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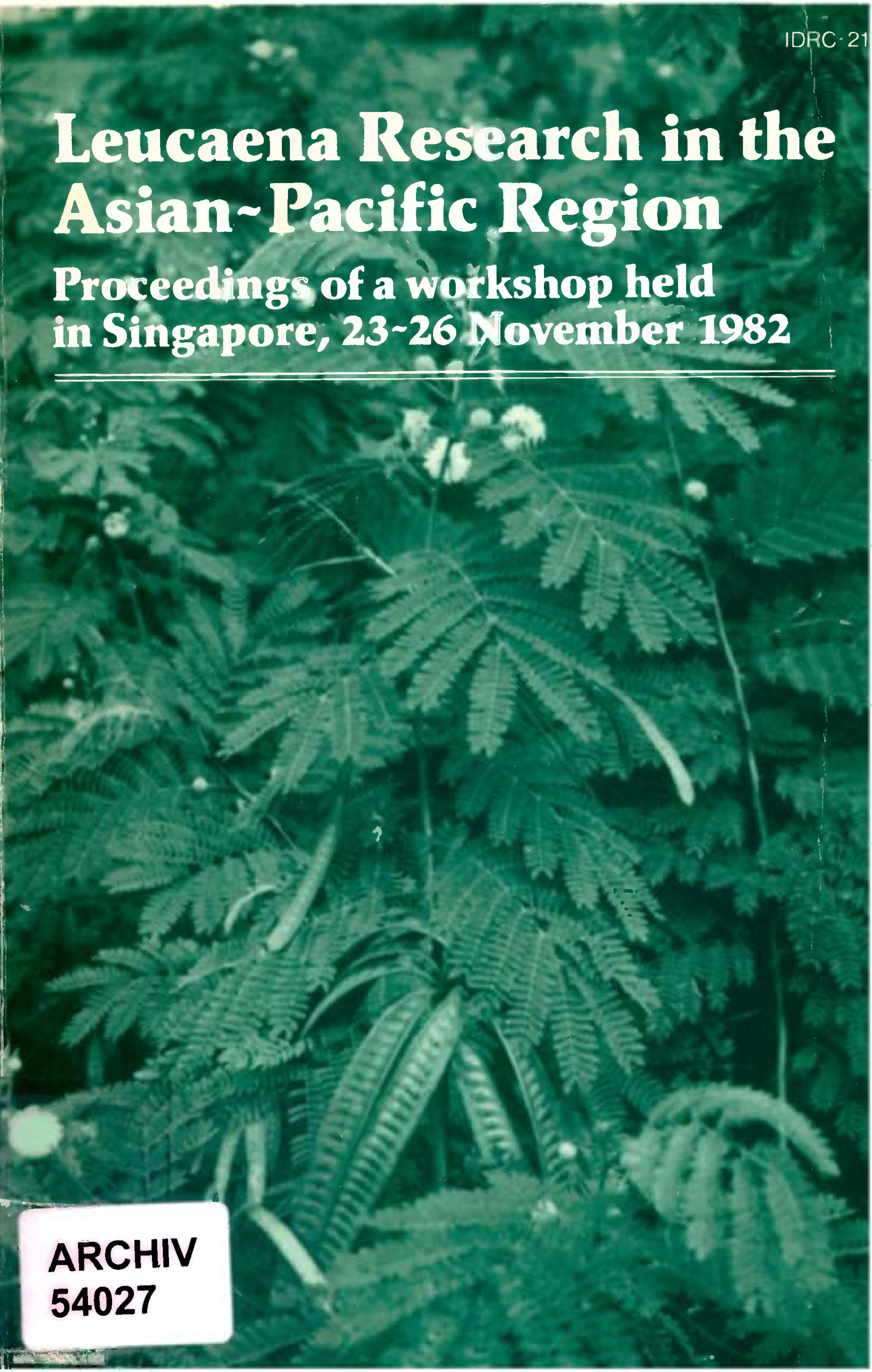
Leucaena Research in the Asian-Pacific Region

Proceedings of a workshop held in Singapore, 23-26 November 1982



Leucaena Research in the Asian-Pacific Region IDRC-211e

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Leucaena Research in the Asian–Pacific Region

Proceedings of a Workshop Held in Singapore, 23–26 November 1982

Organized by the Nitrogen Fixing Tree Association and the International Development Research Centre

Abstract

Because of *Leucaena leucocephala*'s multiple uses as forage, fuelwood, poles, green manure, etc., this fast-growing, nitrogen-fixing tree has been the subject of much research in the last decade. The results have clarified the capabilities of the plant as well as its limitations. One main constraint to cultivation in vast areas of Latin America and Southeast Asia has been leucaena's inability to survive on acidic, aluminum-saturated soils. At low pH, the aluminum complexes with calcium, which is essential for good growth. Trials have shown that some varieties of *L. diversifolia* can make use of the calcium from the complexes and that crosses between these varieties and *L. leucocephala* perform well on acidic soils. The main constraint to use of leucaena as a forage derives from the plant's content of mimosine, a toxic, nonprotein amino acid. Although leucaena has proved to be a highly nutritious animal feed, the mimosine and its breakdown product, DHP (3-hydroxy-4[1H]pyridone), have caused toxicity among animals fed high levels of leaf meal. Scientists now have evidence that the mimosine is converted into DHP when brought into contact with an enzyme contained in some of the plant's cells harbouring mimosine. This finding needs follow up; it suggests that simple processing, such as chopping fresh leaves, will convert all the mimosine into the less-toxic DHP. Elsewhere, researchers have found that DHP can be metabolized by anaerobic microorganisms that have been found in the guts of ruminants in countries like Indonesia. They have successfully transferred the microorganisms to animals in Australia where toxicity from DHP has deterred graziers from using leucaena as forage. Other research has defined optimal approaches to breeding and genetic improvement of leucaena; characteristics of rhizobia that effectively provide the plant with nitrogen-fixing ability; biomass production under widely different soil conditions; effects on fish, poultry, cattle, goats, and sheep fed leucaena leaf meal; management and cultural practices for both large-scale and smallholder operations; etc. The results are the subject of this publication, which comprises 30 papers from researchers in the Asian–Pacific Region.

Résumé

Leucaena leucocephala a fait l'objet de nombreuses recherches au cours de la dernière décennie, cet arbre légumineux fixateur d'azote et de croissance rapide ayant de nombreux usages comme fourrage, combustible, poteau, engrais vert, etc. Ces études ont permis d'en délimiter les fonctions. L'un des facteurs limitants de sa culture dans de vastes régions de l'Amérique latine et de l'Asie du Sud-Est est l'incapacité de *Leucaena* de survivre dans des sols acides, saturés d'aluminium. Dans le cas d'un faible pH l'aluminium complexe le calcium, essentiel à une croissance régulière. Des essais ont démontré que certaines variétés de *L. diversifolia* peuvent utiliser le calcium présent dans les complexes et que les croisements entre ces variétés et *L. leucocephala* prospèrent dans des sols acides. Le principal obstacle à l'utilisation de *Leucaena* comme fourrage est sa teneur en mimosine, acide aminé non protéique toxique. Bien que ce fourrage soit hautement nutritif, la mimosine et DHP (3-hydroxy-4[1H]pyridone) ont provoqué des cas de toxicité chez les animaux consommant de grandes quantités de farine de feuilles. Les scientifiques ont découvert que la mimosine se décompose en DHP lorsqu'elle entre en contact avec une enzyme contenue dans certaines cellules où elle est présente. Cette découverte a permis de déterminer des moyens simples de neutraliser cette substance toxique, tel que le hachage des feuilles vertes qui décompose la mimosine en DHP moins toxique. Ailleurs, des chercheurs ont trouvé que le DHP peut être métabolisé par des microorganismes anaérobiques présents dans l'intestin des ruminants dans certains pays comme l'Indonésie. Ils ont réussi à transférer ces microorganismes à des animaux en Australie où les pasteurs refusent l'emploi du fourrage de *Leucaena* à cause de la toxicité de DHP. D'autres recherches préconisent une approche optimale: de la sélection et de l'amélioration génétique de *Leucaena*; des caractères des rhizobiums qui assurent la fonction de la fixation d'azote chez la plante-hôte; de la production de bio-masse dans diverses conditions de sols très variés; des effets des rations de farine de feuilles sur les poissons, les volailles, le bétail, les chèvres et les moutons; de la gestion et des pratiques culturales des opérations des petites et des grandes exploitations, etc. Tous ces résultats sont détaillés dans la présente brochure qui contient trente communications exposées par des chercheurs de la région du Pacifique asiatique.

Resumen

Debido a los múltiples usos de la *Leucaena leucocephala* como forraje, combustible, madera, abono, etc., este árbol, de rápido crecimiento y habilidad para fijar el nitrógeno, ha sido objeto de abundante investigación en la última década. Los resultados han aclarado las capacidades de la planta, así como sus limitaciones. Uno de los problemas para su cultivo en vastas áreas de Latinoamérica y el Sudeste Asiático ha sido su incapacidad para sobrevivir en suelos ácidos, saturados de aluminio. A niveles bajos de pH, el aluminio forma complejos con el calcio que es esencial para un buen crecimiento. Las pruebas han mostrado que algunas variedades de *L. diversifolia* pueden usar el calcio de los complejos y que los cruces entre estas variedades y la *L. leucocephala* se desempeñan bien en suelos ácidos. El principal inconveniente para usar la leucaena como forraje proviene de su contenido de mimosina, un aminoácido tóxico no proteínico. Aunque la leucaena ha probado ser un alimento animal altamente nutritivo, la mimosina y su producto de descomposición, el DHP (3-hydroxy-4[1H]pyridone), han causado toxicidad entre los animales alimentados con altos niveles de harina de follaje. Los científicos tienen ahora evidencia de que la mimosina se convierte en DHP cuando entra en contacto con una enzima que se encuentra en algunas células de la planta que contienen mimosina. Este hallazgo necesita seguimiento, pero sugiere que un simple procesamiento, como picar las hojas frescas, convierte toda la mimosina en el menos tóxico DHP. En otras partes, los investigadores han encontrado que el DHP puede ser metabolizado por microorganismos anaeróbicos que han sido hallados en el intestino de rumiantes en países como Indonesia. Ellos han traspasado con éxito los microorganismos a animales en Australia donde la toxicidad del DHP ha impedido que los ganaderos empleen la leucaena como forraje. Otras investigaciones han definido los enfoques óptimos para el fitomejoramiento de la leucaena, las características de la rizobia que efectivamente dotará a la planta de la habilidad de fijar nitrógeno, la producción de biomasa bajo condiciones edáficas ampliamente distintas, los efectos sobre los peces, las aves, el ganado, las cabras y las ovejas alimentadas con harina de hoja de leucaena, las prácticas culturales y de manejo para las actividades a gran escala o del pequeño agricultor, etc. Los resultados son el tema de esta publicación que abarca 30 trabajos de investigadores en la región Asiopacífica.

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Research on Leucaena Forage Production in Malaysia

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In Malaysia, where soils are generally acidic and highly saturated with aluminum, research at the Malaysian Agricultural Research and Development Institute indicates that rhizobial inoculation and lime-pelleting of Leucaena leucocephala *seeds are essential for successful establishment and growth. Screening of leucaena cultivars tolerant to aluminum shows some promising results. Other results of research at MARDI have been reviewed. Studies on mimosine content indicate that it is highest in the shoot tips, first-expanded leaves, flowering heads, and young pods. In the foliage and stems, it declines with age and with increases in the time between leaf harvests. Annual dry-matter yields of between 13.5 t/ha and 21.9 t/ha have been recorded from some promising accessions. A 77-day growth study with goats fed leucaena forage and grass at ratios of 1 : 4, 1 : 1, and 4 : 1 showed a positive correlation between increasing leucaena and live-weight gain, with the highest gain being recorded at 75% dietary leucaena. It was suggested that about 50% dietary leucaena level is suitable for goats. Grazing studies with leucaena–grass pastures have been promising, and daily live-weight gains of Sahiwal-Friesian heifers have averaged 443 g. The results, together, demonstrate and emphasize the potential value of leucaena forage for ruminants.*

En Malaisie, où les sols sont généralement acides et fortement saturés d'alumine, les études effectuées par l'Institut de recherches et de développement agricole de la Malaisie (MARDI) révèlent que l'inoculation du rhizobium et l'enrobage des semences de Leucaena leucocephala *avec de la chaux sont indispensables à l'établissement et au développement satisfaisants du végétal. La sélection de cultivars de* Leucaena *tolérants à l'alumine semble annoncer des résultats prometteurs. D'autres constatations enregistrées par MARDI ont été passées en revue. Les études sur les teneurs en mimosine révèlent qu'elle est élevée surtout aux extrémités des pousses, dans les premières feuilles ouvertes, les sommités florales et les jeunes pousses. Elle diminue avec l'âge dans les tiges et dans le feuillage et avec l'allongement des intervalles entre les récoltes de feuilles. Dans certaines situations prometteuses on a pu relever des rendements annuels de matière sèche variant de 13,5 à 21,9 t/ha. Un test de croissance, durant 77 jours, sur des chèvres nourries de fourrage de* Leucaena *et de graminées en proportions de 1 à 4, 1 à 1 et 4 à 1 a révélé une corrélation positive entre l'accroissement des proportions de* Leucaena *et les gains en poids vif, les plus élevés de ces derniers correspondant à 75 % de* Leucaena *dans le régime. On considère qu'une proportion de 50 % conviendrait bien aux chèvres. Les études sur des pâturages à base de* Leucaena *et de graminées ont été encourageantes, et des génisses Sahiwal-Holstein y ont gagné en moyenne 443 g par jour, poids vif. Globalement, les résultats obtenus démontrent et soulignent la valeur que peut avoir le fourrage de* Leucaena *pour les ruminants.*

En Malasia, donde los suelos son generalmente ácidos y altamente saturados de aluminio, la investigación del Instituto Malasio de Investigación y Desarrollo Agrícola (MARDI) indica que la inoculación de rizobia y el recubrimiento con cal de las semillas de Leucaena leucocephala *es esencial para el establecimiento y el crecimiento. La selección de cultivares de leucaena tolerantes al aluminio muestra algunos resultados promisorios. Otros resultados de la investigación de MARDI ya han sido reseñados. Los estudios sobre el contenido de mimosina indican que el más alto se encuentra en las puntas de los retoños, en las primeras hojas abiertas, en las cabezas florecientes y en las vainas jóvenes. En el follaje y en los tallos desciende con la edad y el aumento del tiempo entre las cosechas de hojas. Se han registrado rendimientos anuales de materia seca entre 13,5 t/ha y 21,9 t/ha en algunas líneas promisorias. Un estudio de crecimiento de 77 días con cabras alimentadas con forraje de leucaena y pastos a raciones de 1 : 4, 1 : 1 y 4 : 1 mostraron una correlación positiva entre el aumento de leucaena y la ganancia de peso vivo, con la mayor ganancia registrada a la dieta de leucaena a 75%. Se sugirió que un nivel de 50% de leucaena en la dieta es apropiado para cabras. Los estudios sobre pastos–leucaena han sido promisorios y las ganancias diarias de peso vivo en terneros Sahiwal–Fresian han totalizado aproximadamente 443 g. Los resultados, en conjunto, demuestran y subrayan el valor potencial del forraje de leucaena para rumiantes.*

Forage from *Leucaena leucocephala* has potential as a means of increasing protein in animal feed, especially in the diet of ruminants. Protein feeds are generally in short supply in Malaysia, and their importance derives from the fact that inadequate protein intake seriously limits growth of farm animals at a time when maximum offtake is the main objective. These issues prompted a multidisciplinary research program at the Malaysian Agricultural Research and Development Institute (MARDI). Initiated in 1974, its aim is to examine forage production from leucaena, especially the agronomic management of the crop and utilization in feed for ruminants (cattle, goats, and sheep). This paper presents a comprehensive review as well as results of the work done hitherto.

Establishment

In Malaysia, the areas designated for pasture production are generally acidic (pH 4.2–4.5), highly saturated with aluminum, and low in phosphorus and calcium. On such soils, leucaena grows poorly. Good establishment and rapid growth require liming (up to 2 t/ha) together with rhizobial inoculation with CB 81 and lime-pelleting of seeds (Tham et al. 1977).

Pot studies on two soil series, namely Serdang and Bungor, indicated quadratic responses to liming rates, with marked increase in dry-matter yields at 500 kg/ha but leveling at 2000 kg/ha (Tham et al. 1977). Lime-pelleted, inoculated seed significantly ($P<0.05$) outyielded the noninoculated seeds. Without lime application, there were no significant responses to rhizobial inoculation. The nodule numbers and weight were also increased by rhizobial inoculation and liming (Tham et al. 1977).

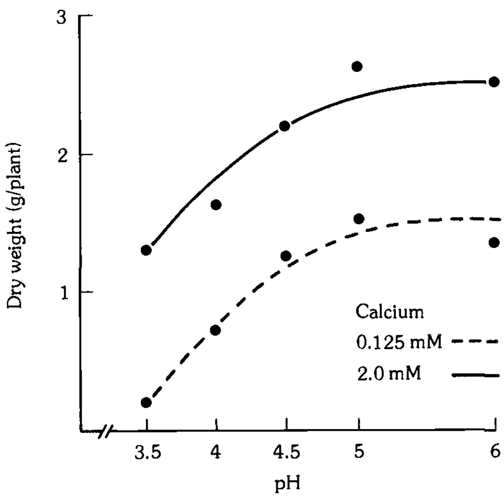

Fig. 1. Effects of pH and calcium concentration in solution on the growth of leucaena (Peru cultivar).

The interactions between lime, phosphorus, and inoculation have also been studied (Tham et al. 1977), and findings were that, in the presence of lime, at 50 kg P/ha, the dry-matter yield of leucaena was significantly greater than at 20 kg P/ha.

Slow seedling growth has been an inherent characteristic of the plant and has posed many establishment problems. Weed control through seed-bed preparation or herbicide treatments is often recommended (Kinch and Ripperton 1962), and nitrogen fertilizer in small quantities has been advocated on poor soils. Studies by Mohd. Najib (personal communication) on the effects of nitrogen fertilizer, clean weeding, and mulching on early establishment of leucaena indicated that mulching, combined with 25 kg N/ha, gave good results.

Influence of pH and Aluminum

Although the plant can thrive on soils with a wide range of pH, it performs better on alkaline, calcareous, clayey soils (Oakes 1968; Hill 1971a). In Malaysia, leucaena is usually grown in limestone outcrops or in the more fertile areas of the coastal alluvium.

Poor growth in acid soils has been attributed to aluminum and manganese toxicity, the effect of hydrogen ions, and calcium deficiencies. To determine the specific effects of soil acidity factors on the growth of leucaena, we tested solution cultures with various levels of pH (3.5–6.0) and calcium concentration. Growth of the Peru variety used in the study increased with increase in pH and calcium concentration (Fig. 1), the optimum pH being about 5; however, there was no single factor, pH or calcium, controlling the growth of leucaena.

Acid soils are often associated with high-aluminum saturation, and those in inland Malaysia exhibit aluminum saturation of 37–86%. The results from solution-culture experiments on aluminum concentration showed that leucaena growth was greatly reduced in solutions containing more than 4 ppm of aluminum (Table 1). The detrimental effects of high aluminum concentration can be ameliorated to some extent by increased calcium levels.

Efforts to identify aluminum-tolerant leucaena were undertaken on the nine top-yielding accessions in the MARDI collection. All the accessions showed reduced yields in response to increasing aluminum, although three accessions performed slightly better than

Table 1. Effect of aluminum and calcium concentration on the growth of Peru in vitro.

	Growth (g/plant)					
	Ca, 1 mM; Al(ppm)			Ca, 5 mM; Al(ppm)		
	0	4	16	0	4	16
Leaf	2.47	1.93	0.10	3.69	2.52	0.46
Stem	1.12	0.73	0.04	1.48	0.48	0.13
Root	1.64	1.66	0.11	1.96	1.60	0.43
RTY %[a]	73.5	60.6	3.5	100	69.6	14.3

[a] RTY % = relative total yield expressed as percentage of maximum total yield.

Table 2. Plant weight response (g/plant) of nine accessions of leucaena grown in nutrient solutions with four concentrations of aluminum.

Accessions/ cultivar	Aluminum concentration (ppm)[a]			
	0	4	8	16
L13	3.30 (100)	2.33 (70.6)	1.61 (48.8)	0.80 (24.2)
L19	3.49 (100)	2.62 (75.1)	1.53 (43.8)	0.88 (25.2)
L42	3.11 (100)	3.08 (99.0)	1.72 (55.3)	0.98 (31.5)
L55	3.52 (100)	2.48 (70.5)	1.59 (45.2)	0.86 (24.4)
L62	3.06 (100)	2.59 (84.6)	1.45 (47.4)	1.02 (33.3)
L65	3.86 (100)	3.10 (80.3)	1.97 (51.0)	0.92 (23.8)
L70	3.16 (100)	2.34 (74.1)	1.39 (43.9)	0.92 (29.1)
L72	2.46 (100)	1.73 (70.3)	1.07 (43.5)	0.71 (28.9)
Cunningham	3.26 (100)	2.55 (78.3)	1.15 (35.3)	0.78 (23.9)

[a] Figures in parentheses refer to relative total yields (RTY) expressed as percentage of the control.

the others (Table 2). Screening is being pursued.

Mimosine

From the viewpoint of forage production, the amino acid mimosine is undesirable. It is toxic to nonruminants and, if consumed in large quantities by ruminants, results in thyroid abnormalities (Jones et al. 1976, 1978). Mimosine occurs in all parts of the leucaena plant (Table 3), and our studies indicate that the shoot tip has the highest mimosine content, followed by the flowering heads and young pods. Mimosine content was high in the first-expanded leaf, and the young green stems had the lowest mimosine content in the plant parts examined.

Differences in mimosine content among strains have been reported (Carangal et al. 1955; Brewbaker and Hylin 1965), with con-

Table 3. Concentration (% fresh weight) of mimosine in various parts of Peru and two leucaena accessions.

Plant part	Mimosine concentration (% fresh weight)		
	Peru	55	65
Shoot tips	1.56	1.82	2.88
1st-expanded leaf	1.12	1.18	2.15
3rd-expanded leaf	0.81	0.83	1.72
5th-expanded leaf	0.69	0.79	1.32
9th-expanded leaf	0.54	0.43	1.05
15th-expanded leaf	0.23	0.21	0.34
3rd-stem internode	0.35	0.57	0.90
5th-stem internode	0.16	0.21	0.41
9th-stem internode	0.10	0.10	0.17
15th-stem internode	0.11	0.10	0.07
Flower heads	0.87	1.34	1.57
Young pods	1.07	1.12	1.43

Table 4. Mimosine content (% of dry matter) of first-expanded leaves of leucaena accessions at Serdang.

Mimosine content (%)	Accession
3.5–4	1, 18, 21, 38, 64, 66, 76
4.1–5	3, 17, 22, 27, 32, 33, 39, 44, 45, 48, 49, 51, 52, 58, 68, 73
5.1–6	5, 6, 10, 12, 25, 28, 29, 35, 40, 31, 41, 46, 47, 50, 57, 59 69, Peru, 72
6.1–7	2, 4, 9, 11, 13, 15, 16, 19, 20, 23, 30, 34, 36, 37, 42, 43, 55, 61 local, Cunningham
>7	8, 62, 65, 70

tent ranging from 2% to 5% (dry-matter basis). The determination of mimosine levels in the MARDI collection indicated a variation from 0.87% to 2.39% based on fresh weight, equivalent, on a dry-matter basis, to 3.5–9.23% (Table 4). Unfortunately, mimosine content was positively correlated with dry-matter production among the promising accessions (Wong et al. in press).

The effect of cutting interval on mimosine content in the leaf and young stems (<5 mm diameter) has also been studied (Table 5). Mimosine levels declined generally with increased time between cutting, and the change was particularly marked among the cutting frequencies from 2 to 8 weeks. Guevarra et al. (1978) reported that cutting regimens from 10 to 16 weeks did not produce differences in average mimosine content.

Management and Production

Plant size, age of crop, growth period, and floral initiation are some of the characters often adopted as means to determine optimum time of harvest for forage production. Many reports indicate that optimum yield is obtained when the plant is cut after it is 100–150 cm high (Anslow 1957; Guevarra et al. 1978). Increasing the time between cuttings enhances dry-matter yield, but the leaf–stem ratio declines — an indication that the proportion of stem is greater in infrequent harvests. Prolonged cutting intervals have never been encouraged for forage production because carbohydrates accumulate in the roots and lower stem and delay the onset of regrowth. These considerations, and an assessment of regrowth associated with the increase in the stem fraction under prolonged cutting intervals, indicate that the optimum time for defoliation would be about 8–12 weeks, other things constant.

In field trials, Peru variety, defoliated at 4- and 8-week intervals over 2 years, at 1 m cutting height, produced average annual yields of 3924 kg/ha and 5701 kg/ha, respectively. These yields are comparable with those reported from the dry tropics (Hutton and Bonner 1960; Oakes and Skov. 1962) but lower than the 20 t reported in the humid tropics (Brewbaker et al. 1972; Jones 1979).

There is some seasonal effect on yield (Fig. 2). The sensitivity of forage yields from leucaena during dry spells could be a reflection of the shallow rooting system of the plant caused by the physical soil structure and low pH. In this connection, Mohd. Najib (personal communication) has reported that leucaena plants, defoliated at 2-month intervals and at 0.5-m cutting height, had taproots growing no more than 60 cm deep. The lateral roots were fairly long but were shallow in penetration. Soil moisture is critical, and the importance of rainfall and its distribution pattern on leucaena-forage production has been em-

Table 5. Effect of cutting frequency on the dry-matter yield, leaf–stem ratio, mimosine content (% fresh weight), and regrowth rate of *L. leucocephala*.

	Cutting interval (weeks)					
	2	4	6	8	12	16
Dry-matter yield (g/plant)	17.4	32.0	87.9	219.3	459.9	756.5
Leaf–stem ratio	3.03	2.91	1.89	1.40	0.8	0.60
Weekly regrowth rate (g/plant)	8.7	7.3	27.9	65.7	60.2	74.2
Mimosine (% in leaf)	2.52	2.06	1.57	1.06	0.85	0.56
Mimosine (% in stem <5 mm)	1.11	0.68	0.39	0.17	0.25	0.05

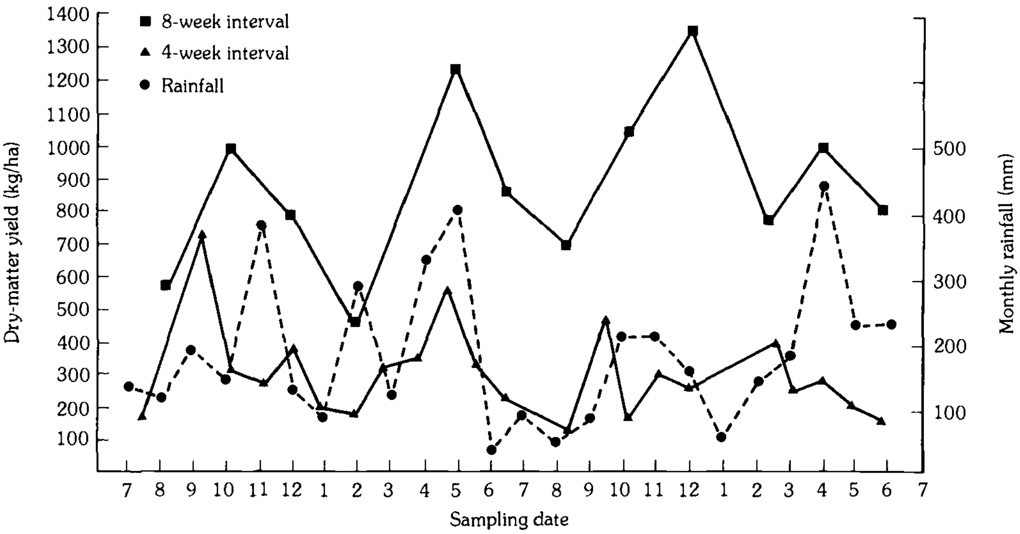

Fig. 2. Effect of rainfall on dry-matter production of Peru cultivar defoliated at 4- and 8-week intervals, July 1980 to July 1982.

phasized despite the fact that the legume is deep-rooted and drought tolerant (Oakes 1968).

Screening of leucaena accessions for improved dry-matter production is one of the objectives of MARDI's leucaena research program. Results of an ongoing experiment involving a number of promising accessions by C.P. Chen (personal communication) indicate that annual dry-matter yields ranging from 13.5 t/ha to 21.9 t/ha could be obtained from the top yielders, defoliated at 2-month intervals and limed at 2 t/ha (Table 6).

Consideration is now being given to the dual-purpose use of leucaena in live fencing and forage production because of the positive implications for the rural areas, especially small farms raising livestock.

Nutritive Value

Two trials investigated the nutritive value of leucaena forage (stems and leaves) when fed ad libitum to livestock. The forage was harvested at 2-month intervals at a cutting height of about 60 cm. Adult goats and sheep of similar live weight (25–26 kg) were also used in an assessment of comparative digestibility (Devendra 1982).

Goats had an average daily dry-matter intake of 51.0–60.9 g/$W^{0.75}$ kg and sheep 39.4–53.7 g/$W^{0.75}$ kg. The digestibility of dry matter for goats was 53.9–56.4%, organic matter 54.1–57.0%, crude protein 44.8–45.0%, and crude fibre 38.5–68.4%. The figures for sheep were dry matter 50.0–50.5%, organic matter 51.1%, crude protein 40.5–46.3%, and crude fibre 31.2–60.2%. Nitrogen retention as a percen-

Table 6. Annual dry-matter yield (t/ha) of promising leucaena accessions defoliated at 2-month intervals and limed at 2 t/ha.

Accession	Annual dry-matter yield (t/ha)
19	13.5
42	14.1
13, 30	15.7
62	17.0
65	18.4
69	18.8
55	21.9
Peru	8.5
Cunningham	11.4

Table 7. Nutritive value of leucaena forage to goats and sheep.

Parameter	Goats	Sheep
Digestible crude protein (%)	9.3–11.0	9.1–10.1
Total digestible nutrients (%)	46.9–67.8	46.7–54.2
Digestible energy (10^6J/kg)	8.66–12.62	8.62–10.00
Metabolizable energy (10^6J/kg)	7.10–10.35	7.07–8.20

Table 8. Effects on growth performance of goats fed *L. leucocephala* (L) and *P. purpureum* (G).[a]

Parameter	100%G	75%G + 25%L	50%G + 50%L	25%G + 75%L
Initial live weight (kg)	12.2	10.1	10.1	10.2
Final live weight (kg)	12.8	12.0	12.6	14.5
Live-weight change (kg)	0.6	1.9	2.5	4.3
Mean live weight (kg)	12.5	11.1	11.4	12.4
Mean daily live gain (g)	11.7a	24.4a	32.9ab	55.8c
Dry-matter intake/day (g)	393.9	404.9	505.3	550.3
Dry-matter intake/weight $^{0.75}$ kg/day	59.7	66.4	81.4	83.4
Dry-matter intake as % of live weight	3.4	4.0	4.8	4.7
Feed efficiency (dry-matter intake/gain)	30.3a	17.1b	15.9b	11.5b

[a] Results refer to the mean value for both males and females (10 goats total). Means in horizontal columns followed by different letters differ significantly (P<0.05).

tage of intake was 22.8–36.3 for goats and 8.7–18.4 for sheep; these differences were significant (Table 7) (Devendra 1982). Continuing work in this program concerns the effect of leucaena forage on the intake and utilization of rice straw.

Animal Performance

A 77-day growth trial was conducted with 40 Katjang × Etawah goats, about 1 year old. The trial had four treatments, replicated twice for males and females in a randomized, block design. The treatments, based on total dry-matter intake (DMI), were napier (*Pennisetum purpureum*) grass (control); 75% grass, 25% leucaena; 50% grass, 50% leucaena; and 25% grass, 75% leucaena.

Leucaena stimulated daily live-weight gain, which was highest (P<0.05) for the animals fed 25% grass, 75% leucaena (Table 8). At this level, however, the mimosine's effects were apparent. No significant differences were distinguishable on the basis of sex, DMI, or body measurements (height at withers, heart girth, and body length). It was concluded that leucaena forage can constitute 50% of the diet of goats (Devendra 1982), which is higher than the level (30%) advocated for steers by Jones (1979).

Grazing studies were undertaken on Peru variety interplanted with native pastures (*Paspalum conjugatum*, *Ottochloa nodosa*, *Centrosema pubescens*, etc.) or *Brachiaria decumbens* in efforts to obtain a highly productive two-canopied pasture. Each leucaena–grass mixture was rotationally grazed at monthly intervals under a two-paddock system and at a stocking rate of 5 Kedah-Kelantan cattle/ha. The mean daily live-weight gains on leucaena–*B. decumbens* and leucaena–native pasture were, respectively, 353 g/head and 305 g/head (Wong et al. 1980). No mimosine toxicity was detected as leucaena formed only about 8% of the total forage available. This level is below that (30%) at which mimosine toxicity symptoms are expressed (NAS 1977).

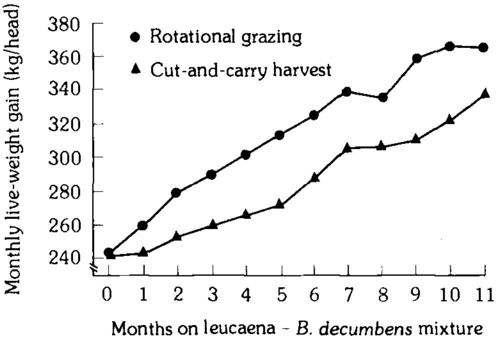

Fig. 3. Cumulative live-weight gains of Sahiwal-Friesian heifers on leucaena –B. decumbens mixture at a stocking rate of 5 beasts/ha under rotational and cut-and-carry management systems.

In another experiment currently in progress, the daily live-weight gain of Sahiwal-Friesian heifers, grazing leucaena–*B. decumbens* rotationally, on a four-paddock system, at a stocking rate of 5 head/ha was 443 g/head. The average dry-matter yield, on a 6-week basis, was 2326 kg/ha, with leucaena accounting for approximately 28% of the forage. However, when the animals were stall fed with forage from a similar pasture, the daily live-weight gain was 368 g/head (Fig. 3).

Rotational grazing, thus, appears to give better performance than feeding livestock in stalls. These live-weight gains were comparable with, if not higher than, those obtained from nitrogen-fertilized, improved pasture (Chen et al. 1982) and from a guinea grass–legume mixture (Eng et al. 1978).