and field works. At this time, the name lamtoronisasi was introduced. BIMAS, the national foodcrop intensification programme, not only benefits the most from this soil conservation activity, but also has helped to expand it as a local regulation stipulated that only farmers who practiced lamtoronisasi could take advantage of the BIMAS. Local authorities reasoned that lamtoro hedgerows would halt run-offs and so ensure that food crops planted and the fertilizers dressed would not be washed away. Perenial crops such as cloves, cocoa, pepper, coffee, etc., were also planted on the terraced lands and became an integral part of a permanent agriculture based on lamtoro. By 1982 it was estimated that about 20,000 ha of hilly agriculture lands in Sikka had been lamtoronized.

The Paronisasi

> ... the successful establishment of Leucaena in this single district has sparked what can only be called a Leucaena revolution... (NRC: 1984).

With the increase in cattle population in NTT, fodder supply then became a problem. The traditional burnings and now overgrazing, reduced not only the quantity but also the quality of the grasslands and so abortion in cows and mortality among young calves became very common in the dry seasons. In Amarasi then the condition was getting worse with the infestation of *Lantana camara*, a woody shrub that entered Timor around 1912. By 1949, about 80% of Amarasi was covered with this weed. The weed dominated grasslands and was not eaten by livestock. Ormeling (1955) considered that livestock numbers in the early 1950s were lower in Amarasi than the Timor average because of lantana. Metzner (1980) suggested that the decline in livestock numbers in Amarasi from 6,000 (cattle, water buffalo and horses) in 1916 to 4,000 in 1948, was largely due to lantana. Under the influence of powerful cattle owners, attempts were then made around 1955 to control lantana biologically with the beetle *Teleonemia lantanae* and with herbicides. These methods, however, had little effect and control was then ultimately achieved by replacing lantana with lamtoro. In 1971, cattle production on the Island of Timor was stimulated by the government with the introduction of the Panonisasi, a cattle feeding activity where a farmer is given a bull to feed on crop residues and plant products. When the animal reached export weight (350 kg) and sold, the profit is shared by the government and the farmer. The programme is considered to be very successful by the participants and is the basis for an extensive paron programme, where cattle owners provide the animal for feeding and share the profits with the farmer doing the feeding. And because of its abundant lamtoro fodder, Amarasi then benefits the most from this paron scheme. According to Metzner (1980) and a survey of Jones (1983 a and b), the average farmer in Amarasi own ± 2 ha of land. Lamtoro is established at a density of about 10,000 tree/ha over the whole area, from which 1/3 of it are used for planting foodcrops and the other 2/3 are used to provide fodder for the tethered cattle in a cut and carry system.

4. The Impact of the Lamtoronisasi and the Paronisasi

The successes of the Lamtoronisasi and the Paronisasi followed by the introduction of the Hawaiian Giants (=Lamtoro Gung is the Indonesian name) and the Peru type of Peru and Cunningham, have stimulated the plantings of lamtoro through the whole of NTT. Lamtoronisasi has become the standard practice for erosion control and soil conservation activities. Sponsored by the government, aid agencies and non-government organizations, farmers were send to Sikka to observe, learn, and practice this system. As livestock given 100% lamtoro leaves as fodder didn't show any bad effects, Peru and Cunningham then were planted widely by individual farmers with the support of the Livestock Service. And Hawaiian Giants were used widely as shade trees for plantation crops and in regreening and reforestation projects. By 1986 it was estimated that about 4,300 km² of lands in NTT were planted with lamtoro. But alas, the infestation of the psyllid *heteropsylla cuban* in 1986 have brought extensive and severe damages.

5. The Infestation of Heteropsylla cubana

The Leucaena psyllid *Heteropsylla cubana* was first detected around Bogor, West Java, in March 1986. In NTT, it was first recorded in Ende on the Island of Flores in mid-May 1986, in Kupang on the Island of Timor in mid-June 1986. By late August 1986, almost all the kabupatens were infested, and it was estimated that some 50% of the 4,300 km² of lamtoro plantings in NTT was effected by the psyllid. This has caused serious problems to Paronisasi, and has seriously affected cocoa and vanilla production, has had a negative effect on lamtoronisasi and other reforestation and soil reclamation activities. In response to this infestation, the government of NTT then initiated an Operasi Flobamora III on June 1986 with objective of cutting down and burning all infested and uninfested lamtoro plants and to undertake chemical control. The hope was, that this could wipe out the psyllid in the shortest time. But vast areas of lamtoro plantings demand too much energy and time, and the cuttings themselves probably served only to weaken established trees and provide abundant psyllid food resources from the young regrowth stimulated by the cuttings. Efforts that are considered more logical are the introduction of the predator *Curinus coeruleus* and diversification with legume pioneer trees. In 1986, Curinus adults were brought from Hawaii and from November 1986 until September 1987, about 10,000 adult Curinus were released in many places of NTT. Resistante varieties, species and hybrids of Leucaena are also introduced. Legume demonstration plots and seed gardens are opened in all the kabupatens, and planted with Leucaena, Calliandra, Gliricidia, and other legume trees. Based on observations, losses in Sikka, where good terraces were already created and planted with various food and perenial crops, were not as serious as in Amarasi. In Amarasi, almost 2/3 of its total land area was covered with lamtoro monoculture forests, and lamtoro was the only source of forage and green manure.

Conclusion

To create sound, productive and lasting dryland agriculture or farming systems in NTT, fit and rewarding technologies are needed. Fit and rewarding to the social and economic conditions of the rural farmers and to their environment/agroecosystems. It must be simple low-input, and self-sustaining. Particularly due to the climatic conditions, the marked fluctuation in rainfall and the long dry seasons, it has to be based on a philosophy "... not to see them as constraints or catasthrophy bringers, but as potential resources..." The average rainfall of 2,000 mm a year can be rated as fair, but with some daily downpours of more than 100 mm a day, it only means erosion and floods, then long and harsh dry seasons afterwards. The presence of barriers that can halt run-offs and secure water penetration is the *sin qua non.* Then in order to benefit the most from the abundant solar energy, these barriers must consist of deep rooted pioneer trees that with their evergreen foliage can perform the days long photosinthetic processes. So the terraces to be built has to be indirect terraces by growing legume pioneer tree hedgerows (Alley-Croppings) along contour lines. And legume trees than not only mean favourable micro-climate created and green manure/mulch that can stimulate the activities of soil organisms, but also the presence of forage for the livestock industry. With the Lamtoronisasi and Paronisasi has entered a new era in the history of the dryland agriculture in NTT. A very promising one for the development of sound, productive, and lasting farming systems with the help of legume pioneer trees. And how severe the destructions caused by the Leucaena psyllid are, it doesn't mean the banishing of lamtoro with its Lamtoronisasi and Paronisasi practices. Lamtoro will always be honoured as the pioneer of the pioneer trees, that had paved the way. And many of the practices invented and used in the Lamtoronisasi and Paronisasi still will be recommended in the dryland agriculture practices in NTT.

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Leucaena as a Multi-Purpose Tree for Coconut Plantation in Sri Lanka

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INTRODUCTION

Leucaena (*Leucaena leucocephala* (Lam.) de Wit) is a fast growing leguminous tree widespread throughout Southeast Asia. Although the exact date of its introduction to Sri Lanka is not well documented, it is believed that Leucaena was brought into the country in the 1970s. Coconut (*Coco nucifera* L.) on the other hand has a long history in this country dating back to the 5th Century and is certainly the most extensively cultivated plantation tree crop occupying about 400,000 ha of arable land. It has been shown that in India Leucaena grows well under coconut shade (Vioayakumar, Mammen, Pillair and Vamadevan, 1986).

Since 1980 the Coconut Research Institute has been interested in evaluating the potential of nitrogen fixing tree species in coconut plantations. Among these, Leucaena is one species which has figured prominently in several trials. In contrast to Gliricidia (*G. sepium*), establishment of Leucaena by seeds is perhaps the most convenient and reliable method of establishment. Leucaena seedlings is particularly beneficial in coconut plantations as they develop a deep-root system which does not interfere with coconut roots and is also more effective in drawing and recycling nutrients from deeper layers of soil. Furthermore, Leucaena being harder and coppices more vigorously then Gliricidia, the former tolerates repeated pruning and consistently produce a high biomass yield for a longer period. Preliminary trials on Leucaena under coconut have shown that it is capable of producing a satisfactory biomass and wood yield (Liyanage, Abeysoma and Jayamanna, 1983). Therefore, research on Leucaena under coconut has been intensified since 1984, to explore its potential uses in relation to coconut plantations. Although Leucaena has proven itself as a potential source of green manure for agricultural crops (National Academy of Sciences [NAS], 1977) and in alley cropping (Wilson, Kang and Mulongoy, 1986), as a high protein supplementary feed for cattle and as a renewable source of fuelwood in many other Asian countries, the multi-purpose qualities of this species and its increased utilization in coconut plantation has not been well recognised. This paper discusses results from several field experiments undertaken to demonstrate the potential role of Leucaena in coconut plantation of Sir Lanka.

Biomass Yield of Leucaena Under Mature Coconut Plantations

Coconut plantations in Sri Lanka are widely distributed in different agro-ecological zones and soil types. A trial was, therefore, initiated in 1984 to test the adaptability of Leucaena under coconut, in terms of biomass yield. For this purpose double rows of Leucaena (cv. K 636) seedlings were established in the coconut avenue with 2.0 m between and 0.9 m within the row giving a planting density of approximately 1900 trees/ha. One year after planting, trees were lopped to 100 cm height above ground and thereafter trees were lopped regularly four times a year. Fresh biomass yields estimated three years after planting are given in table 1. It has been shown that highest biomass yield (13.4 tonnes/ha/year) was obtained in the Dry Zone on Entisols with a pH of 6.0. From these results, it is concluded that Leucaena is more adaptable to coconut plantations in dry areas where the soils are light but not too acid.

Table 1
Performance of Leucaena under Coconut in Different Agro-Ecological Zones

Agro-climatic	Annual Rainfall (mm)	Rainy Days	Soil Type	pH	Biomass Yield (t/ha/year)	
					Fresh	Dry
Wet	2700	137	Ultisol	5.1	9.6	1.9
Intermediate	1900	128	Entisol	5.5	10.8	2.6
Dry	1300	110	Entisol	6.0	13.4	4.1

Role of Leucaena as a Green Manure for Coconut Palms

There is an increasing awareness and renewed interest throughout the developing countries to increase crop production by substituting inorganic fertilizer either entirely or partially with organic sources. Among nitrogen fixing trees, green manuring with Gliricidia has been practised for sometime in Sri Lanka on a number of agricultural crops including tea, coffee, black pepper and cocoa (Joachim, 1961). However, Leucaena has gained very little recognition as a valuable green manure in tree plantations sector.

Although coconut growers are aware that inorganic fertilization could substantially increase coconut production, particularly the smallholders do not use inorganic fertilizer because it is beyond their means. In fact, it has been estimated that the cost of fertilizer application constitutes 64% of the total cost of maintaining one hectare of coconut land (Liyanage, 1986). Therefore, during the past few years, much attention has been drawn to evaluate Leucaena and Gliricidia as a potential source of *in situ* green manure for coconut. This trial was set up in 1984 in a mature coconut plantation where Leucaena was planted in double rows in the coconut avenue.

Results from this trial demonstrated that application of 30 kg/palm/year fresh Leucaena loppings and incorporating to a depth of 20 cm in a 2 m radius around the palm could supply the total nitrogen and supplement 20% of phosphate and potash requirement of the palm per annum, amounting to a saving of 40% on the cost of fertilizer. This has significant economic implications in terms of reduction in cost of production of coconut. The potential of intercropping Leucaena in coconut plantation *in situ* for the production of green manure for coconut palms has also been demonstrated by Vioayakumar *et al.*, 1986. The effectiveness of Leucaena as a green manure is attributed largely to its rapid decomposition of nitrogen rich foliage with a "half life" value of 30.7 days and low lignin content of 7%.

Use of Leucaena Foliage for Soil Improvement in Coconut Plantations

It has been observed that coconut palms even in well managed plantations produce relatively low yields (44.46 nuts/palm/year) in spite of the favourable weather conditions prevailing in the Wet and Intermediate agro-ecological zones. It has been observed that this condition of "induced senility" of palms has been relatively more widespread in degraded

Ultisols in the Intermediate Zone with poor physco-chemical properties. Therefore another trial was set up in 1984 in which Leucaena foliage was incorporated in trenches around low yielding palms in order to rehabilitate the Ultisols and improve the yield. Fresh Leucaena loppings were buried in 60 cm wide, 30 cm deep quarter, half and full circle trenches around the palms, 30 cm away.

Results showed that among these treatments, incorporating 30 kg of Leucaena in quarter-circle trenches around the palms produced the highest nut and copra yield per palm after two years, with the minimum root damage (Table 2). The beneficial effects of incorporating Leucaena on the improvement of Ultisols was clearly demonstrated by the reduced bulk density (3%) and increased organic matter (45%) and water holding capacity (82%) three months later (Table 3). The improved soil conditions induced regeneration of new roots around the palms resulting in a considerable improvement of nut and copra yield of palms. The enhanced earthworm activity (Table 4) in Leucaena incorporated plots were a reflection of the significant improvement to the physical structure of Ultisols. It is interesting to note that earthworms also contribute to the improvement of physico-chemical properties of soil by their constant burrowing habits and enriching the soil with phosphate and potash through the accumulation of worm-cast.

Table 2
Effect of Incorporating Leucaena in Trenches on the Yield of Coconut Palms (after 2 years)

Treatments	Nuts/palm/year	Copra Content (g/nut)
30 kg Leucaena in 1/4 trenches	62.0	202.8
60 kg Leucaena in 1/2 trenches	58.7	174.4
120 kg Leucaena in full trenches	54.5	192.0
Control (without Leucaena)	47.8	174.2

Table 3
Effect of Leucaena Loppings on Soil Improvement (ultisols)

Treatments	Organic Carbon (%)	Bulk Density (g/cm^3)	Water holding Capacity (mm/m)
With Leucaena	1.21	1.40	75.8
Without Leucaena	0.83	1.47	41.5

Table 4
Effect of Leucaena on Earthworm Activity

Treatments	Population (no/m^2)	Wormcast	
		(No/m^2)	Weight/g/m^2
With Leucaena	163	418	32
Without Leucaena	112	336	25

Leucaena as a Supplementary Feed for Cattle

Integration of cattle with coconut is a popular practice among coconut grower essentially to control weeds and provide organic manure for the palms. It has been estimated that nearly 25% of the national cattle heard is living in coconut growing areas (Jayawardane, 1988). Generally, pasture production in these areas follow a bimodel pattern with an acute shortage of fresh pasture during the dry season. To alleviate this feed shortage, attention has been focused on integrating improved pasture with leguminous trees. In this trial, double rows of Leucaena was established in the coconut avenue 2.0 x 0.5 m apart of the standing mixed sword of *Brachiaria miliiformis* and *Pueraria phaseoloides*. In addition, alternate trees of Leucaena and Gliricidia were established in 1.0 m apart along the boundary fence.

Cattle consisting of Jersy x Local cross-bred heifers were grazed with the pasture/legume mixture on a rotational system which was sufficient to satisfy the feed requirement of cattle during the wet season. Leucaena trees associated well with the pasture/legume mixture which produced 7.19 t/ha/year of fresh fodder while alternate trees of Leucaena and Gliricidia along the fence produced 2.0 t/ha/year fresh fodder with three to four cuttings per year (Table 5).

Table 5
Fodder Production of Leucaena in the Coconut/Pasture/Cattle Integrated System

Component	Fresh Fodder Yield (t/ha/year)
Leucaena, double rows in the avenue	7.19
Leucaena + Gliricidia along fence	2.0

During the dry season when there was a shortage of pasture, Leucaena foliage served as a high protein (20% crude protein) supplementary feed which when mixed with rice straw improved its digestibility. In this trial, feeding up to 6.0 kg of fresh Leucaena mixed with Gliricidia in 1:1 ratio along with 10 kg/head/day of rice straw during the dry season produced a satisfactory liveweight gain of 306 g/head/day at the end of first year. These results indicated that use of Leucaena fodder being palatable, highly nutritious and easily digestible, could largely contribute to alleviate feed shortages for cattle in coconut areas during the dry season.

Use of Leucaena for Fuelwood in Coconut Areas

The gradual destruction of valuable forest reserves over the years has resulted in a serious shortage of fuelwood supply in Sri Lanka, resulting in a steady increase in it's price. It has been estimated that about 80% of Sir Lankans living in rural areas depend on firewood for their domestic cooking and heating purposes. However, potential use of Leucaena as a renewable fuelwood source has not be explored under coconut, in order to prevent a possible fuelwood crisis in the future. In this trial, Leucaena cv. K8 was established in the avenues of a mature coconut plantation in 1986 consisting of double rows 2.0 x 0.5 m apart with a density of 2240 trees/ha and single rows with 1120 trees/ha. Three years after planting, trees were cutback to a height of 1.0 m above ground to estimate fuelwood production. The quality of fuelwood was assessed by measuring the specific gravity and heating value of over-dried samples.

Preliminary observations indicated that Leucaena in double rows performed significantly better than those in single rows in terms of increased tree height and diameter at breast height (DBH). These trees also produced the highest wood dry matter giving 5.17 t/ha three years after planting (Table 6). Also, Leucaena trees raised under coconut produced fuelwood of satisfactory quality with a specific graviting of 0.53 and heating value of 4200 k cals/kg three years after planting. Coconut palms too benefitted from intercropping with Leucaena which showed a considerable improvement in terms of nut and copra yield over the control without Leucaena (Table 6). It is interesting to find that palms in plots with double rows of Leucaena produced more nuts and higher copra compared with the single row system.

Table 6
Fuelwood Production of Leucaena Under Coconut (3 years after planting)

Treatments	Sundried Wood Production t/ha	Coconut Production nuts/ha/year	Coconut Production Copra t/ha/year
Leucaena in double row	5.17	9744	1.75
Leucaena in single row	4.49	9276	1.70
Control (without Leucaena)	-	8906	1.64

Conclusion

These studies and observations discussed in this paper demonstrated that Leucaena, which was well adapted to the non-acid Entisols and performed well under coconut shade, could serve as an alternative species to Gliricidia in the dry regions. The multiple uses of Leucaena for improving coconut plantation were amply demonstrated by the fact that it served as a useful green manure for substituting inorganic fertilizer, improvement on physico-chemical properties of soil and as a source of high protein supplementary feed for cattle and, fuelwood for household cooking and heating purposes. It is often argued that Gliricidia supports used for black pepper under coconut sometimes compete with coconut and pepper for plant nutrients and soil moisture. In this situation Leucaena can be used as a possible support tree for training pepper vines.

For these reasons, there is a need to improve the awareness of local farmers on the potential use of this species for agricultural activities in coconut areas. One disadvantage for the popularization of Leucaenas is that currently it suffers damage from Psyllid (*Heteropsylla cubana*) and germplasm evaluation trials have already begun for biological screening of psyllid resistant lines. Preliminary observations have suggested that *L. diversifolia*, *L. pallida* and *L. esculenta* shows certain degrees of tolerance to psyllid damage particularly during the dry season.

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Work of BAIF Shows Leucaena to be a Very Useful Multipurpose Plant

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INTRODUCTION

First of all let me thank the University of the West Indies for providing me with this opportunity to participate and present the work done on *Leucaena leucocephala* at our organisation and on the utilisation of this plant in our Development Programmes, on the basis of our studies and information available from other sources. I feel, it would be appropriate to briefly introduce our organisation, its objectives and approach to development, as well as towards utilisation of plant species like Leucaena. Being one of the first few organisations to introduce Leucaena in India and having supplied large quantities of seed all over the country, this plant became a kind of "Trade Mark" for the organisation, however, we try to explain that we are not wedded to any particular plant or species and for that matter any particular programme but choose it wherever we fell it is appropriate.

The BAIF is a non-Government organisation estasblished with the basic objective of generating remunerative employment for the benefit of the rural poor, through improvement of natural resources and the uptaking of an integrated programme of development, extension and applied research. Our target is the family in rural areas living below the poverty line and the natural resources like land, water, vegetation and livestock. BAIF has been implementing an Integrated Programme since the last two decades, in the Western States of the Country like Karnataka, Maharashtra, Gujarat and Rajasthan. We also have a large Cattle Development Programme in the Eastern part of Uttar Pradesh (State) and in some parts of Madhya Pradesh. As an organisation recognised by the Government of India for Rural Development, it is invited by these State Governments to participate in Development Programmes in some selected areas of each State; in most of these areas resources like land, water, vegetation and livestock are poor. In the majority of places where BAIF is involved, the soils are poor; there are problems of alkalinity and salinity or in some cases the soil cover is hardly 3 to 4 cms. In most of these areas there is a lack of irrigation facilities, the ground water resource is poor and at many places it is brackish. In other areas the rainfall is high but is limited to three to four months of the year and in the remaining months there is an acute scarcity of water. In many areas soil erosion is a serious problem, as we have large livestock populations with low yields. This has resulted in over-grazing of most of the forest and grasslands. There are intensive Livestock Development Programmes in all the States of the country, but these are facing serious problem of shortage of good quality feed. Most of the livestock are managed on crop residues or poor quality grasses. Most of our grassland lacks legumes and the predominating grasses are is very poor in protein. In each of these States in which we are involved there are large areas which are hilly and the ranges at one time had thick forest and formed very good resource for fodder, fuel and other forest produce. These are now turned into a typical landscape representing totally denuded, over grazed, eroded hills.

In this kind of situation we were trying to search for plants which would be multipurpose with low water requirements but with reasonably fast growth and *Leucaena leucocephala*, particularly the Hawaiian Giant varieties, provided the ideal choice. We have found it very useful in development of wastelands for fodder production under unfavourable soil and moisture conditions. This crop is found useful for checking soil erosion, enrichment of the soil through addition of humus and nitrogen fixation as well as windbreak. It is also being used for agro-forestry systems by planting along the boundaries of the plots for windbreak as well as a source of fodder and fuel, besides enrichment of the soil. Its use for paper pulp will probably be an important outlet in India.

We have also recognised its limitations in terms of soil water requirements. We avoid its planting in areas which are flooded for extended periods and in desert areas. Leucaena needs very good protection under Indian conditions, where livestock numbers are very large, in view of its palatability. This calls for a specific system of tree planting. The problem due to mimosine content limits its utility. We are also watching keenly the recent pest problem faced in the Philippines. The psyllid problem has already affected plantations in Sri Lanka and some parts of South India; fortunately its progress is slow and we feel that the spread to drier regions would be limited.

In the following pages are described, briefly, selected points on some of our studies on Leucaena carried out during the last 16 years. Studies on Leuceana carried out in India have been well reviewed during a National Seminar in 1981 and during the International Grassland Congress in 1988. I also propose to briefly describe some of the interesting reports from other Research Institutes and Agricultural Universities working on Leucaena, with particular reference to its use as fodder for ruminants.

CULTIVATION OF LEUCAENA AS FODDER FOR RUMINANTS

We were attracted towards use of Leucaena, for dairy cattle, in view of it's reported high protein content and it's tolerance to unfavourable soil moisture conditions. While cultivating fodder crops in India we are concerned with the amount of dry matter and nutrients that we get per unit of land, time and number of irrigations as well as the need for inputs like fertilisers and insecticides. Leucaena seemed to suit well since it could be cultivated in plots with very shallow soil cover or with soils having fairly high pH and salt content. The fast regrowth of Leucaena was a very attractive feature. In order to standardise cultivation practices several trials on plant spacing, cutting heights and intervals were carried out. In most of the conditions it was found that spacing of 10 cm x 1.5 m gave best results in terms of management and yields.

Deshmukh, Relwani, Sutar and Patil (1981) obtained linear increase in green yield with increase in stubble height and cutting intervals. The highest yield reported was with 60 days interval at 90 cms height. Spacing trials reported by Relwani, Deshmukh, Nakat and Khandala (1982a) showed that for high green matter and crude protein yields close spacing of 1m x .1m or .75m x 0.1m is most desirable. Results are shown in Table 1. In Table 2 are summarised results of observations on various Hawaiian Giant varieties compared to Hawaiian Common as reported by Relwani *et al* (1982b). As expected Hawaiian Giants Yield much more forage than Cunningham.

Table 1
Forage Yield from K8 Variety of Leucaena with Different Spacing

Green Yields (q/ha)

Inter row spacing	Intra row spacings 0.1m	0.2m	0.3m	Average	Average per year
1.0 m	2924.3	2621.7	2535.5	2693.9	635.2
1.5 m	2478.0	2322.4	2136.3	2231.2	545.2
2.0 m	2236.2	1956.8	1948.4	2047.2	482.7
Average	2546.5	2300.1	2206.8		

L.S.D. at 5% Main effect - 113.8 : Interaction - Not significant.

Dry Matter Yields (q/ha)

Inter row spacing	Intra row spacings 0.1m	0.2m	0.3m	Average	Average per year
1.0 m	753.9	687.3	668.9	703.3	165.8
1.5 m	656.2	609.8	579.7	615.0	145.0
2.0 m	604.8	529.4	477.7	537.3	126.7
Average	671.6	608.6	575.4		

L.S.D. at 5% Main effect - 26.8 : Interaction - 46.5.

Crude Protein Yields (q/ha)

Inter row spacing	Intra row spacings 0.1m	0.2m	0.3m	Average	Average per year
1.0 m	168.3	151.8	145.4	155.2	36.6
1.5 m	147.8	133.4	126.1	135.8	32.0
2.0 m	133.6	117.7	107.9	119.7	28.2
Average	149.9	134.3	126.5		

L.S.D. at 5% Main effect - 6.8 : Interaction - Not significant.
Ref.: Relwani, Deshmukh, Nakat and Khandala (1982b).

Table 2
Forage Production from Different Leucaena Cultivars

Cultivar	Green Yield (Total of 36 cuttings) q/ha	Green Yield Annualized q/ha/yr	(Average of Nine Cuttings) Dry Matter %	Crude Protein %
K8	3895.1 *(108.2)	873.3	24.35	24.10
K29	3801.2 (105.6)	852.2	25.72	24.42
K67	4274.4 (118.7)	958.3	24.98	24.00
K72A	4069.6 (113.0)	912.4	24.08	23.86
K341	2779.9 (77.2)	623.2	25.29	26.29
Hawaiian Common (India)	2703.3 (75.1)	606.1	26.10	24.70

L.S.D. at 5% 839.5
CV % 18.8
*Figures in parantheses show green yield q/ha/cutting.
Ref.: Relwani, Deshmukh, Nakat and Khandala (1982b).

Observations were also recorded using different varieties of Leucaena for fodder production. Relwani, Mohatkar, Bhavsar and Nakat (1983a) compared Cunningham and K8 varieties for fodder production under saline deep sandy loam soils and shallow basaltic graveley soils with different spacings and cutting height and found the results comparable. Raina, Lahane and Gadekar (1984) reported results of initial evaluation of Leucaena cultivars, in which observations from 20 selected cultivars grown in radomised block design were gathered. Initially highest yield were obtained from new selection four to three, however, K8 variety caught up after about one year and there was very little difference between the two. Observations of fodder trials with a number of varieties commonly used in India under mountainous wasteland conducted between 1982 to 1985 were reported by Lahane, Relwani, Raina and Gedakar (1987). While most of the varieties produce fairly high fodder yield as well as crude protein yield the cultivars from IGFRI showed significantly better green and dry matter yields. There was, however, not much difference between protein yields of various varieties.

Cultivation trials were also conducted to study forage production among four cultivars of Leucaena and three of the commonly cultivated grasses i.e. hybrid Napier variety, NB-21, Guinee grass and Rhodes grass. Results of about two years observations have been reported by Relwani, Nakat and Khandale (1982) which involved 15 cuttings of Leucaena and 18 cuttings of the grass. Highest production was observed in the combination of Cunningham, variety of Leucaena and Hybrid Napier.

CULTIVATION OF LEUCAENA FOR WOOD PRODUCTION

The BAIF workers have conducted several trials with Leucaena being used for the production of fuel and medium type of timber, particularly for poles. Initial observations taken on the site located at Urulikanchan near Pune (latitude 18.5 N longitude 73.6E at an elevation of 560 m.a.s.l. with an average rainfall of 440 mm and having shallow basaltic soils) and comparisons were made between Hawaiian Common and Hawaiian Giant K8 varieties. It was observed that with the Hawaiian Common variety the yields were very low compared to K8, which yielded 12 times more. The total production was 9.72 tonnes per hectare in Hawaiian Common as compared to 126.1 tonnes per hectare for K8. (Relwani *et al.* 1983a). Subsequent trials were aimed at studying wood yield as well as economy for the benefit of farmers in different management systems. In one of the trials reported by Relwani *et al.* (1983b), observations were recorded when Leucaena K8 variety was planted at spacing of 2.75m x 2.5m and protective irrigation was given from a small pond at site prepared for harvesting rain water. Watering was done manually four to five times during the first tow years. Twenty trees was randomly cut to study the growth and yield data and the results are indicated in Table 3.

Table 3
Mean growth parameters and yields of *Leucaena leucocephala* trees at age 5.7 years.

Basal dia cm	DBH cm	Height (clear bole) m	Total Height m	Fresh weight per tree (63.5% d.m.) Main Stem kg	Branches kg	Total kg
12.24	8.72	0.3	12.9	47.55	22.23	69.78

The total weight of the plant including main stem and branches with 75% day matter will be 59.15 kilos at 5.7 years age. With a surviving population of 1636 plants per hect. it was estimated that such plantation would give a net income of about Rs. 3000/hect/year. Studies were also conducted to observe growth of the plants with different plant population and watering intervals inview of the criticality of moisture available. Plant population varying from 2500 per hectare to 40,000 per hectare were studied with watering intervals ranging from two to eight weeks. The data reported by Relwani *et al.* (1983a&b) are summarised in Tables 4 and 5. It was observed that while the height of the trees had not varied much with plant population the diameter significantly decreased. The increase in interval of watering adversely affected height as well as the diameter and the affect was more pronounced when interval was increased from sic to eight weeks. With regard to volume and yield of wood there was increase with increasing population as well as frequency of watering. The best results were observed with the 40,000 plants per hectare and two week interval of watering (in terms of total biomass).

Table 4
Effect of Spacing and Frequency of 2L of Water/Tree on the Growth of Trees (85 Weeks after Transplanting)

Plant Population/ha	Height and DBH at Watering Interval in Weeks of									
	2		4		6		8		Avg.	
	Ht. (m)	DBH (cm)	Ht. (m)	DBH (cm)	Ht. (m)	DBH (cm)	Ht. (m)	DBH (cm)	Ht. (m)	DBH (cm)
2,500	6.3	5.2	7.3	4.7	7.9	5.1	4.8	3.4	6.6	4.6
5,000	7.1	4.8	6.6	4.3	6.3	4.0	5.3	3.1	6.8	4.0
10,000	7.2	4.5	6.2	3.7	6.3	4.0	6.1	3.2	6.5	3.0
20,000	6.6	3.5	5.7	3.4	5.5	3.0	5.6	2.9	5.0	3.2
40,000	6.0	2.9	5.4	2.8	5.1	2.2	5.2	2.2	5.4	2.6
Avg.	6.6	4.2	6.2	3.7	6.2	3.7	5.4	3.0	5.1	3.6

Table 5
Yield of Wood per Hectare*

Plant Population/ha	Height and DBH at Watering Interval in Weeks of									
	2		4		6		8		Avg.	
	Vol.	Wgt.	Vol.	Wgt.	Vol.	Wgt.	Vol.	Wgt.	Vol.	Wgt.
2,500	21.1	11.4	20.0	10.8	25.0	13.9	7.0	3.8	18.5	10.0
5,000	40.1	21.7	28.1	15.2	24.8	13.4	13.1	7.1	26.5	14.3
10,000	71.3	38.5	41.8	22.6	50.7	27.4	31.2	16.9	48.7	26.3
20,000	79.3	42.8	66.6	35.9	50.2	27.1	48.3	26.1	61.1	33.0
40,000	90.5	53.3	81.1	43.8	49.4	26.7	59.5	32.1	72.1	38.9
Avg.	62.0	33.5	47.5	25.6	40.2	21.7	31.8	17.2	45.4	24.5

* Vol = Vol in m3 = 0.5 (dbh2 x height) x number of trees/ha
Wgt = Yield/ha in tons = volume x 0.54

Ref.: Relwani, Deshmukh, Nakat and Khandala (1982b).

An interesting study was taken-up on growth rate of Leucaena under different management systems to observe and compare performance of Hawaiian Common and K8 (Relwani, Deskmukh, Nakat and Khandala, 1982d). In this study observations were taken on height and diameter of the plants grown under rain fed condition without supplementation, with some supplementation, with protective irrigation in dry months and using different spacings. Satisfactory growth under poor soil and moisture condition were reported when protective irrigation is provided in dry months. Improvement in diameter was observed with wider spacing.

Since the last few years the BAIF workers have taken up comparative studies on a fairly large scale with various multipurpose nitrogen fixing plants on a number of its campuses. The species commonly being studies along with Leucaena are various species of Acacia, Sesbania, Albizia, along with commonly used species like *Casurina equistifloria*, *Dalbergia sissoo* and *Azadirachta indica*. It has been observed that at most of the sites Sesbania species grow fast in the initial stages compared to Leucaena and other, however, after a few months Leucaena overtakes these species. Best results were observed wherever protective irrigation was available. Amongst the species tried *Acacia nilotica* variety. Cupressiformis maintained steady satisfactory growth throughout the period.

UTILIZATION OF LEUCAENA IN THE FEEDING OF RUMINANTS

Chemical Composition

The average values for Leucaena Forage (Leaf Stem Mixture) for proximate principles and fibre fraction as observed through various studies are indicated in Table 6.

Table 6
Summarized Chemical Composition of Leucaena.

	Content (%DM)
Crude protein	29.98
Ether extract	3.56
Crude fibre	16.76
Nitrogen-free extract	44.86
Ash	5.54
Fibre fractions	
Neutral detergent fibre	52.21
Acid detergent fibre	29.83
Hemicellulose	22.38
Cellulose	17.80
Lignin	12.32

Chemical composition of different cultivars of Leucaena was also studied and as can be seen in Table 7, Badve, Joshi, Rangnekar and Waghmare (1985). There was not much variation between the different varieties. All the varieties had more than 25% crude protein. With a view to assess nutrient yield from Leucaena harvested at different heights and intervals a study was undertaken analysing samples of proximate principles and fibre fraction collected by harvesting the plant at four different heights and with 30 and 60 days intervals. The results reported by Rangnekar, Sobale, Waghmare and Badve (1981) showed that while the dry matter increased with increasing cutting height and interval best results can be obtained with 90 cm height and 30 days interval (Table 8).

In view of possibilities of making leaf meal from Leucaena and specially in areas where there are extensive plantations, the composition of the leaf meal was studied and compared with the alfa alfa leaf meal. It was observed that the Leucaena leaf meal compares well with alfa alfa leaf meal on all accounts (Rangnekar *et al.* 1981), Table 9.

Table 7
Chemical Composition of Different Cultivars of Leucaena, Stem and Leaf Mixture (% on DM basis) 60 days Cut at Stubble Height (mean of three replications)

Varieties	DM	CP	EE	CF	Mimosine	Ash	Ca	P
K72	28.35	19.66	3.68	17.21	1.80	6.70	1.71	0.18
K8	28:67	19.33	3.04	18.04	1.71	6.10	1.66	0.17
Piricikaba	27.10	18.08	3.71	23.60	1.38	6.28	1.48	0.17
Hawaiian Common	29.63	20.81	3.56	18.81	1.54	5.87	1.45	0.13
Campena Grande	27.10	19.19	2.84	21.17	1.25	6.17	1.09	0.13
Cunningham	25.78	22.79	3.43	18.70	1.82	8.10	1.83	0.18
Peru	29.54	18.78	3.85	20.02	1.40	6.77	1.84	0.16

DM - Dry Matter, CP - Crude Protein, EE - Ether Extract, CF - Crude Fibre, Ca - Calcium, P - Phosphorus
Ref.: Badve, Joshi, Rangnekar and Waghmare. 1985.

Table 8
Effect of Cutting Height and Interval on Chemical Composition of Subabul % on CM Basis

Different Height	Age	DM	CP	Total Ash	DF	ADF	Hemicell-ulose	Lignin	Cellulose	ADF Ash
1. 40 cm	30 days	32.69	28.30	5.0	51.77	23.69	28.08	8.51	15.00	0.18
2. 65 cm	30 days	38.11	28.70	5.21	49.11	24.65	24:46	10.86	13.71	0.08
3. 90 cm	30 days	31.29	29.17	5.65	44.25	27.23	17.02	11.45	15.56	0.22
4. 115 cm	30 days	33.79	29.76	6.67	50.11	33.47	16.64	14.86	18.04	0.14
5. 40 cm	60 days	40.51	25.80	4.67	55.26	34.20	21.06	13.00	21.00	0.20
6. 65 cm	60 days	33.53	25.99	5.49	49.21	30.25	18.96	11.91	18.13	0.21
7. 99 cm	60 days	35.11	27.83	6.23	50.44	31.71	18.73	11.92	19.99	0.21
8. 115 cm	60 days	41.17	28.90	7.87	63.03	32.39	30.64	11.58	20.67	0.14

DM - Dry Matter, C - Crude Protein, DF - Neutral Detergent Fibre, ADF - Acid Detergent Fibre
Ref.: Rangnekar, Sobale, Waghmare and Badve. 1981.

Table 9
Composition and Nutritive Value of Subabul Leaf Meal Compared with Alfalfa Leaf Meal

	Subabul Leaf Meal*	Alfalfa (Lucerne)** Leaf Meal
Crude protein (g/100g)	30.0	24.0
Crude Fibre	13.0	16.4
Ether Extract	3.6	3.1
Nitrogen fee Extractives	43.1	45.8
Ash	10.3	10.7
Calcium	3.48	2.38
Phosphorous	0.4	0.30
Copper mg/100g	2.6	11.5
Iron	92.0	34.0
Zinc	3.9	35.1
Manganese	8.5	48.3
IVDMD	75.9	73-80
ß Carotene mg/kg	536.0	253.0
Gross energy (MJ/kg)	20.1	17.8
Metabolizable energy (ME) (MJ/kg)	15.2	10.2

* Average of six samples analysed at BAIF
** Values as reported in the Literature
Ref.: Rangnekar *et al.* 1981.

Table 10
Digestibility Coefficients (% on DM basis) for Leucaena, Leucaena + Straw, Molasses and Leucaena + Conc. Mixture Diets.

Proximate Constituents	Leucaena	Leucaena + Straw Molasses	Leucaena + Conc. Mixture
Dry matter	60.07	61.90	63.0
Crude Protein	73.25	58.34	68.0
Ether extract	28.70	34.93	29.0
NFE	63.01	64.43	73.0
Van Soest Fibre Fractions			
Neutral detergent fibre	50.25	40.65	-
Acid detergent fibre	40.84	45.77	-
Hemicellulose	69.10	57.33	-
Cellulose	50.90	48.88	-
Lignin	18.97	20.17	-

Nutritive Value

With a view to study the nutritive value and ultimately develop practical feeding recommendations for dairy cattle a series of experiments were conducted. Initial studies were taken up on crossbred bull calves in which one group was offered Leucaena *adlib*, while the other received restricted amount of Leucaena and Sorghum straw and molasses. It was found that Leucaena alone supported good growth (570 gms/d) and the digestibility for dry matter crude protein as also the fibre fraction were fairly high Table 10. There were no untoward affect on the animals during these 90 days feeding experiment.

With a view to compare the fodder quality for Leucaena with conventional leguminous crop like lucerne, studies were taken up with three fistulated bulls in a 3 x 3 latin square design experiment, *Desmanthus virgatus*, a promising leguminous bush, was also chosen for the comparison since it grows well in saline alkaline soils. The observations on Chemical Composition indicated that Leucaena has the highest crude protein content followed by lucerne and Desmanthus, while NDF and ADF values were highest in Desmanthus as also the Lignin content. The details are shown in the enclosed Table 11. The digestibility figures for various fractions compared well between the three groups, with lucerne showing best results (Kharat *et al.* 1980).

Studies were also conducted on sugarcane tops and Leucaena silage, chopped sugarcane tops and Leuceana mixture, in a proportion of 80:20 was ensiled and the material was taken out for study after three months. The objective was to study possibilities of ensiling sugarcane tops supplemented with leguminous material like Leuceana, to develop cheap nutritious material. The combination produced good quality silage with 10% crude protein and was quite acceptable to the animals. The digestibility values for various fractions ranged between 50 to 58% (Rangnekar *et al.* 1981).

Table 11
Chemical Composition of the Fodder Crops and Digestibility Coefficients of Various Nutrients

	Chemical Composition			Digestibility Coefficient		
	Leucaena	Desmanthus	Lucerne	Leucaena	Desmanthus	Lucerne
Dry matter	100	100	100	58.90±2.30	54.76±2.38	62.47±0.87
Organic matter	93.79±0.74	93.05±0.43	92.07±0.48	60.40±2.04	56.46±2.44	64.84±0.36
Crude protein	22.22±1.11	18.24±1.41	20.15±0.73	64.71±3.12	57.77±6.63	76.24±0.84
Ether extract	3.56±0.44	2.58±0.13	2.72—0.02	44.95±2.22	42.56±1.39	45.30±2.78
Neutral-detergent fibre	46.30±2.21	53.18±1.96	41.43±0.89	44.75±1.68	44.25±2.68	45.30±0.46
Acid-detergent fibre	29.79±2.06	41.55±1.80	30.06±1.35	29.95±3.21	37.40±4.36	47.34±6.87
Cellulose	16.77±1.00	21.17±0.56	20.10±1.19	49.64±5.31	52.97±5.63	58.35±1.74
Hemicellulose	16.51±2.31	11.60±0.68	11.36±1.04	70.15±4.81	65.95±1.05	59.70±4.76
Permanganate lignin	12.81±1.20	20.20±1.79	9.73±0.59			

Ref: Kharat, Prasad, Sobale, Sane, Joshi and Rangnekar. 1980

Mimosine Content, its Metabolism and Detoxification

One of the major limitations in Leucaena is the presence of anti-nutritional factor in form of mimosine. In the earlier years when we had taken up cultivation of Leuceana on a large scale and started feeding to the dairy animals, we got concerned because of report from Australia and intregued due to absence of any untoward effect on our animals. I may mention here that during some parts of the year Leucaena was the only leguminous material available and this prompted us to take-up studies on mimosine content and its metabolism. A large number of samples were analysed for mimosine content and we found that it varies considerably depending on the type of material analysed (Badve *et al.*, 1985). In new open leaf we found mimosine to be in highest concentration (between 10 to 11%) and lowest in stem (between 0.5 to 1%). The Leucaena fodder as is fed on our farms (cut and carry system) wherein we generally harvest leaving 1m stubble height, the mimosine content varied according to the cutting intervals. The values being lowest for 60 days cut (1.6% to

5.8%) and highest for 15 days cut. This is essentially due to change in the leaf stem ratio (Table 12). The values for mimosine in the leaf meal that we have been preparing generally varied between three to four percent. We also found some variation between varieties that we have tried on our institutional f[illegible] *diversifolia* gave the lowest value. While with most of the other varieties the values ranged between from 2.6 to 3.5%.

Table 12
Mimosine Content of Different parts of Leucaena (% on DM basis)

1. Unopened leaf	10.54
2. Next to unopened leaf	8.84
3. Fourth leaf from top	6.25
4. From base	1.76
5. Whole fodder (Leaf + stem mix, 1m stubble)	
15 days cut	5.8
30 days cut	3.2
45 days cut	2.8
60 days cut	1.6
6. Leaf meal	3.2

Ref.: Rangnekar et al. 1981.

Observations of some of the initial trials reported earlier indicated absence of any untoward effect on the animals. Subsequently we planned long term feeding trials with Jersey, Holstein and crossbred bulls. Results of growth performance and semen characteristics of bulls was studied using Leucaena as a sole roughage supplemented with concentrate mixture at the rate of 1.25 kilos per day. For the sake of comparison a group of bull calves was fed Desmanthus virgatus, which is almost devoid in mimosine. Ten bull calves were used for each group and the feeding lasted six months. In last two months semen was collected and studied for aspects like ejaculate volume, concentration, motility fructose, fructoslytic index, calcium, phosphate, inorganic phosphorous and magnesium. Digestibility study was also conducted at the end of the period. There were no breed or treatment differences for the aspects studied except in sperm concentration, which varied between breeds. No toxicity symptoms were observed in the animals. The digestibility co-efficiency in dry matter organic matter, crude protein and energy were higher for Leucaena than Desmanthus (Rangnekar *et al.*, 1983).

The above study was followed by another long term study with crossbred bulls which were fed 0%, 50% and 100% level of Leucaena as the sole feed, for more than two years. Mimosine metabolism was studied by analysing urine collected for over one week. Serum protein-bound-iodine (PBI) levels were determined at monthly intervals. It was found that the urinary excretion of mimosine was low, serum PBI levels were in normal range and there were no toxicity symptoms in these animals. The low levels of mimosine in urine are indicative of breakdown of mimosine and DHP to non-toxic compounds (Badve *et al.*, 1985). Results are summarised in Table 13, 14.

Table 13
Mimosine Metabolism and Serum PBI Levels

	I	II	III
Mimosine intake g/day	–	220	112
Urinary excretion g/day	–	9.44	7.9
Urinary concentration %	–	0.06	0.08
Serum PBI levels, ug/100ml			
Pre-experimental period	4.87	4.67	6.1
Experimental period	4.86	4.58	4.72

Ref.: Badve et al., 1985.

Table 14
Serum Protein Bound Iodine (PBI* levels)

Group	Before Staring Experiment (mg/100 ml)	After 18 months of Leucaena feeding (mg/100 ml)
1	4.9	5.0
2	4.7	4.7
3	6.1	5.7

*PBI levels were checked every fortnight
Ref.: Badve *et al.* 1985.

Subsequently studies were conducted on feeding of Leucaena to goats and the goats were found to maintain well on Leucaena and no toxicity symptoms were observed. It has now been well accepted that in many Asian Countries there is breakdown of mimosine in the rumen due to presence of some microbes and hence there is low incidence of toxicity on Leuceana feeding. We feel cut and carry system also contributes by lowering mimosine level. Some workers had recommended detoxification and we conducted trials with regard to extraction of mimosine with water, ferrous sulphate and calcium sulphate used on Leucaena leaf meal. It was observed that the extraction of mimosine varied with the period rather than type salt used. Calcium sulphate extracted more mimosine compared to $FeSO_4$ water (Gadekar, Hoshi, Lahane and Rangnekar, 1986).

Lucerne is a prolific seed producer and wherever large plantations have been developed seed is available in large quantities. Studies were undertaken on crossbred bulls to find out possibilities of use in concentration mixture. Animals were kept with sugarcane, as the basic feed and ground soaked and unsoaked Leucaena seed were fed to meet protein requirements. The chemical composition of Leucaena seed shows that it is rich in crude protein. The results as reported indicated that Leucaena seed can be safely used as a protein supplement. It has a DCP value of 20% and TDN content 67%, when the seed are soaked. values are slightly lower for unsoaked seed being 19 and 66% respectively.

Work Done at Other Institutes in India on Use of Leucaena as Fodder for Ruminants

The Indian Grassland and Forage Institute at Jhansi is one of the primary institutes in the country working on grasses and other fodder crops and a number of interesting reports have been published from there on cultivation as well as utilisation of Leucaena for feeding or ruminants.

Interesting studies were carried out on combination of Leucaena with a variety of grass and forage crops and most of these reports indicate improved yields in terms of green and dry matter as well as quality of the material. Leucaena has been used in combination with sorghum, pearl millet, maize, hybrid napier, panicum species of grasses etc. (Gill and Patil 1981, 1983, 1984, Rawat and Gill, 1987). Some of the other institutes from where interesting work on Chemical Composition nutritive value and utilisation of Leucaena were reported are the Agricultural University at Hisar, Veterinary College at Mathura, National Dairy Research Institute at Karnal. Most of the reports generally indicate high protein value, along with fairly high mineral contents (Pathak, Roy and Patil, 1977; Akbar and Gupta, 1985; Joshi and Upadhyay, 1976. Some of the workers like Kewalramani, Ramachandra, Upadhya and Gupta (1987), Yadav and Yadav (1988) and Akbar (1983 have done detailed analysis of Leucaena Forage studying fibre fractions and various macro and micro minerals. Yadav and Yadav (1988) have undertaken detailed analysis for various parts of the crops and compared the values for most the common varieties studied in India (Table 15). These workers have also estimated mimosine content in various parts of the crops and the results are comparable to what we have been observing. Mimosine content in various parts of Leucaena has been estimated and compared between different varieties by Krishnamurthy and Gowda (1983). Krishnappa (1984) has also undertaken studies on detoxification and has recommended wilting for four to six hours in sun, soaking overnight in water and addition of 1% ferrous sulphate, as some of the effective method to reduce mimosine toxicity. Recent reports by Chakraborty and Ghose (1988) from the Agriculture University at Mohanpur, West Bengal, on feeding of Leucaena Foliage to Black Bengal Goats, shows that it can be used with good results and without any untoward effect. Fresh foliage was offered adlib for 45 days in this study and the growth and digestibilities were studied.

Studies on use of subabul seed for feeding of Goats have also been carried out by workers like Chakraborty and Chabbra (1986, 1988) and Gupta, Virk, Khatta, Kumar and Sagar (1987) and others. Recent report is from Ganpawar, Gorantiwar and Bhaiswar (1988) on its use for crossbred dairy cattle. These workers have reported that the Leucaena seed can be used with advantage as a protein supplement in ruminants without any toxic effect. In most of these studies the seeds were used in concentrate mixture up to level of 30%. Chakraborty and Chabbra (1988) have used Leucaena seed to the extent of forming 70 parts of the concentrate mixture and there were no apparent toxic symptoms, except some alopecia in one animal which after a period of 30 days showed regrowth of hair, indicating development of tolerance after sometime. They have also reported presence of useful fatty acids in the Leucaena seeds.

Table 15
Cell Wall Constituents and Mineral Contents in Different Parts of *Leucaena leucocephala* Cultivars (DM basis)

Cultivars/Plant parts	Cell Wall Constituents (per cent)						Mineral Contents						
	NDF	ADF	Hemi-cellulose	Cellulose	Lignin	Silica	Macro-mineral (%)			Micro-minerals (ppm)			
							Ca	P	S	Zn	Ca	Fe	Mn
(1) Cunningham													
Leaves	19.8	12.7	7.1	7.1	5.1	0.5	1.8	0.2	0.4	42	15	250	75
Young Shoots	20.5	14.2	6.3	7.8	5.4	1.0	0.3	0.3	0.1	44	15	250	50
Stems	43.8	38.8	5.0	25.9	11.5	1.0	0.5	0.1	0.3	40	40	250	25
Seeds	36.1	22.4	13.7	17.4	2.6	0.4	0.5	0.2	0.5	28	40	250	50
Green pods	47.6	33.2	14.4	20.4	12.5	0.3	0.6	0.2	0.3	40	15	375	25
Dry pods	58.2	49.8	8.4	37.0	12.1	0.7	1.4	0.1	0.1	40	15	375	50
(2) Glauca													
Leaves	23.0	14.6	8.4	9.4	5.1	0.1	1.5	0.2	0.2	40	15	125	100
Young Shoots	25.8	13.9	1.9	8.8	4.6	0.5	0.1	0.3	0.1	40	40	123	50
Stems	44.7	33.9	10.8	22.5	10.5	0.9	0.7	0.1	0.1	60	40	375	50
Seeds	35.9	17.0	18.9	13.5	3.0	0.5	0.4	0.2	0.3	30	40	125	50
Green pods	44.8	28.1	16.7	16.9	11.1	0.1	0.1	0.2	0.4	55	15	375	25
Dry pods	58.6	50.7	9.9	35.0	15.1	0.6	1.3	0.1	0.1	75	15	450	50
(3) Hawaiian Common													
Leaves	18.8	12.8	6.0	5.8	5.4	0.6	1.1	0.2	0.2	40	60	250	100
Young Shoots	22.5	14.6	7.9	7.9	6.2	0.5	0.1	0.4	0.2	54	40	125	50
Stems	49.5	38.6	10.9	25.2	12.5	0.9	0.7	0.1	0.1	20	40	375	25
Seeds	32.2	18.0	14.2	14.4	3.2	0.4	0.3	0.2	0.3	22	40	125	50
Green pods	45.6	27.0	18.6	15.5	11.3	0.2	0.7	0.2	0.7	40	15	375	25
Dry pods	57.5	48.0	8.5	30.2	17.5	0.3	1.9	0.1	0.1	60	40	500	75
(4) Hawaiian Giant													
Leaves	22.0	14.8	7.2	8.2	5.8	0.8	1.0	0.2	0.2	28	40	125	100
Young shoots	18.7	13.0	5.7	5.3	7.2	0.5	0.1	0.3	0.2	30	40	250	50

Ref.: Yadav and Yadav, 1988.

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Conference Programme

FIRST INTERNATIONAL CONFERENCE ON LEUCAENA

THEME: LEUCAENA IN AGRICULTURAL DEVELOPMENT

Sponsored by: The Organization of American States (OAS) Caribbean Leucaena Project

In association with:

- The University of the West Indies (UWI), Faculty of Agriculture
- Sugarcane Feeds Centre (SFC)
- The National Institute of of Higher Education (Research, Science and Technology) (NIHERST)
- The Caribbean Agricultural Research and Development Institute (CARDI)
- The Ministry of Food Production and Marine Exploitation of the Republic of Trinidad and Tobago

July 10th – 13th 1989

Holiday Inn, Port of Spain, Trinidad and Tobago, West Indies

A.M.

8:00 - 9:00 REGISTRATION

9:00 - 10.30 OPENING CEREMONY

Chairman, Dr. Theodore U. Ferguson

- National Coordinator (Trinidad & Tobago) OAS Caribbean Leucaena Project and Head, Department of Crop Science, UWI, St. Augustine, Trinidad and Tobago

OPENING PRAYER

OPENING REMARKS

Dr. Theodore U. Ferguson

WELCOME ADDRESS
Dr. Lloyd B. Rankine
- Acting Dean, Faculty of Agriculture, UWI, St. Augustine, Trinidad and Tobago

ADDRESS
Mr. Frank Rampersad
- President of National Institute of Higher Education (Research Science and Technology) (NIHERST), Port of Spain, Trinidad and Tobago

THE FEATURE ADDRESS
"Leucaena - a General View"
Dr. Miguel Laufer
- Director, Department of Scientific & Technological Affairs, OAS, Washington, D.C.

OPENING ADDRESS
The Honourable Dr. Brinsley Samaroo
- Minister of Food Production & Marine Exploitation, Trinidad and Tobago

VOTE OF THANKS
Mr. Robert Quintyne
- Regional Co-ordinator, OAS Caribbean Leucaena Project, Ministry of Agriculture, Food & Fisheries, Barbados

10:30 - 11:00 COFFEE BREAK

A.M. **TECHNICAL SESSION I**
Overview and Genetic Improvement
Chairman, Dr. Mirtha Verstelyen
- Principal Scientist, Department of Scientific and Technological Affairs, OAS Washington DC.

11:00 - 11:45 **An Overview of Research on Leucaena in Trinidad & Tobago**
Dr. K.A.E. Archibald
- Director of Agriculture, St Kitts-Nevis [Former Lecturer in Livestock Production UWI, Trinidad, and former Regional Co-ordinator OAS Caribbean Leucaena Project]

11:45 - 12.15 **Genetic Improvement in Leucaena**
Dr. E. Mark Hutton
- Plant Breeder, Australia

12:15 - 12:45 DISCUSSION

12:30 - 2:00 LUNCH

P.M. 2:00 - 2:45	VIDEO PRESENTATION ON LEUCAENA RESEARCH IN THE CARIBBEAN **OAS Caribbean Leucaena Project**
P.M.	**TECHNICAL SESSION II** **Germplasm Evaluation** *Chairman, Mr. Howard Batson* - USAID , Barbados
2:45 - 3.05	**Breeding Strategies for Leucaena Species hybrids** *Mr. Charles Sorensson* - University of Hawaii, Hawaii, USA
3.05 - 3.25	**Evaluation of Leucaena Germplasm in Trinidad & Tobago** *Dr. T.U. Ferguson, Mr. H. Batson and Dr. K.A.E. Archibald* - Department of Crop Science, UWI, St. Augustine, Trinidad and Tobago
3:25 - 3:45	DISCUSSION
3:45 - 4:00	TEA BREAK
	TECHNICAL SESSION III **Soils and Leucaena** *Chairman, Dr. George Wilson* - Jamaica Agricultural Development Foundation, Jamaica.
4:00 - 4:20	**Use of Leucaena to Control Soil Erosion** Dr. R.T. Paterson - CARDI, Antigua.
4:20 - 4:40	**A Comparison of the Growth of *Leucaena Leucocephala*, *Sesbaria gradiflora and Albizia falcateria* for Seven Years at the Northern Range Reforestation Project in Trinidad** Mr. *N.P. Lackhan, Mr. S.Ramnarine and Mr. C. Ramsaran* - Department of Soil Science, UWI, St. Augustine, Trinidad and Tobago
4:40 - 5:15	DISCUSSION

A.M.	**TECHNICAL SESSION IV** **Leucaena in Animal Nutrition** *Chairman, Dr. F.G. Youssef* - Head, Department of Livestock Science, UWI, St. Augustine, Trinidad and Tobago
8:30 - 8:50	***Leucaena leucocephala* as a Feed for Ruminants, Nutritive Value, Forage Productivity and Suggested Use in Trinidad & Tobago** *Dr. G.W. Garcia, Mr. F.A. Neckles, Dr. T.U. Ferguson and Dr. K.A.E. Archibald* - Sugarcane Feeds Centre and UWI, St. Augustine, Trinidad and Tobago
8:50 - 9:10	**Production and Utilization of Leucaena in Barbados** *Mr. R. Quintyne and Mr. G. Proverbs* - Ministry of Agriculture, Food and Fisheries and CARDI, Barbados
9:30 - 9:50	**Leucaena for Livestock Production – The Grenada Experience** *Mr. Kenneth Buckmire* - CARDI, Grenada.
9:50 - 10:10	**The Use of Leucaena with Grasses in Forage Banks in St. Kitts and Nevis** *Mr. H. Patterson* - CARDI, St. Kitts-Nevis
10:10 - 10:30	DISCUSSION
10:30 - 10:45	COFFEE BREAK
10:45 -11:05	**Feed Production of *Leucaena leucocephala* (Lam.) de Wit Cultivars on Acid Sandy Loams of the Zanderij Formation in Suriname: Some Observations Concerning Yields** *Miss M. Callebaut and Mr. P. Kerkoff* - Suriname
11:05 - 11:25	**Feed Production of *Leucaena leucocephala* (Lam.) de Wit Cultivars on Acid Sandy Loams of the Zanderij Formation in Suriname: Some Observations Concerning Chemical Composition** *Mr. P. Kerkoff, Miss M. Callebaut and C.M. Mehairjan-Kalpoe* - Suriname
11:25 - 12:15	DISCUSSION
12:15 - 2:00	LUNCH