Early growth and native nodulation of leguminous shrub and tree species in Brazil

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Abstract
The early growth and nodulation potential of 13 species of the following genera: Cajanus, Codariocalyx, Cratylia, Desmanthus, Desmodium, Leucaena and Sesbania, comprising 20 accessions, were evaluated under greenhouse conditions. The accessions were harvested 6 times at 7-day intervals starting 21 days after planting. At each harvest, the following characters were recorded: plant height (PH), root length (RL), top growth dry weight (TGDW), root dry weight (RDW), and nodule number (NN). Significant differences (P<0.01) were revealed among accessions, harvest times and their interaction in all characters. The species, S. exasperata, S. sesban and S. tetraptera, exhibited abundant nodulation, with nodules of the astragaloid type, and surpassed the other species in PH, TGDW and RDW. Desmodium and Codariocalyx produced small desmodioide type nodules, and Cajanus cajan large, round nodules. S. punicea, S. virgata and L. leucocephala did not nodulate in the soil used.

Introduction
Various studies have been conducted in recent years to evaluate the forage potential of leguminous shrub and tree species in tropical and subtropical regions (Gutteridge 1990; Wandera et al. 1991; Shelton et al. 1991). However, one of the limitations to the utilisation of these species is their poor establishment (Maasdorp and Gutteridge 1986), with some species such as Leucaena leucocephala showing slow seedling growth (Wandera et al. 1991; Sorensson et al. 1994). Success or failure in establishment depends on the growth rate of the tree species selected, particularly where the tree seedlings are competing with grasses or weeds (Maasdorp and Gutteridge 1986).

The Sesbania genus, in particular S. sesban, is fast-growing and becomes established quickly
The purpose of this study was to evaluate growth during the first 2 months after planting and the ability to nodulate with indigenous soil rhizobia in a red-yellow latosol soil of São Paulo State, Brazil, of 13 species belonging to 7 genera of leguminous shrubs and trees with forage potential.

Materials and methods

The following 7 genera were evaluated: *Cajanus*, *Codariocalyx*, *Cratylia*, *Desmodium*, *Leucaena* and *Sesbania*. The species used are listed in Table 1.

Table 1. List of species/accessions of shrub and tree legumes, introduction numbers and origin or sources of seeds.

<table>
<thead>
<tr>
<th>Species</th>
<th>Nº1</th>
<th>Origin/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cajanus cajan</em></td>
<td>314</td>
<td>IRI1 1214 – Matão/SP</td>
</tr>
<tr>
<td><em>Codariocalyx gyroides</em></td>
<td>2509</td>
<td>CSIRO2-CPI 76104 – Australia</td>
</tr>
<tr>
<td><em>Cratylia mollis</em></td>
<td>565</td>
<td>E.E.A. Salles/PI</td>
</tr>
<tr>
<td><em>Desmodium virgatus</em></td>
<td>2027</td>
<td>Tanquinho da Feira/BA3</td>
</tr>
<tr>
<td><em>Desmodium discolor</em></td>
<td>396</td>
<td>UEPAF7/Itagua – IS 68036</td>
</tr>
<tr>
<td><em>Desmodium distortum</em></td>
<td>1273</td>
<td>Miranda/MS</td>
</tr>
<tr>
<td><em>Leucaena leucocephala</em></td>
<td>2029</td>
<td>IRI 2984 – Matão/SP</td>
</tr>
<tr>
<td><em>Leucaena leucocephala</em></td>
<td>2030</td>
<td>IRI 3541 – Matão/SP</td>
</tr>
<tr>
<td><em>Leucaena leucocephala</em></td>
<td>2031</td>
<td>IRI 3164 – Matão/SP</td>
</tr>
<tr>
<td><em>Leucaena punicea</em></td>
<td>2032</td>
<td>IRI 3219 – Matão/SP</td>
</tr>
<tr>
<td><em>Leucaena pallida</em></td>
<td>2507</td>
<td>CSIRO-CPI 94581 – Australia</td>
</tr>
<tr>
<td><em>Sesbania exasperata</em></td>
<td>1017</td>
<td>Campinas/SP</td>
</tr>
<tr>
<td><em>Sesbania exasperata</em></td>
<td>1545</td>
<td>Itumbiara/GO3</td>
</tr>
<tr>
<td><em>Sesbania punicea</em></td>
<td>1422</td>
<td>Cananéia/SP</td>
</tr>
<tr>
<td><em>Sesbania seshan var. seshan</em></td>
<td>934</td>
<td>USP4 – São Paulo/SP</td>
</tr>
<tr>
<td><em>Sesbania seshan var. bicolor</em></td>
<td>1030</td>
<td>Campinas/SP</td>
</tr>
<tr>
<td><em>Sesbania seshan var. seshan</em></td>
<td>2419</td>
<td>Rongwa Research Centre – Tanzania</td>
</tr>
<tr>
<td><em>Sesbania tetrapera</em></td>
<td>1660</td>
<td>Moçambique</td>
</tr>
<tr>
<td><em>Sesbania virgata</em></td>
<td>1256</td>
<td>Rod. F/Dutra – Km 110/RJ3</td>
</tr>
<tr>
<td><em>Sesbania virgata</em></td>
<td>1289</td>
<td>Miranda/MS</td>
</tr>
</tbody>
</table>

1 Introduction number at the Instituto de Zootecnia, Nova Odessa, SP, Brazil.
2 Instituto de Pesquisas IRI.
3 Federal States in Brazil: SP = São Paulo; PI = Piauí; RJ = Rio de Janeiro; BA = Bahia; GO = Goiás; MS = Mato Grosso do Sul.
4 Commonwealth Scientific and Industrial Research Organisation, Australia.
5 Unidade de Execução de Pesquisa de Âmbito Estadual.
6 Universidade de São Paulo.
of each accession were hand scarified, pre-

germinated at 20–30°C and, upon emergence of

the radicle, planted in 18 × 15cm polythene bags

containing 2 kg of red-yellow latosol soil limed

at 1.8 t/ha and fertilised with the equivalent of

70 kg/ha P (KH₂PO₄), 88 kg/ha K (KH₂PO₄) and

30 kg/ha S (Na₂SO₄). Three-five seeds were

planted, then thinned back to one plant per bag.

Two days after planting, the following micro-

nutrients were applied: 0.5 kg/ha boron, 2 kg/ha

copper, 2 kg/ha zinc and 0.25 kg/ha moly-

debenum. Chemical analysis of soil samples taken
during Harvest 5 revealed the following com-

position: 20 ppm P, 0.17 meq/100 cm³ K,

1.69 meq/100 cm³ Ca, 1.33 meq/100 cm³ Mg

(Ion-Exchange Resin procedure), 1.83% organic

matter (Walkley-Black procedure) and pH 5.16

(Van Raij et al. 1987).

At each harvest, the following characters were

recorded: plant height (PH), root length (RL), top

growth dry weight (TGDW), root dry weight

(RDW), and nodule number (NN). Plants were
destructively harvested; after watering, the plastic

bags were cut and the soil was separated by hand

from the roots, which were later washed carefully

to remove the remaining soil. Dry weight of top
growth and roots was obtained after oven drying
at 65°C for 48 h. In addition, the distribution of

nodules on the root system was noted as well as

their size and shape. The seeds were not inocu-
lated with rhizobial strains and, therefore, observa-
tions on nodulation related solely to the effects

of the natural populations of *Rhizobium* present

in the soil utilised. Data were subjected to uni-

variate analysis of variance.

**Results**

**Plant growth**

Highly significant differences (P<0.01) between

accessions (Table 2) and between harvest times

and in the interaction accessions × harvest times

were detected for all traits evaluated.

Changes in plant height (PH), top growth dry

weight (TGDW) and nodule number (NN) over
time for species representing the 7 genera evalu-
ated are shown in Figures 1–3, respectively. For

<table>
<thead>
<tr>
<th>Species and Nº</th>
<th>PH (cm)</th>
<th>RL (cm)</th>
<th>R/S (cm)</th>
<th>TGDW (g)</th>
<th>RDW (g)</th>
<th>NN</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cajanus cajan</em> 314</td>
<td>52.42 bcd</td>
<td>52.85 de</td>
<td>0.49 ef</td>
<td>4.29 cd</td>
<td>0.96 cdef</td>
<td>23.26 e</td>
</tr>
<tr>
<td><em>Codariocalyx gyroides</em> 2509</td>
<td>31.22 f</td>
<td>27.93 de</td>
<td>0.89 cdef</td>
<td>3.16 fg</td>
<td>0.99 cde</td>
<td>50.46 cd</td>
</tr>
<tr>
<td><em>Cratylium mollis</em> 565</td>
<td>32.50 f</td>
<td>22.08 e</td>
<td>0.77 def</td>
<td>1.53 j</td>
<td>0.33 h</td>
<td>4.59 f</td>
</tr>
<tr>
<td><em>Desmanthus sp.</em> 2027</td>
<td>48.67 cd</td>
<td>48.83 a</td>
<td>1.08 bcde</td>
<td>2.41 ghj</td>
<td>0.43 gh</td>
<td>0.78 fg</td>
</tr>
<tr>
<td><em>Desmodium discolor</em> 396</td>
<td>49.00 cd</td>
<td>27.67 de</td>
<td>0.58 ef</td>
<td>4.09 de</td>
<td>1.03 cd</td>
<td>59.71 bcd</td>
</tr>
<tr>
<td><em>Desmodium distortum</em> 1273</td>
<td>31.42 fg</td>
<td>32.67 bcde</td>
<td>1.05 bcde</td>
<td>3.31 ef</td>
<td>1.00 cd</td>
<td>63.13 bc</td>
</tr>
<tr>
<td><em>Leucaena leucocephala</em> 2029</td>
<td>20.83 hi</td>
<td>41.50 abc</td>
<td>2.14 a</td>
<td>1.55 j</td>
<td>0.58 fgh</td>
<td>0.13 fg</td>
</tr>
<tr>
<td><em>Leucaena leucocephala</em> 2030</td>
<td>22.25 gh</td>
<td>33.27 bcde</td>
<td>1.54 ab</td>
<td>1.93 haj</td>
<td>0.78 defg</td>
<td>0.27 fg</td>
</tr>
<tr>
<td><em>Leucaena leucocephala</em> 2031</td>
<td>20.83 hi</td>
<td>29.33 cde</td>
<td>1.41 bc</td>
<td>2.21 hij</td>
<td>0.76 defg</td>
<td>0.38 fg</td>
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<tr>
<td><em>Leucaena leucocephala</em> 2032</td>
<td>17.92 i</td>
<td>36.18 abcd</td>
<td>2.04 a</td>
<td>1.64 hj</td>
<td>0.59 fgh</td>
<td>0.00 g</td>
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<tr>
<td><em>Leucaena pallida</em> 2507</td>
<td>45.58 de</td>
<td>26.93 de</td>
<td>0.60 ef</td>
<td>2.24 hij</td>
<td>0.61 dfgh</td>
<td>0.55 fg</td>
</tr>
<tr>
<td><em>Sesbania exasperata</em> 1017</td>
<td>60.50 b</td>
<td>35.17 abcd</td>
<td>0.58 ef</td>
<td>5.39 ab</td>
<td>3.22 a</td>
<td>97.58 a</td>
</tr>
<tr>
<td><em>Sesbania exasperata</em> 1545</td>
<td>57.35 bc</td>
<td>36.00 abcd</td>
<td>0.63 ef</td>
<td>6.14 a</td>
<td>2.93 a</td>
<td>82.92 ab</td>
</tr>
<tr>
<td><em>Sesbania punicea</em> 1422</td>
<td>34.85 f</td>
<td>35.00 abcd</td>
<td>0.96 bcdef</td>
<td>3.16 fg</td>
<td>1.24 c</td>
<td>0.00 g</td>
</tr>
<tr>
<td><em>Sesbania sesban</em> 934</td>
<td>59.17 b</td>
<td>31.62 bcde</td>
<td>0.54 ef</td>
<td>5.04 bc</td>
<td>1.85 b</td>
<td>59.95 bcd</td>
</tr>
<tr>
<td><em>Sesbania sesban</em> 1030</td>
<td>81.50 a</td>
<td>38.00 abcd</td>
<td>0.48 ef</td>
<td>5.47 ab</td>
<td>1.79 b</td>
<td>40.77 d</td>
</tr>
<tr>
<td><em>Sesbania sesban</em> 2419</td>
<td>76.08 a</td>
<td>33.50 bcde</td>
<td>0.45 f</td>
<td>4.44 cd</td>
<td>1.81 b</td>
<td>44.02 cd</td>
</tr>
<tr>
<td><em>Sesbania tetraptera</em> 1660</td>
<td>36.02 ef</td>
<td>42.50 ab</td>
<td>1.26 bcde</td>
<td>3.83 cd</td>
<td>1.62 b</td>
<td>55.32 cd</td>
</tr>
<tr>
<td><em>Sesbania virgata</em> 2556</td>
<td>29.25 fgh</td>
<td>30.42 bcde</td>
<td>1.06 bcde</td>
<td>3.10 fg</td>
<td>1.00 cd</td>
<td>0.00 g</td>
</tr>
<tr>
<td><em>Sesbania virgata</em> 2589</td>
<td>37.75 ef</td>
<td>28.08 de</td>
<td>0.74 def</td>
<td>2.70 fg</td>
<td>0.77 defg</td>
<td>0.00 g</td>
</tr>
</tbody>
</table>

CV% (B) | 19.51 | 22.18 | 29.37 | 27.45 | 37.72 | 26.33

1 Original data [converted to square root (x + 0.5)].
2 Means followed by the same letter within a column are not significantly different at P<0.05 by the Tukey Test.
the graphic analysis, one accession/species, when there was more than one, was chosen for each genus evaluated. Thus, the species Desmodium discolor (Nº 396), Leucaena leucocephala (Nº 2030), Sesbania sesban (Nº 934) and S. exasperata (Nº 1017) were selected for these genera.

Comparing, for example, Leucaena leucocephala and Desmodium discolor in Figure 1, plants of the former were taller up to Harvest 2 (28 d), after which it was surpassed by D. discolor. A similar pattern of behaviour for these species can be observed in Figure 2 for TGDW. A similar comparison can be made for other species, as for example, the TGDW of Leucaena pallida (not shown) and Codariocalyx gyroides (Figure 2). The species, C. gyroides (syn. Desmodium gyroides), displayed slow initial growth, similar to Desmodium distortum and D. discolor. However, after 42 and 49 days (Harvests 4 and 5, respectively), it surpassed L. leucocephala and L. pallida in terms of TGDW. D. discolor displayed an excellent recovery at Harvest 3 (35 d) (Figure 2).

In comparing the Leucaena species evaluated, L. pallida presented faster initial growth than the L. leucocephala accessions, made evident from the PH (Table 2). The TGDW of L. pallida, however, was not significantly different (P>0.05) from that of the L. leucocephala accessions.

![Figure 1](image_url)

**Figure 1.** Plant height at each harvest (21, 28, 35, 42, 49 and 56 days after planting) for different leguminous shrub and tree species.
Figure 2. Top growth dry weight at each harvest (21, 28, 35, 42, 49 and 56 days after planting) for different leguminous shrub and tree species.

- *Desmodium discolor*
- *Codariocalyx gyroides*
- *Cajanus cajan*
- *Leucaena leucocephala*
- *Desmanthus virgatus*
- *Sesbania sesban*
- *Cratylia mollis*
Sesbania sesban and S. exasperata showed rapid early growth, followed by Cajanus cajan, as evidenced by the PH and TGDW data 56 days after planting (Table 2; Figures 1 and 2).

The species Cratylia mollis displayed slow initial growth and was surpassed by all other species from approximately 42 days for RL, RDW and TGDW (Figure 2).

At 35 days growth (Harvest 3), Desmanthus virgatus had the longest roots but the lowest RDW. At all harvests, the root system of this species consisted of a thin, long tap root, with few lateral roots and rare nodules.

**Root/shoot ratio**

The results from the final root/shoot ratio (R/S), equivalent to the root length/plant height ratio recorded at the last harvest (Table 2), showed that some species allocate more energy to below-ground biomass in the early growth period, e.g. Desmanthus virgatus, Desmodium distortum, L. leucocephala, S. punicea, S. tetraptera and S. virgata (Nº 1256). Others allocate more energy to the above-ground biomass, e.g. C. cajan, Codariocalyx gyroides, C. mollis, Desmodium discolor, L. pallida, S. exasperata and S. sesban.

**Figure 3.** Number of nodules at each harvest (21, 28, 35, 42, 49 and 56 days after planting) for different leguminous shrub and tree species.
Nodulation

The species, *S. exasperata*, *S. sesban*, *S. tetraptera*, *C. cajan*, *Desmodium* spp. and *Codariocalyx gyroides*, exhibited high nodulation, whereas *L. leucocephala*, *L. pallida*, *S. virgata* and *S. punicea* produced a maximum of 2 nodules per plant (Table 2; Figure 3).

As for the morphology of nodules, round as well as multilobed nodules were observed in the nodulated *Sesbania* species. Chlorophyllated nodules were observed near the surface for *S. exasperata* as well. At 56 days growth (Harvest 6), the species *D. discolor*, *D. distortum* and *Codariocalyx gyroides* displayed a large number of small, round nodules, typically desmodioid and located principally on the lateral roots. At the same harvest, pigeonpea (*C. cajan*) averaged 25 nodules per plant of medium size, some of them bifurcated. *Cratylia mollis* displayed small globular nodules of the desmodioid type, few in number and located as much on the tap root as on the lateral root system.

Discussion

Plant growth

Rapid early growth was observed for *Sesbania exasperata*, *S. sesban*, and to a lesser degree *C. cajan*, *D. discolor* and *S. tetraptera* (Table 2). There are few references in the literature concerning *S. exasperata* and *S. tetraptera*, both fast-growing annuals. The perennial, *S. sesban*, however, has potential as a multipurpose species for use as browse, fodder, green manure, wind-breaks, living fences and firewood and even in folk medicine (Evans and Macklin 1990). Also, it displays fast growth (Gutteridge and Akkasaeng 1985; Maasdorp and Gutteridge 1986; Veasey et al. 1995), relative to species like *L. leucocephala*, which has high forage value but slow and difficult initial plant growth (Wandera et al. 1991), also evident in this study. After 6 months of evaluation, Gutteridge and Akkasaeng (1985) observed faster growth and greater production of edible dry matter for *S. sesban* compared with other species belonging to different genera, including *L. leucocephala*. Similar results were observed by Maasdorp and Gutteridge (1986) for *S. formosa* and *S. sesban* in comparison with *Calliandra calothyrsus*, *Acacia angustissima* and *L. leucocephala*. Consequently, they were less susceptible to competition from weeds.

*L. pallida* was taller than *L. leucocephala* accessions with higher top growth dry weight, showing faster initial plant growth. Similar results were obtained by Sorensson et al. (1994), reporting much better seedling vigour for the *L. pallida* lines and their hybrids with *L. leucocephala* than for either *L. leucocephala* or *L. diversifolia* lines.

*Cratylia mollis* showed slow early growth relative to the other species. Despite its slow initial growth, once established in the field it proves to be very vigorous (observations from introduction garden made by O.M.A.A. Ghisi, unpublished data).

*Desmanthus virgatus* presented curious results in this study, with high RL values after Harvest 3 when compared with the other species. However, this species also presented the lowest RDW, suggesting that the notable growth in root length constitutes a physiological adaptation of the plant to dry and poor soil conditions, bearing in mind that this species is drought-tolerant (Skerman 1977).

Considering the desirable character of fast early plant growth, to compete effectively with weeds, as demonstrated by Maasdorp and Gutteridge (1986), initial growth of the species tested was rated as: very quick for *S. exasperata*, *S. sesban*, *S. tetraptera*, *Cajanus cajan* and *Desmodium discolor*; intermediate for *D. distortum*, *Leucaena pallida*, *S. punicea* and *S. virgata*; and slow for *L. leucocephala*, *Cratylia mollis*, *Desmanthus virgatus* and *Codariocalyx gyroides*. The latter species, however, presented better development from Harvest 4 (42 d after planting).

Root/shoot ratio

Different allocation strategies were observed for the different species, some allocating more energy to below-ground biomass, e.g. *L. leucocephala*, and others to the above-ground biomass, e.g. *S. sesban*. These observations are consistent with the results presented by Fownes and Anderson (1991), showing that *L. leucocephala* allocated a greater fraction of its total biomass below ground than did *S. sesban*. It is also in agreement with the hypothesis that relatively
lower biomass allocation to below-ground storage tissue is the cause for sesbania’s relatively greater sensitivity to cutting. *S. sesban*, therefore, displays rapid early growth (Gutteridge and Akkasaeng 1985; Maasdorp and Gutteridge 1986; Veasey et al. 1995), but decreased regrowth vigour after severe cutting (Yamoah and Getaahun 1990). However, care must be taken in extrapolating conclusions about growth efficiency obtained in pot experiments to systems in which below-ground competition is more intensive.

**Nodulation**

High nodulation potential was observed for *S. exasperata*, *S. sesban* and *S. tetraptera*, which presented round as well as multilobed nodules. Harris et al. (1949) reported the presence of young and spherical nodules in species of *Sesbania grandiflora*, characterised by hemispherical meristems in contrast to multiple, interrupted, apical meristems in the old lobed nodules. The author observed that nodules in 12-month-old plants formed a compact mass distributed along the tap root, yet each nodule was distinct and could be separated from the group without interfering with the adjacent nodules. The average number of nodules per plant on accessions of *S. sesban* after 56 d in this study was 50 (range 30–89). Ramani et al. (1990) recorded 148 nodules per plant in this species at 55 d after planting, also obtaining greater plant heights and above-ground biomass production in comparison with other species of *Sesbania*. Kadiata and Kape (1991) recorded up to 308 nodules per plant in 1–6-month-old *S. sesban* non-inoculated plants in Zaire.

Surprisingly, *S. virgata* and *S. punicea*, both native to Brazil and found frequently in areas close to rivers and streams and even along the coast, failed to nodulate. Such results indicate that the *Sesbania* species present different levels of host specificity. The *Sesbania* species are considered to possess little nodulation specificity and yet markedly variable efficiency (Allen and Allen 1981). The predominant type of nodule of the Robineae tribe, to which this genus belongs, is the astragaloid type (Monteiro 1984). According to the author, this type of nodule, in *Sesbania*, characterises strains of *Rhizobium* that, in general, induce nodules only in host plants of the same genus. In some cases, however, the strain that nodulates one species does not nodulate other species (Evans and Brewbaker 1990). This phenomenon was observed in the present study, in which the soil presented native strains of *Rhizobium*, nodulating the roots of *S. exasperata*, *S. sesban* and *S. tetraptera*, but failing to infect roots of *S. punicea* and *S. virgata*. Thus, nodulation responses depend on both the presence of suitable rhizobia in the soil from either native or previously introduced legume, and the specificity of the legume species. Complementary studies of cross inoculation among the *Sesbania* species referred to above, showed specificity of *Rhizobium* isolated from *S. virgata*, which exhibited different esterase electrophoretic patterns as well, in contrast with *S. sesban* whose isolates nodulated all other species tested (M.J. Valarini, unpublished data).

The absence of nodulation in the *Leucaena* species (Table 2) is probably due to the non-occurrence of specific rhizobia for these legumes, which associate with strains of *R. loti* required for seed inoculation at sowing (Högberg and Kvarnström 1982; Bushby 1982; Valarini and Bufarah 1984). The lack of biological N₂ fixation may, in part, explain their late development, although these species are known to be slow starters (Maasdorp and Gutteridge 1986), even when inoculated with specific strains of *Rhizobium*. This can be a disadvantage for *L. leucocephala*, widely recognised as a legume of excellent value as a forage plant. The lower above- and underground dry matter production observed for the species that did not nodulate or produced only a few nodules, such as *L. leucocephala*, *L. pallida*, *S. virgata*, *S. punicea*, *Cratylia mollis* and *Desmanthus virgatus*, indicate, therefore, a clear association between nodulation and plant development, possibly reflecting the beneficial effects of biological nitrogen fixation for the nodulated plants. It is possible that specific *Rhizobia* were lacking or even N₂ fixation was suppressed by other soil nitrogen sources. Therefore, it is assumed that, although the quantity of soil N available probably from organic matter mineralisation was sufficient for the plant growth obtained, it could still limit plant yield.

In conclusion, there was a high potential for nodulation, under the soil conditions utilised without inoculation with specific strains of rhizobia, for *S. tetraptera*, *S. sesban*, *D. discolor*,
D. distortum, Codariocalyx gyroides, and, in particular, S. exasperata, for the high number of nodules, with chlorophyllated nodules near the surface. Cajanus cajan nodulated but with fewer nodules. In addition, nodulation was virtually absent in L. leucolephala, L. pallida, S. panicea and S. virgata, probably due to host specificity. However, the consensus still remains that tropical legumes cannot nodulate, either because they lack specific Rhizobium or because inoculation is not successful since they associate with a wide range of indigenous strains in the soil.

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