Leguminous trees, potential and utilisation
by U. Granhall

SUMMARY

The energy crisis of tropical, developing countries is often that of a fuelwood shortage. The potential and rhizobiology of certain leguminous NFT for use as fuelwoods in such countries is thus reviewed, with special reference to Sri Lanka.

Experiments with or without inoculation and at different levels of fertilization include selected species of Leucaena, Sesbania, Albizia and Acacia, as well as non-NFT, like Eucalyptus spp. The biomass productions of uninoculated trees of these and other species are also compared within an Int.Nft-site adaptability trial. Mixtures of indigenous and iternational Rhizobium-strains are used in the main experiment. Those for Leucaena were selected for acid conditions and toxic aluminium-levels. Numbers of indigenous rhizobia were found inadequate in most cases. Inoculations of both Leucaena and Sesbania was therefore necessary to ensure rapid nodulation and plant development.

The subsequent primary limiting growth factor for all tree species was found to be moisture stress (in combination with high temperatures). S.grandiflora plants, however, reached mean heights of 120 cm after 9 months although total rain fall was only 270 mm.

Pest problems were sometimes encountered in Eucalyptus (white ants) and Sesbania (stem borers), whereas Leucaena was unaffected. Unfertilized plots of the latter indicated a possible biomass production of at least 20 tons wood (dw) per ha per annum at sites with reasonable rain falls.

An action programme on site preparation, selection of tree species and rhizobial inocula, planting density, fertilization and rotation times for maximized fuelwood production is presented.

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Leguminous nitrogen fixing trees (NFT) are often quite versatile as many, e.g. Leucaena, can be used for both fodder, fuel and fibre. Others, like wattles (Acacia spp.) produce gums and resins, besides being important pulpwoods and desert trees. Within the family Leguminosae NFT are included in the subfamilies Caesalpinoideae, Mimosoideae and Papilionoideae but there are relatively less nodulated species among the Caesalpinoideae than among the others.

In my speach I would like to emphasize the rhizobiology and potential of certain leguminous NFT for use as fuelwoods in tropical countries according to my general experience from energy forest production in Scandinavia and from a recently started fuelwood project in Sri Lanka with leguminous species in particular. The main objectives of these studies have been to maximize fuelwood production in coppicing, fast-growing trees at a minimum use of fertilizer nitrogen. The overall purpose of such studies are of course to find cheap renewable energy sources that could replace eventually imported fossil fuels.

In tropical, developing countries the energy crisis is often that of a fuelwood shortage. The deficit in fuelwood supply in developing countries have been estimated to raise from 450 million m^3 1980 to 1 000 million m^3 in year 2 000 (Gilliusson, 1985). In e.g. Sri Lanka more than 60% of total energy consumption is wood based and almost 95% of all food is prepared by the use of firewood. As Sri Lanka has experienced rapid deforestation (44% forest cover to less than 20% of total land area in the last 30 years) it will soon join the ranks of these countries experiencing acute fuelwood shortages (Soussan & O'Keefe, 1985). The major cause of deforestation lately is attributed to state-sponsored clearances associated with new settlements created by one of the greatest irrigation schemes of the Third World, namely the Mahaweli programme. This programme opens up new territories in the semi-arid northern parts of the country, where already the lack of fuelwood is pronounced. Immediate actions are therefore called upon to preserve remaining forest resources in the area. It is also necessary to replant forests around the new water reservoirs in order to protect these and surrounding watersheds from erosion and siltation and to create a social forestry system from which the new settlers can satisfy their increasing demand of house-hold fuelwood. Short-rotation village wood lots and commercial larger plantations of energy forests are absolutely necessary to be introduced to meet future demands.

The following criteria of suitable plant species and managemental approaches are adopted to fulfill this task: a) the trees should be nitrogen-fixing in order to save fertilizer-N; b) they should be extremely fast-growing, with good possibilities of resprouting from short (5-10 years) coppicing practices; c) they should be drought resistant to stand the monsoonal climate with extented drought periods twice a year; d) they should have a high calorific value; e) managemental aspects involve aspects on rhizobiology, i.e. to find suitable strains of rhizobia for the various plant hosts and soil conditions (low pH, salinity or metal-toxicity problems)

- stands should be density planted (20-40 000 plants per ha) to quickly get a canopy closure that maximize PP and minimize weed problems. Thinning may be necessary after first cut (2-4 years).
- nutrients, other than N, should be given at non-limiting amounts prior to vegetational periods (e.g. twice a year) at repeated occasions according to expected biomass development for the particular growth period i.e. generally an S-shaped dose-curve with low amounts at start and end. Apart from P and K microelements, especially Fe, Mo and B, might be necessary amendments. The nutrient balance is quite important.
- irrigation has been shown necessary in several cases during initial stand development. Water availability generally will govern growth at extended periods between monsoons.
- protective measures must be taken against damage by cattles, insects and not the least human activities. Fencing and insecticide treatments might be necessary as well as the employment of watchers.
- mechanical weeding should be done at early stages. The rapid canopy closure will prevent much further weedings.
- no-till-procedures are recommended to protect soil from erosion and to increase infiltration. Browsing will add organic mulch at

later stages to further protect the soil and to help in building up soil fertility. Decomposition of leaf litter should be studied so that the amount of nutrients input of available substrates may be estimated in order to reduce subsequent fertilization.

I would now like to give examples of plant species suitable for this purpose and the eventual problems that might arise from their use particularly in relation to their rhizobiology.

In Sri Lanka we have chosen mainly three exotic extremely fastgrowing species of leguminous NFT species for this purpose, i.e. Leucaena leucocephala, Sesbania grandiflora and Gliricidia maculata, but also Acacia spp. and Albizia falcataria are used at one site. With the exception of Gliricidia they all have extremely good calorific values. Comparison are made with non-NFT species like Eucalyptus grandis and E. calamaldulensis. I should also mention that a NFT species trial is being conducted at several experimental sites where the above species are also being compared with other exotic and indigenous species. No rhizobiological work is, however, attached to these latter trials. Leucaena (common name "ipil-ipil") and Gliricidia are the most important tree legumes at use today in Sri Lanka, mainly for forage. The leaves are important complements in lifestock feeding, especially during the dry season, but those of Leucaena can be toxic due to their mimosine content at excess consumption rates (Falvey, 1982). These trees also have many other uses. The leaves can serve as green manure and the wood as excellent firewood or construction material. They are often planted as living fences or as shade trees and for erosion control in plantations.

Sesbania, which has similar multiple uses is not commonly grown in Sri Lanka today, but is frequent in other Asian countries. The only research on such species in Sri Lanka sofar have been a project on Conservation Farming where Leucaena and Gliricidia are planted in avenues and annual crops like mays and vegetables are grown in between. The leaves from the trees are used as mulch and some fuelwood is also produced every year.

The above mentioned legumes are all quite able to fix nitrogen with proper rhizobia, but these are not always present in the soil (Table 1-3). According to conditions normally found in tropical soils

Table 1. Rhizobial populations at two different sites according to plant infection counts.

Site	Plant host	
	L. leucocephala	*S. grandiflora*
	(no. of rhizobia/g soil)	
Kundasale	58	170
Maha Illuppallama	170	1700

Table 2. Effect of seed inoculation of *Sesbania grandiflora* at Kundasale and Maha Illuppallama (MI). Values in parentheses refer to 2nd observations after repeated inoculation prior to planting in the field.

Site	No. of nodules	dw of nodules (mg)	dw of plants (g)
Kundasale	4.0 (11.9)	1.8 (21.0)	0.11 (0.50)
Control (uninoc.)	0 (0)	0 (0)	0.11 (0.13)
MI	5.1	23.2	0.31
Control	0.2	0.04	0.18

This did, however, occur in *L. leucocephala* at MI (Tab. 3) even though plants at this stage were still only 1/2 the size (dw) of inoculated ones.

Table 3. Effect of inoculation of seedlings of *Leucaena leucocephala* at Kundasale and Maha Illuppalama (MI).

Site	No. of nodules	dw of nodules (mg)	dw of plants (g)
Kundasale	1.2 (3.2)	1.3 (0.4)	0.06 (0.31)
Control	0.4 (0.8)	0.9 (0.1)	0.17 (0.22)
MI	- (2.0)	- (4.7)	- (0.18)
Control	- (1.5)	- (1.8)	- (0.09)

In conclusion, inoculation with effective rhizobia seem absolutely necessary for rapid nodulation and plant development at early stages for both plant species at both sites tested.

either stimulating or inhibiting nutritional factors may affect the symbiosis. Phosphorous deficiency, e.g. is often the main limiting nutrient for legumes in the tropics, although there are great differences between species in their response to added phosphorus (Franco, 1977). Fertilization with phosphorus in acid soils is complicated by the high capacity of such soils to fix this element. In the lateritic soils of the wet zone of Sri Lanka e.g. the phosphate is retained by extremely insoluble aluminium- and ironoxide complexes (Dissanayake & Senaratne, 1982). Vesicular-arbuscular (VA) mycorrhizae, which is common in these legumes (Asimi et al., 1980), makes the phosphorus question even more complex. Some crops appear to be quite dependent upon a mycorrhizal association for P-absorption from soils of high P-fixing capacity.

Sulphur, iron and molybdenum are all required for the nitrogen-fixing enzyme system nitrogenase. While Fe-deficiency is rare, molybdenum and sulphur are often limiting factors in the tropics (Bergerson, 1977). Addition of Mo usually reduces the nodule numbers but increases their size and the amount of nitrogen fixed per unit of nodule (Andrew, 1976).

The main effects of S are found directly on the host legume itself, which becomes unable to synthesize proteins. Inoculation with Rhizobium in a sulphur deficient soil can therefore be completely wasted (Norris & Date, 1976).

Both calcium and magnesium are essential for the legume plant as well as the bacteria. A change in the Ca/Mg quotient can interrupt the accessibility of either nutrient. An inbalance is almost always induced by relatively high uses of potassium compounds or by liming (Andrew, 1976). Common low-Mg-lime should therefore not be used alone as free-living rhizobia are sensitive to Mg-deficiency (Edwards, 1977).

According to Norris & Date (1976) the relative balance of Ca^{2+} and H^+ ions determines whether nodules form at all and whether or not they fix nitrogen, at levels of calcium and pH adequate for full plant growth. Within the pH range 4 to 6 the calcium requirements for nodulation progressively increases.

Boron and copper are other essential minor elements that are necessary for normal development of roots and nodules (Andrew, 1976). The balance of nutrients are therefore most essential for a successful cultivation also of tree legumes used for fuelwood production.

Among the inhibitory nutritional factors I would like to emphasize the toxicity of aluminium and manganese that are likely to occur in many tropical acidic soils. The effect of Al^{3+}-ions on the plant is largely through root damage whereby nodulation is severely restricted (Norris & Date, 1976). Manganese antagonizes Ca^{2+} uptake reducing both nodulation and the effectiveness of molybdenum in the fixation of nitrogen. Mulching have been proved as one remedy to stimulate nodulation as it alleviates Mn-toxicity and also removes inhibitory levels of available inorganic nitrogen. It also breaks up the concretions formed by manganese migrating into the upper soil layers.

As to the rhizobia per se tropical species are generally slow-growing and alkali producing. Those associated with <u>Leucaena</u> and <u>Sesbania</u>, however, are exceptions in being fast-growing acid-producing (Norris & Date, 1976).

Other stress factors to consider are salinity problems in the dry tropics, as well as high temperatures and low soil moisture content. Regardless of the abiotic qualities of the environment, an effective symbiosis can only be established by specific combinations of host-legume and rhizobia. Tropical legumes can be delineated into three broad groups according to nodulation and N_2-fixing capacity.

1) Some host legumes accept infection only by a very restricted range of rhizobia, e.g. <u>Leucaena leucocephala</u> (Bergerson, 1977).
2) Others e.g. <u>Gliricidia</u>, may be infected by rhizobia isolated from the nodules of a wide range of legumes (Graham & Hubbell, 1974). Most tropical legumes fall into this so called "cowpea miscellaneous" group.
3) Between these two extremes there are legumes which nodulate with a variety of rhizobia which often, however, give raise to ineffective symbioses (Graham & Hubell, 1974).

The general rule is that new legumes in an area usually have to be inoculated. The inoculum of rhizobia must, however, be able to compete with the native rhizobia by having the ability to colonize soils, to have a good saprophytic capacity and of course a good infectiveness. Obaton (1977) have shown that one way of overcoming competitiveness even with already present moderately effective strains may be to spread a large number of rhizobia with the first-rain after the dry period (when the native population is low). In the case of planted woody leguminous NFT, however, the best is to inoculate plants in the nursery stage. Gliricidia which is propagated by cuttings do generally not need inoculation (see above). In case the inoculum has to be imported shipment and storage in customs may create unsuitable conditions of survival.

In our case we found that selection of rhizobia for Leacaena under acid stress and Al-toxicity conditions were absolutely necessary. Rhizobial acid-stress-tolerance generally is a consistent and stable strain property (Munns & Keyser, 1981).

The process of symbiosis, notably nodulation is about ten times more sensitive to acidity than either bacterial or root growth alone (Evans et al., 1980). Selection for acid-tolerant rhizobia must therefore be done in green-house trials, where pH can be rigorously controlled. Media with low pH and high Al, however, are quite useful for prescreening rhizobia for acid-stress-tolerance, as more than 40% of strains tolerant of pH 4.5 anyway would not tolerate the Al-toxicity that would normally be associated with soil acidity. Indigenous acid soils are the best substrates but a defined medium containing a mixture of galactose and arabinose (instead of mannitol) with added glutamate as N-source are quite suitable (Munns & Keyser, 198111). The symbiotic effectiveness of rhizobia at low pH may be tested according to the method described by Cooper (1978).

Isolates of woody legume rhizobia from different climatic zones were made by two of my students in Sri Lanka in 1982. A strain for Gliricidia was obtained from the Soya Bean Center in Sri Lanka. This strain was tested on Macropitilium atropurpureum known to establish symbiosis with most tropical rhizobia (Stowers & Elkan, 1980). Strains for Leucaena and Sesbania were sent for from Japan (NIAS, Tsukuba Science City). We found that all isolates showing good acid tolerance seemed to withstand an Al-concentration of 50 µM of Al.

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Indigenous strains were found as effective as foreign strains and are recommended as they are more likely to be adapted to local conditions.

Finally I would like to present some pictures from our initial fuelwood trials in Sri Lanka with the leguminous NFT species Leucaena, Sesbania and Albizia where we have used combined inocula containing mainly such indigenous selected rhizobial strains.

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