# *Leucaena—Rhizobium* Compatibility and Nitrogen Fixation

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**Abstract**

The compatibility and effectiveness of potentially nitrogen fixing associations between two *Rhizobium* strains and thirteen collections of *Leucaena leucocephala*, five other species of *Leucaena*, and *Albizia occidentalis* were determined. The appearance, dry weight, and nitrogen content of plants grown with and without *Rhizobium* were determined. A comparison was made of nitrogen fixed per plant and per unit weight of plant, and the ratio of plant weight (grown with *Rhizobium*) to plant weight (grown without *Rhizobium*). The various collections of *L. leucocephala* made compatible and equally effective nitrogen fixing associations with the two strains of *Rhizobium*. Compatible and effective nitrogen fixing associations also occurred with *L. pulverulenta*, *L. esculenta*, *L. diversifolia*, and *L. collinsii*. Less effective nitrogen fixing associations occurred with *L. retusa*. Although root nodules formed on *A. occidentalis*, effective nitrogen fixation did not occur.

## Introduction

In recent years the genus *Leucaena* has received considerable attention as an economically important plant group throughout the tropics and sub-tropics (Anon., 1977; Anon., 1979; Brewbaker, 1975; Brewbaker, 1978; Brewbaker et al., 1972; Yabes, 1977). Greatest attention has been given to *L. leucocephala*.

The wood of *L. leucocephala* is used for lumber and paper pulp. The foliage is used as a livestock feed and green manure. The seeds provide a source of gum and are used to make decorative necklaces. The tree is planted as an ornamental, in windbreaks, and as a shade or nurse tree for other crops such as coffee, cacao, tea, cinchona, and citrus. The attention given to *L. leucocephala* is well deserved because it has many desirable qualities which include high growth rate, good drought resistance, high resistance to insect pests, tolerance to a wide range of soil and climatic conditions, ability to improve soil, and high nutritional value.

Brewbaker (1978) and Brewbaker et al. (1972) suggest that other species of *Leucaena* may be equal or superior to *L. leucocephala* in some qualities. *L. pulverulenta* has approximately half the mimosine (toxic amino acid) content of *L. leucocephala*. Greater quantities of *L. pulverulenta* foliage and leaf meal can be eaten by animals without problems such as loss of hair in swine and horses. *L. esculenta* is a vigorous tree of the Mexican and Guatemalan highlands and may be better suited to higher elevations than *L. leucocephala*.

A major aspect of the ability of *Leucaena* to improve soil and to provide nutritional forage is the presence of certain nitrogen fixing bacteria, *Rhizobium*, in their roots. The *Leucaena* - *Rhizobium* association is capable of fixing more than 500 kg of nitrogen per hectare per year (Anon., 1977).

Galli (1958) and Trinick (1965) have shown that the *L. leucocephala* - *Rhizobium* association is very specific. Few *Rhizobium* isolates from other legumes produce nitrogen fixing nodules on *L. leucocephala*. However, *Rhizobium* isolates from effective nodules of *L. leucocephala* infect other plants of *L. leucocephala* and result in the formation of nitrogen fixing root nodules.

Brewbaker et al. (1972) recognize ten taxonomically valid species of *Leucaena* with considerable variation in form of some species. Fourteen previously reported species of *Leucaena* are synonymous with *L. diversifolia*. *L. leucocephala* has a number of forms (Brewbaker et al., 1972; Anon., 1977) ranging

**Table 1.** Plant Material Evaluated.

| Species | Seed Identification, Source, and Collection Data |
|---|---|
| *Leucaena leucocephala* | 1. Hawaii No. K8 (Brewbaker) |
| | 2. Hawaii No. K67 (Brewbaker) |
| | 3. Hawaii No. K132 (Brewbaker) |
| | 4. Hawaii No. K341 (Brewbaker) |
| | 5. cv. Hawaii - CPI 18624 (Bray) |
| | 6. cv. Cunningham - Bred from crosses between CPI 18624 and CPI 18228 (Bray) |
| | 7. cv. Peru - CPI 18614 (Bray) |
| | 8. El Salvador type - CPI 33029 (Bray) |
| | 9. El Salvador type - CPI 64189 (Bray) |
| | 10. CPI 70545 (Bray) |
| | 11. 4 km. NE of La Paz, Southern Baja California, Mexico by Thoma. |
| | 12. Within Miraflores in cape region of Southern Baja California by Thoma. |
| | 13. 3 km. E of Edinburg, Texas, USA by Thoma |
| *L. retusa* | 14. 6 km. W of Comstock, Texas, USA by Thoma |
| *L. pulverulenta* | 15. Within Brownsville, Texas, USA by Thoma |
| | 16. 0.5 km. E of Hidalgo, Texas, USA by Thoma |
| *L. esculenta* | 17. Hawaii No. K459 (Brewbaker) |
| *L. diversifolia* | 18. Hawaii No. K454 (Brewbaker) |
| *L. collinsii* | 19. CPI 46567 (Bray) |
| *Albizia occidentalis* | 20. SW of Miraflores in cape region of Southern Baja California by Thoma |

from tall, treelike plants with thick branchless trunks (Salvador types), to short shrubby plants (Hawaiian types).

The aims of this investigation were to determine the degree of plant-*Rhizobium* compatibility between *Rhizobium* strains and various forms of *L. leucocephala*, other species of *Leucaena*, and *Albizia occidentalis*; and to determine the effectiveness of these potentially nitrogen fixing associations.

## Materials and Methods

The seed material consisted of 20 collections (Table 1) and was obtained from a number of sources: Dr. James L. Brewbaker of the University of Hawaii; Dr. R. A. Bray of CSIRO, Australia; and field collections by Paul E. Thoma. Two *Rhizobium* strains were evaluated (Table 2). These were isolated from root nodules obtained from seedlings of *L. leucocephala* and *L. pulverulenta* according to procedures established by the Nitragin Company (Anon., 1968). *Rhizobium* cultures were grown and maintained on sterilized nutrient agar and inoculum was prepared by growing the cultures in a nutrient solution.

Seeds were mechanically scarified and their surface chemically sterilized. They were germinated on sterile moist filter paper in petri dishes placed in a growth chamber (Table 3).

Plants were grown in a sterilized, self-irrigating, coarse sand system (Leonard, 1943) having a nutrient solution lacking nitrogen (Thoma, 1980). Germinated seeds were placed in the sand media and four plants were grown for seven weeks in a growth chamber. *Rhizobium* inoculum was added to the sand around the germinated seeds at the time the seeds were placed in the sand media. Each seed type was grown in a separate container in duplicate with each *Rhizobium* strain and without *Rhizobium*.

**Table 2.** *Rhizobium* Strains Evaluated

| Strain Number | Source of Rhizobium Strain |
|---|---|
| R1C | Isolated from a root nodule on a *L. leucocephala* seedling growing 3 km E of Edinburg, Texas, USA by Thoma |
| R7A | Isolated from a root nodule on a *L. pulverulenta* seedling that was pot grown from a seed and in soil collected at the same location within Brownsville, Texas, USA by Thoma |

**Table 3.** Growth Chamber Conditions

| | |
|---|---|
| Total Light Period | 14½ hours |
| High Intensity Light Period - 2000 to 2400 footcandles | 14 hours |
| Low Intensity Light Period 100 to 110 footcandles | 15 minutes before and 15 minutes after the high intensity period |
| Light Period Air Temperature | 28°C |
| Dark Period Air Temperature | 20°C |

The dry weight and nitrogen content were determined for the entire plant after 7 weeks of growth. To determine the dry weight, the total plant material (4 plants) was dried at 75±5°C for 48 hours.

The nitrogen content was determined using a maximum of 0.5 gram of the pulverized plant material. The plant material was digested in low nitrogen concentrated sulfuric acid (10 ml) to which was added a catalyst salt mixture (4 grams) of anhydrous sodium sulfate (200 parts) and anhydrous copper sulfate (3 parts). The digest solution was diluted to 100 ml with distilled water and the nitrogen determination made using an ammonia probe.

## Results

Plants grown without *Rhizobium* have no root nodules. In contrast, all plants grown with *Rhizobium* strains have root nodules (Fig. 1, 3). The nodules occur on the main root and the principal branches of the main root near the surface of the growth media. The interior of the nodules of all *Leucaena* species grown with either *Rhizobium* strain is deep pink to red (cross-section appears dark in Fig. 2). The interior of the nodules from plants of *A. occidentalis* is whitish (cross-section appears light gray in Fig. 4).

All plants grown without *Rhizobium* have yellowish green foliage after seven weeks of growth. The plants of *L. leucocephala*, *L. pulverulenta*, *L. esculenta*, *L. diversifolia*, and *L. collinsii* grown with either *Rhizobium* strain have medium to dark green foliage, have more and larger leaves, and are larger than plants grown with no *Rhizobium*. Plants of *L. retusa* grown

**Figure 1.** *Nodules on roots of* Leucaena leucocephala *(Edinburg, Texas) inoculated with Rhizobium strain R1C. Scale divisions are in mm.*

with *Rhizobium* strain R1C have similar characteristics, while plants of *L. retusa* grown with *Rhizobium* strain R7A have light green foliage, have fewer and smaller leaves, and are smaller than plants grown with *Rhizobium* strain R1C. The plants of *A. occidentalis* grown with either *Rhizobium* strain appear similar to plants grown without *Rhizobium*.

The average weight and nitrogen content of the plants after seven weeks of growth are listed in Table 4. The compatibility of a plant type and a *Rhizobium* strain is determined by comparing the ratios of plant weights (grown with and without *Rhizobium*), and the nitrogen fixed per plant and per unit weight of plant (Table 5).

Plants grown with *Rhizobium* strain R1C have a weight ratio from 0.90 (*A. occidentalis*) to 1.80 (*L. retusa*) to 5.20 (*L. diversifolia*). When grown with *Rhizobium* strain R7A, the plants have a weight ratio from 0.93 (*A. occidentalis*) to 1.15 (*L. retusa*) to 4.89 (*L. diversifolia*).

The nitrogen fixed per plant is the difference between the nitrogen content (mg) per plant grown with *Rhizobium* and the nitrogen content (mg) per plant grown without *Rhizobium* (Table 5). With *Rhizobium* strain R1C, the nitrogen fixed per plant ranges from 0.44 mg (*A. occidentalis*) to 5.08 mg (*L. retusa*) to 27.07 mg (*L. esculenta*), and with *Rhizobium* strain R7A from 0.81 mg (*A. occidentalis*) to 2.07 mg (*L. retusa*) to 21.60 mg (*L. leucocephala* - CPI 70545).

The amount of nitrogen fixed per unit weight of plant indicates the efficiency of the nitrogen fixation process in a plant -*Rhizobium* system (Table 5). With *Rhizobium* strain R1C, the nitrogen fixed per gram of plant ranges from 1.29 mg (*A. occidentalis*) to 15.88 mg (*L. retusa*) to 26.98 mg (*L. leucocephala* - La

**Figure 2.** *Longitudinal section of root nodule from* Leucaena leucocephala *(Edinburg, Texas) inoculated with Rhizobium strain R1C. Scale divisions are in mm.*

**Table 4.** Average weight and nitrogen content of plants grown with and without *Rhizobium*.

| Plant Material | Average Dry Weight Per Plant, mg | | | Average Weight of Nitrogen Per Plant, mg | | | Average Percent Nitrogen in Plants | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plant without *Rhizobium* | Plant with *Rhizobium* R1C | Plant with *Rhizobium* R7A | Plant without *Rhizobium* | Plant with *Rhizobium* R1C | Plant with *Rhizobium* R7A | Plants without *Rhizobium* | Plants with *Rhizobium* R1C | Plants with *Rhizobium* R7A |
| *Leucaena leucocephala* Hawaii No. K8 | 230 | 765 | 736 | 2.46 | 18.51 | 17.52 | 1.07 | 2.42 | 2.38 |
| *L. leucocephala* Hawaii No. K67 | 207 | 888 | 687 | 2.15 | 19.54 | 15.94 | 1.04 | 2.20 | 2.32 |
| *L. leucocephala* Hawaii No. K132 | 342 | 815 | 939 | 3.35 | 18.42 | 22.16 | 0.98 | 2.26 | 2.36 |
| *L. leucocephala* Hawaii No. K341 | 143 | 634 | 618 | 1.69 | 15.22 | 15.57 | 1.18 | 2.40 | 2.52 |
| *L. leucocephala* cv. Hawaii - CPI 18624 | 210 | 718 | 686 | 2.14 | 19.10 | 17.29 | 1.02 | 2.66 | 2.52 |
| *L. leucocephala* cv. Cunningham | 231 | 855 | 746 | 2.63 | 20.01 | 17.38 | 1.14 | 2.34 | 2.33 |
| *L. leucocephala* cv. Peru - CPI 18614 | 244 | 848 | 837 | 2.39 | 19.16 | 19.42 | 0.98 | 2.26 | 2.32 |
| *L. leucocephala* El Salvador type - CPI 33029 | 284 | 772 | 736 | 2.95 | 17.60 | 17.52 | 1.04 | 2.28 | 2.38 |
| *L. leucocephala* El Salvador type - CPI 64189 | 332 | 915 | 878 | 2.99 | 21.41 | 20.72 | 0.90 | 2.34 | 2.36 |
| *L. leucocephala* CPI 70545 | 340 | 988 | 1011 | 3.88 | 22.13 | 25.48 | 1.14 | 2.24 | 2.52 |
| *L. leucocephala* La Paz, S.B.C., Mexico | 172 | 622 | 562 | 2.00 | 18.78 | 16.75 | 1.16 | 3.02 | 2.98 |
| *L. leucocephala* Miraflores, S.B.C., Mexico | 244 | 884 | 808 | 2.64 | 22.28 | 20.04 | 1.08 | 2.52 | 2.48 |
| *L. leucocephala* Edinburg, Texas, U.S.A. | 209 | 694 | 613 | 2.57 | 20.82 | 19.00 | 1.23 | 3.00 | 3.10 |
| *L. retusa* Comstock, Texas, U.S.A. | 178 | 320 | 205 | 2.79 | 7.87 | 4.86 | 1.57 | 2.46 | 2.37 |
| *L. pulverulenta* Brownsville, Texas, U.S.A. | 58 | 166 | 123 | 0.78 | 4.52 | 3.37 | 1.34 | 2.72 | 2.74 |
| *L. pulverulenta* Hidalgo, Texas, U.S.A. | 67 | 185 | 112 | 0.85 | 4.81 | 2.89 | 1.27 | 2.60 | 2.58 |
| *L. esculenta* Hawaii No. K459 | 339 | 1277 | 995 | 4.34 | 31.41 | 23.88 | 1.28 | 2.46 | 2.40 |
| *L. diversifolia* Hawaii No. K454 | 65 | 338 | 318 | 1.01 | 9.33 | 9.41 | 1.56 | 2.76 | 2.96 |
| *L. collinsii* CPI 46567 | 218 | 732 | 732 | 2.59 | 19.18 | 20.50 | 1.19 | 2.62 | 2.80 |
| *Albizia occidentalis* Miraflores, S.B.C., Mexico | 379 | 340 | 352 | 5.95 | 6.39 | 6.76 | 1.57 | 1.88 | 1.92 |

Paz, S.B.C.). With *Rhizobium* strain R7A, it ranges from 2.30 mg (*A. occidentalis*) to 10.10 mg (*L. retusa*) to 26.80 mg (*L. leucocephala* - Edinburg, Texas).

## Discussion

Wilson (1939) found that *Rhizobium* isolates prepared from nodules on plants of *Albizia julibrissin, Dalea alopecuroides, Desmodium canadense, Glycine max, Sesbania macrocarpa, Stizolobium deeringianum, Strophostyles helvola, Swainsonia coronillaefolia,* and *Vigna sinensis* produced nodules on *leucaena glauca,* now known as *L. leucocephala.* Galli (1958) showed that, of twenty legumes investigated, a *Rhizobium* isolate from *L. glauca* produced nodules only on *L. glauca.* Isolates from the other legumes investigated, including *Vigna sinensis,* failed to form nodules on *L. glauca.* Trinick (1968) found that isolates from *Acacia farnesiana, Mimosa invisa,* and *L. leucocephala* of forty-six legume plant types from which isolates were prepared, formed an effective association with *L. leucocephala.* Isolates from *Mimosa pudica* produced a partially effective association and *Sesbania grandiflora* produced completely ineffective nodules on *L. leucocephala.* Isolates from *Glycine max, Stizolobium deeringianum,* and *Vigna sinensis* produced no nodules on *L. leucocephala.* Of forty-two legumes that Trinick (1968) evaluated, two isolates from *L. leucocephala* produced effective nodules on *L. leucocephala, Acacia farnesiana,* and *Vigna sinensis* ssp. *sesquipedalis.* A

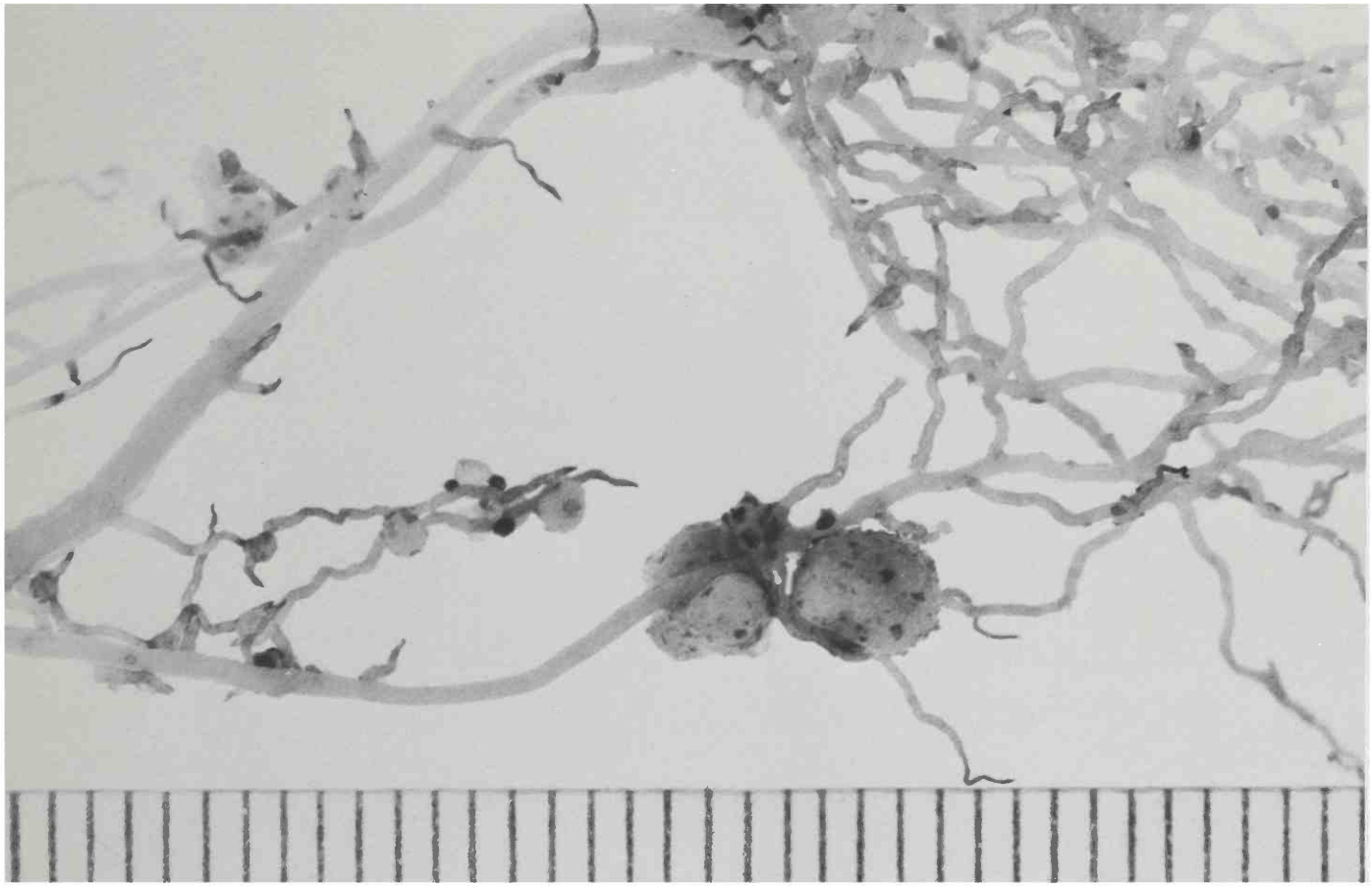

**Figure 3.** *Nodules on roots of* Albizia occidentalis *inoculated with* Rhizobium *strain R1C. Scale divisions are in mm.*

third isolate from *L. leucocephala,* in addition to the above plants produced effective nodules on *Mimosa invisa.* Trinick (1965) and Trinick (1968) reported that *Rhizobium* isolates from *L. leucocephala* produced completely ineffective nodules or none on *Medicago sativa.*

In this investigation, the medium to dark green color of the foliage, and the larger and healthy appearance of all *L. leucocephala* plants grown with *Rhizobium* indicate a compatible association with the *Rhizobium* strains used. Quantitatively, the larger size of the *Rhizobium* associated plants is indicated by the ratios of plant weight, when grown with *Rhizobium,* to plant weight when grown without *Rhizobium. L. leucocephala* weight ratios range from 2.38 to 4.43 for plants grown with *Rhizobium* strain R1C and 2.59 to 4.32 with *Rhizobium* strain R7A. The root nodules of *L. leucocephala* have a deep pink to red interior from the presence of leghemoglobin. Leghemglobin provides an anaerobic condition in that portion of the nodule where nitrogenase is present and is essential for the nitrogen fixation process. Nitrogen fixation occurs in the root nodules and results in an increase in plant nitrogen. The amount of nitrogen fixed per plant and per gram of plant is relatively large for all of the *L. leucocephala* plant types (Table 5), and indicates a compatible association between all of the *L. leucocephala* plant types and the *Rhizobium* strains.

*L. retusa* does not follow the pattern established by *L. leucocephala.* Plants of *L. retusa* grown with *Rhizobium* strain

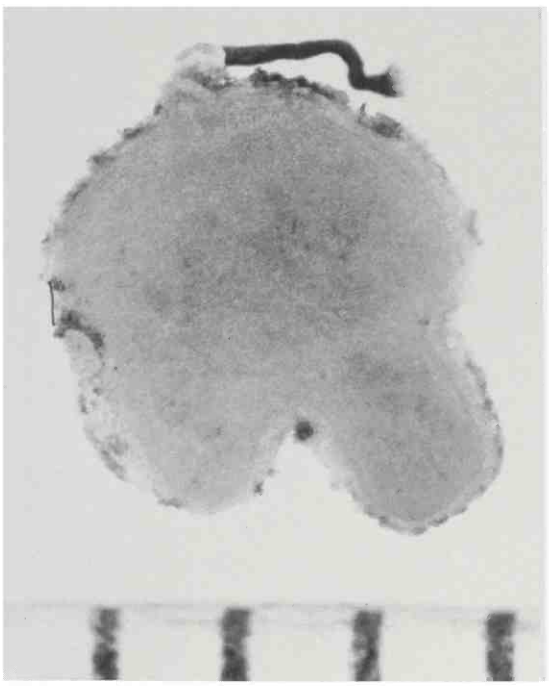

**Figure 4.** *Longitudinal section of root nodule from* Albizia occidentalis *inoculated with* Rhizobium *strain R1C. Scale divisions are in mm.*

**Table 5.** Weight and nitrogen content relationships between plants grown with and without *Rhizobium*.

| Plant Material | Ratio of Plant Weight (Grown with *Rhizobium* R1C) to Plant Weight (Grown without *Rhizobium*) mg:mg | Ratio of Plant Weight (Grown with *Rhizobium* R7A) to Plant Weight (Grown without *Rhizobium*) mg:mg | mg Nitrogen Fixed Per Plant | | mg Nitrogen Fixed Per Gram of Plant | |
|---|---|---|---|---|---|---|
| | | | *Rhizobium* R1C | *Rhizobium* R7A | *Rhizobium* R1C | *Rhizobium* R7A |
| *Leucaena leucocephala* Hawaii No. K8 | 3.33 | 3.20 | 16.05 | 15.06 | 20.98 | 20.46 |
| *L. leucocephala* Hawaii No. K67 | 4.29 | 3.32 | 17.39 | 13.79 | 19.58 | 20.07 |
| *L. leucocephala* Hawaii No. K132 | 2.38 | 2.75 | 15.07 | 18.81 | 18.49 | 20.03 |
| *L. leucocephala* Hawaii No. K341 | 4.43 | 4.32 | 13.53 | 13.88 | 21.34 | 22.46 |
| *L. leucocephala* cv. Hawaii - CPI 18624 | 3.42 | 3.27 | 16.96 | 15.15 | 23.62 | 22.08 |
| *L. leucocephala* cv. Cunningham | 3.70 | 3.23 | 17.38 | 14.75 | 20.33 | 19.77 |
| *L. leucocephala* cv. Peru - CPI 18614 | 3.48 | 3.43 | 16.77 | 17.03 | 19.78 | 20.35 |
| *L. leucocephala* El Salvador type - CPI 33029 | 2.72 | 2.59 | 14.65 | 14.57 | 18.98 | 19.80 |
| *L. leucocephala* El Salvador type - CPI 64189 | 2.76 | 2.64 | 18.42 | 17.73 | 20.13 | 20.19 |
| *L. leucocephala* CPI 70545 | 2.91 | 2.97 | 18.25 | 21.60 | 18.47 | 21.36 |
| *L. leucocephala* La Paz, S.B.C., Mexico | 3.62 | 3.27 | 16.78 | 14.75 | 26.98 | 26.25 |
| *L. leucocephala* Miraflores, S.B.C., Mexico | 3.62 | 3.31 | 19.64 | 17.40 | 22.22 | 21.53 |
| *L. leucocephala* Edinburg, Texas, U.S.A. | 3.32 | 2.93 | 18.25 | 16.43 | 26.30 | 26.80 |
| *L. retusa* Comstock, Texas, U.S.A. | 1.80 | 1.15 | 5.08 | 2.07 | 15.88 | 10.10 |
| *L. pulverulenta* Brownsville, Texas, U.S.A. | 2.86 | 2.12 | 3.74 | 2.59 | 22.53 | 21.06 |
| *L. pulverulenta* Hidalgo, Texas, U.S.A. | 2.76 | 1.67 | 3.96 | 2.04 | 21.41 | 18.21 |
| *L. esculenta* Hawaii No. K459 | 3.77 | 2.94 | 27.07 | 19.54 | 21.20 | 19.64 |
| *L. diversifolia* Hawaii No. K454 | 5.20 | 4.89 | 8.32 | 8.40 | 24.62 | 26.42 |
| *L. collinsii* CPI 46567 | 3.36 | 3.36 | 16.59 | 17.91 | 22.66 | 24.47 |
| *Albizia occidentalis* Miraflores, S.B.C, Mexico | 0.90 | 0.93 | 0.44 | 0.81 | 1.29 | 2.30 |

R1C have medium green foliage and are somewhat larger than plants grown without *Rhizobium*. The plants of *L. retusa* grown with *Rhizobium* strain R7A are small, have light green foliage, and appear intermediate to plants grown with *Rhizobium* strains R1C and without *Rhizobium*. The dry weight ratios also indicate a substantial plant size difference between plants grown with *Rhizobium* strains R1C and R7A (1.80 and 1.15 respectively). A comparison of the nitrogen fixation relationships reveals less nitrogen fixed per plant and per gram weight of plant with *L. retusa* than with *L. leucocephala*. Considerably less nitrogen is fixed in *L. retusa* grown with *Rhizobium* strain R7A (2.07 mg N/plant and 10.10 mg N/gram of plant) than in *L. retusa* grown with *Rhizobium* strain R1C (5.08 mg N/plant and 15.88 mg N/gram of plant). The *L. retusa* - *Rhizobium* strain R7A association is relatively incompatible on the basis of plant appearance, weight ratio, and nitrogen fixation. The *L. retusa* - *Rhizobium* strain R1C association is a more compatible nitrogen fixing system than the *L. retusa* - *Rhizobium* strain R7A system, but less compatible than the *L. leucocephala* - *Rhizobium* systems.

Plants of *L. pulverulenta* grown with the *Rhizobium* strains are smaller than the plants of *L. leucocephala*. They have, however, medium green foliage and appear healthy. The dark pink interior of root nodules from a plant of *L. pulverulenta* indicates the presence of leghemoglobin. The weight ratio for plants of *L. pulverulenta* grown with *Rhizobium* strain R1C is similar to those of several *L. leucocephala* plant types. The weight ratio for the *L. pulverulenta* plant types grown with

*Rhizobium* strain R7A is less than when grown with *Rhizobium* strain R1C. Slightly more nitrogen is fixed per plant and per gram of plant when plants of *L. pulverulenta* are grown with *Rhizobium* strain R1C than with strain R7A. *L. pulverulenta* grown with either *Rhizobium* strain have considerably less fixed nitrogen per plant than the *L. leucocephala* types. The amount of nitrogen fixed per gram of plant in *L. pulverulenta* is similar to the nitrogen fixed per gram of plant in *L. leucocephala*, but on the low side of their range. The *L. pulverulenta* plant types have a compatible association with the two *Rhizobium* strains. The association between *L. pulverulenta* and *Rhizobium* strain R1C appears to be slightly more effective than with strain R7A.

The appearance of the plants of the remaining species of *Leucaena* indicates a compatible *Rhizobium* association. The plants of *L. esculenta*, *L. diversifolia*, and *L. collinsii* have medium green foliage, appear healthy, and are larger than plants grown without *Rhizobium*. The weight ratios for these plants are similar to or greater than the weight ratios for *L. leucocephala*. Nitrogen fixed per plant in *L. esculenta* and *L. collinsii* is similar to or greater than that in the *L. leucocephala* types. Plants of *L. diversifolia* have less nitrogen fixed per plant. The nitrogen fixed per gram of plant is similar in *L. esculenta*, *L. diversifolia*, *L. collinsii*, and the various forms of *L. leucocephala*. The results indicate that *L. esculenta*, *L. diversifolia*, and *L. collinsii* form a compatible association with both *Rhizobium* strains.

The yellowish green foliage, similar size, and appearance of the plants of *Albizia occidentalis* grown with the *Rhizobium* strains and without them indicate an incompatible nitrogen fixing association. Although nodulation occurs on the roots of *A. occidentalis*, the whitish nodule interior indicates an absence of leghemoglobin and an inability to fix nitrogen. The plant weight ratio is less than 1.00 indicating less plant growth when the plants are grown with *Rhizobium* than when grown without *Rhizobium*. The nitrogen fixed is very low on a per plant and per gram of plant basis with both *Rhizobium* strains.

## Summary and Conclusions

The 13 forms of *L. leucocephala* and the two strains of *Rhizobium* used in this investigation produce compatible and equally effective nitrogen fixing associations. Compatible and effective nitrogen fixing plant-*Rhizobium* associations also occur in plants of *L. pulverulenta*, *L. esculenta*, *L. diversifolia*, and *L. collinsii*, although the growth of these plants varies considerably between the different species. Plants of *L. retusa* and the *Rhizobium* strains do not form as effective nitrogen fixing associations, and the effectiveness of the association is dependent on the *Rhizobium* strain used. Root nodules form on plants of *Albizia occidentalis*, when grown with *Leucaena* compatible *Rhizobium* strains, but effective nitrogen fixation does not occur.

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