

# *Leucaena leucocephala* (Lam.) de Wit

## A Fodder Legume with a Future

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### INTRODUCTION

*Leucaena leucocephala* is a native of Central America, where it was first recorded in Yucatan, Mexico (Henke *et al.*, 1946). But it has now become pan-tropical especially in moist regions at low altitudes (Whyte *et al.*, 1953). The first reference to *Leucaena* in the agricultural literature was in 1900, when it was reported as a shade and green manure crop for coffee in Java (Dijkman, 1950). Later on, the crop gained recognition as a forage in Hawaii, Tropical Australia and the Philippines. Particularly during the last war, research in Hawaii was expanded to investigate the value of this forage for dairy cattle, following the wartime disruption of concentrates supply (Takahashi and Ripperton, 1949).

Now *Leucaena* is grown extensively as a forage crop in Hawaii and the Philippines and is utilized to a lesser extent as a protein source in Tropical Australia, Central and South America and Caribbean islands. Lately, increase in the number of reports from various parts of tropics and sub-tropics indicates the growing interest on the use of *Leucaena* in pastures. *Leucaena* appears to be superior to other tree legumes when judged by forage yield, crude protein content, palatability, ensiling qualities and ease of handling the crop. Its persistence following repeated harvests, its capacity for high production of palatable forage and its virtual immunity to chlorosis make *Leucaena* outstanding amongst tree legumes (Oakes and Snove, 1962).

### A VERSATILE LEGUME

The multiple use of *Leucaena* for soilage, browse, soil improvement, shade, erosion control, reforestation is another important reason for the growing concern on the crop during recent times.

*Leucaena* is useful as a shade and browse tree, and when planted densely and pruned as a soil cover and green manure crop in tea, coffee and young rubber plantations, and as hedges (Whyte *et al.*, 1953). As a green manure

crop its contribution is tremendous. *Leucaena* can produce upto 120 tons of green manure material per hectare per year (Anon, 1977). The fertilizing value of its leaves has been reported to range as follows.

Table 1—Fertilizing value of *Leucaena* leaves (Yabes, 1977)

Element	Kg nutrient per ton of leaves
Nitrogen	20.9–35.8
Phosphorus	1.5– 3.0
Potassium	13.4–23.7
Calcium	7.3–20.3
Magnesium	3.5– 9.8

As the shoot portion of *Leucaena* is extremely tender and succulent it decomposes within 120 days giving a well rotted compost. The stem to leaf ratio is 1:2.3 and this also enhances its value as a green manure (Narayanan and Sivagnanam, 1962).

*Leucaena* improves the soil in three ways: through nitrogen fixation, addition of humus, and action of deep roots which penetrate compacted soils. In the Philippines it is appreciated as a source of firewood (Mendoza, 1975). Its high density wood makes an excellent firewood and charcoal and the burning was found to be steady and effective (Narayanan and Sivagnanam, 1962). *Leucaena* wood can also be hydrolized to sugar which later can be fermented to alcohol. Some 160 litres can be produced from every ton of dry wood. Further, it can be converted into paper pulp, hard board and polyvinyl plastic film (Anon, 1977).

The foliage of *Leucaena* is very palatable, rich in protein and nutritious. This may be utilised as green chop feed, silage or as drymeal. In the Philippines *Leucaena* meal is a common feed ingredient in swine and poultry rations (Mendoza, 1975). The seeds too, when boiled and crushed, make a very useful cattle feed (Arnold, 1934). *Leucaena* leaves can also be used to produce torula yeast, a 50 per cent protein product fit for both animal and human consumption (Anon, 1977).

#### BOTANY OF THE CROP

*Leucaena*, commonly known as wild tamarind in India and Sri Lanka, is a perennial arborescent shrub which given suitable conditions may reach a height of ten meters. The chromosome number of *Leucaena* has been determined as  $2n=104$  (Tjio, 1949). The species was known as *Leucaena glauca* (L.) Benth. until 1961, when de Wit (1961) in a comprehensive study concluded that the name should be changed to *Leucaena leucocephala*. The botanical name for the species as now accepted being *Leucaena leucocephala* (Lam.) de Wit.

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The plant could be botanically described as follows:

- Leaves:** Bipinnately compound, 15 to 25 cm long; Rachis long, glabrous; Pinnae 4 to 8 & pairs, 5 to 10 cm long; Glands at the insertion of first and last pairs of pinnae; Leaflets small, linear-oblong, acute, inequilateral, 10 to 15 pairs, 7 to 15 mm long and 3 to 4 mm wide.
- Stipules:** Triangular, glabrous, about 0.5 to 3 mm long.
- Flowers:** White flowers massed together in a globular head 2 to 2.5 cm in diameter; solitary, axillary, long pedicelled about 3 to 4 cm in length; Each flower minute, perfectly regular; Sepals 5, valvate and united to form a toothed calyx; Petals 5, valvate; Stamens 10, free Style filiform, stigma small and terminal; Ovary superior, monocarpellary, unilocular with marginal placentation.
- Seed pods:** Thin, flat, acuminate, 12 to 24 cm long, 1.4 to 2 cm wide, usually up to 30 per cluster, 10 to 25 seeds per pod.
- Seeds:** Elliptic, compressed, shiny brown, 3 to 4 mm wide, 6 to 8 mm long and about 2 mm thick; About 26,000 seeds per kg.

However, botanical descriptions of *Leucaena* from different environments are quite inconsistent and it is evident that considerable intraspecific variation exists (Dijkman, 1950).

### VARIETIES

Based on the growth rhythm and branching habit, Gray (1969) classified *Leucaena* into three types.

- Type I Short, bushy, well branched, early flowering and low forage yielding ability.  
Example: 'Hawaii'
- Type II Very tall, erect, sparsely branched and late flowering.  
Example: 'Guatemala' and 'El Salvador'
- Type III Tall, erect, but well branched at the base, late flowering and high forage yielding ability.  
Example: 'Peru'

Cultivar Hawaii is the shrubby type naturalized throughout the Pacific region and Tropical Australia. Fast growing and high yielding varieties of this cultivar, commonly known as 'Hawaiian giants' (K8, K 22, K28 and K67), have been now evolved and are gaining popularity in these countries. Cultivar Peru, which is the most productive of the above three types (Hutton and Bonner, 1960), is also becoming popular, although it is not as vigorous as the K lines (Mendoza, 1975).

## SOIL AND CLIMATIC REQUIREMENTS

*Leucaena* is a relatively temperature-sensitive crop and it rarely grows well at temperatures below 15°C (Anon, 1975). In Sri Lanka (6° to 10°N) *Leucaena* grows freely from sea level upto about 750 m within the 1651 to 2540 mm rainfall zone (Whyte *et al.*, 1953). The growth of the crop in Dimbula and Dickoya at about 1200 m has been reported to be unsatisfactory (Holland, 1931).

In the Philippines (5° to 20° N) for ideal production it is recommended that the crop should not be planted beyond 210 m on the windward slopes and upto 450 m on the drier leeward locations. *Leucaena* has been observed to thrive in places upto 750 m, but is not as productive as at lower elevations (Mendoza, 1975). This may be due to a nodulation problem, as better growth was reported when plants were inoculated (Farinas, 1951). In Indonesia (5° to 10°S) *Leucaena* occurs in wild stands upto 550 m and has been planted upto 1500 m (Dijkman, 1950).

Being deep rooted, *Leucaena* is drought resistant which makes it a desirable high protein forage for the drier areas. Once established, it can withstand several months of drought. Indeed, this is one of its major virtues. According to Sprague (1975) the minimum annual rainfall required by *Leucaena* is only 525 mm. It can survive with a rainfall as low as 230 mm per annum, but foliage production is greatly reduced (Yabes, 1977). It also tolerates salinity and shade (FAO, 1959).

Whyte *et al.*, (1953) report that it requires a well drained soil. Sprague (1975) also records its tolerance to waterlogging as poor. However, in Thailand *Leucaena* thrives well even on the wet paddy field soils, where other types of leguminous fodders will not grow (Semple, 1970). In the Philippines *Leucaena* grows on almost any type of soil (Mendoza 1975). In Indonesia *Leucaena* is non-specific in its soil requirement, but its growth rate depends on soil texture and pH (Dijkman, 1950). One common feature to almost all reports on *Leucaena* is its ability to flourish on soils with alkaline pH and to grow on rocky soils with little top soil (Hill, 1971 a). It thrives well on neutral or near neutral soils, but is sensitive to acidity. Generally pH should not be lower than 5.0. Optimum pH is between 6-7 (FAO, 1959).

## NUTRIENT REQUIREMENTS

A number of fertilizer trials have been done with *Leucaena*, but with relatively little response to lime, phosphates, potash or nitrogen (Kinch and Riperton, 1962). This was the case even in soils having a pH of 5.5, only a trace of available phosphate and only about 100 lb. of available potash per acre. Accordingly, it appears that *Leucaena* is tolerant of low fertility soils, but is much more productive on good soils.

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The preference of the crop for a rather high lime content is now well recognised (Hill, 1971 b.). Esquivel (1965) concluded that the effect of lime was to alter the soil pH and to allow more efficient nodulation. According to Andrew and Hutton (1974), dry matter yields and nodulation were poor at lower levels of pH and Ca. Takahashi and Ripperton (1949) obtained increased yields by applying Ca and P together. Thus application of these elements is recommended for forage production on acid to moderately acid soils with low levels of available Ca and P.

### SEED TREATMENT

*Leucaena*, in common with many legumes, is hard-seeded which makes germination poor and consequently results in an uneven crop stand. Germination percentage recorded for unscarified seed range from 2% (Venkataratnam, 1948) to 5% (Gray, 1969.) Physiological dormancy is not implicated, as all seed will germinate if scarified to remove a small part of the testa. Several workers have studied ways of scarifying *Leucaena* seed in large quantities without damaging the embryo Akamine, 1942; Gray, 1962; Ramdeo, 1971; Chandola *et al.*, 1973). Of the methods tested, scarification with acid and boiling water technique have been reported to be superior.

Akamine (1942) reported that soaking seeds in hot water at 80°C until the temperature cools down to ambient resulted in a germination percentage around 80% with 5 to 9% damaged seeds. A disadvantage was that seeds treated in this way imbibed water and a rapid decline in viability was observed in storage. Gray (1962) stated that satisfactory results could be obtained by immersing seeds in hot water at 80°C for two minutes. This seems to cause minute cracks in the seed coat (Gray, 1969). The seeds treated in this way were stored for 15 months after treatment, without loss of viability. One modification of this method- involves immersing the seeds in boiling water for three seconds (Yabes, 1977).

Acid sacarification is done by the use of concentrated sulphuric acid, 4% by volume, for 10–15 minutes and this will give a germination of around 90-95% (Mendoza, 1975). However, Gray (1962) did not consider this method satisfactory, because of the long washing process required to remove the acid and of the risk of injury during treatment.

### SEED INOCULATION

Unlike many tropical legumes, *Leucaena* is highly selective of the strain of rhizobium needed to produce root nodules (Norris, 1967). In areas where *Leucaena* has not been grown previously it is advisable to inoculate the scarified seeds before planting.

For seedbeds, the inoculants can be watered in after the seeds have germinated. Otherwise, seed pelleting is recommended. Pelleting involves mixing the inoculant with the sticker solution, coating the seeds with the sticker/inoculant solution and then adding a dry coating material, such as powdered lime (Yabes, 1977).

### CULTURAL PRACTICES

The establishment and maintenance of *Leucaena* in the nursery and field have been reported in detail by Mendoza (1975) and Yabes (1977).

*Leucaena* is a slow starter; Therefore weed control must be practiced until the crop forms a ground cover. Several workers have reported significant reductions in yield from weed competition (Hill, 1970; Kinch and Ripperton, 1962). In Indonesia, weed control in newly planted *Leucaena* is achieved by handweeding every 2 to 4 weeks for the first 3 or 6 months (Dijkman, 1950). Little information is available about chemical weed control in *Leucaena*.

*Leucaena* appears to have no serious pests or diseases. The only disease recorded in the literature is a root disease caused by the fungus *Poria hypobrunnea* Petch. (Park, 1931). In Hawaii two insect pests, namely black twig borer and pantropical seed weevil, have been reported to cause damage to *Leucaena*.

The feathery nature of *Leucaena* leaves while providing some shade, also rapidly filters sufficient sunlight (Guzman and Allo, 1975). Thus shade tolerant grasses, such as Guinea grass, may be grown in association with it. The grass should be interplanted 2-3 months after the planting of *Leucaena* to give the slow growing legume sufficient time to get well established (Whyte *et al.*, 1953).

### PRODUCTIVITY OF *LEUCAENA*

Productivity trials on *Leucaena* have been conducted at a number of sites. Oakes and Skov (1962) obtained large variations in the dry matter yields of *Leucaena*, which ranged from 3049 to 20,516 kg per hectare per year depending on the rainfall. In Australia Hutton and Bonner (1960) recorded the following dry matter yields from four harvests over a period of nine months, Peru 12,594 kg per ha, El Salvador 6548, Guatemala 5444 and Hawaii 1505.

Yield trials with *Leucaena* have generally been based on cutting the plant at or near the ground level. Increasing the cutting height lowers the dry matter yields (Table 2).

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**Table 2. Effect of cutting intensity on the yield of *Leucaena* (TAKAHASHI and RIPPERTON, 1949).**

Height of cutting (cm)	Wet matter yield (Kg/ha)
0-5	50,673
38	43,251
76	40,269

The above results indicate that *Leucaena* can be cut near the ground level without any reduction in yield. Takahashi and Ripperton (1949) also studied the effect of cutting frequency on yield (Table 3).

**Table 3. Effect of cutting frequency on yield of *Leucaena*.**

Cuts per year	Dry matter yields (Kg/ha)
3	18,767
4	20,561
6	15,987
Mean	18,438

Accordingly, the optimum frequency of cutting *Leucaena* for maximum yield appears to be about 4 times a year. It is generally recommended that the first cut can be taken 6-9 months after seeding (Whyte *et al.*, 1953) and the following cuts at intervals of 3 months. During optimum growth periods, shorter cutting frequencies may be used (Yabes, 1977).

Very little information is available on the productivity of *Leucaena* under local conditions. Jayawardene (1975) reported that at Gannoruwa, it could be cut every 45 days during the monsoons. From small nursery plots, he estimated the dry matter yields to be over 30,000 kg per ha per year.

## FEEDING VALUE OF *LEUCAENA*

Some published analyses of *Leucaena* are presented in Table 4. The high contents of crude protein and nitrogen-free extractives (NFE) underline the potential of this forage legume as a supplement for the protein-deficient pasture grasses in the tropics.

Table 4—Chemical composition of *Leucaena* (Dry matter %)

			Crude Protein	Ether Extract	Crude Fibre	Ash	NFE
Hay <sup>1</sup>	...	...	25.56	2.16	11.35	9.89	51.04
Green leaf <sup>2</sup>	...	...	21.45	6.54	14.25	8.25	49.48
Young twigs <sup>3</sup>	...	...	27.85	3.16	10.44	3.48	55.06
Old twigs <sup>3</sup>	...	...	23.82	4.71	12.56	6.54	52.35

1 Joachin (1929). 2. Upadhyaya *et al.*, (1974). 3. Whyte *et al.*, (1953).

The following digestibility coefficients have been reported for *Leucaena*: Dry matter 71.36% Crude Protein 78%, Ether Extract 47.52% Crude Fibre 56.72% and NFE 81.8% (Upadhyaya *et al.*, 1974). Another desirable feature of *Leucaena* is its high carotene and/or vitamin A levels, which vary from 275 PPM for the whole *Leucaena* meal to 523 PPM for the leafy fraction (Kinch and Ripperton 1962).

#### MIMOSINE TOXICITY—A PROBLEM

Mimosine,  $\beta$ -N-(3-[hydroxy-4-pyridone])- $\alpha$ -aminopropionic acid, was first isolated from *Leucaena* seeds in 1939 during investigations into loss of hair in young women who had eaten the seed. This amino acid contained in the leaves and seeds of *Leucaena* is generally recognised as the toxic principle which limits the use of *Leucaena* in livestock feeding. A specific method for the estimation of mimosine has been described by Hegarty *et al.*, 1964 b).

Owen (1958) reviewed literature on the toxic effects of *Leucaena* and reported loss of hair in horses. However, hair growth returned to normal once *Leucaena* feeding was withdrawn. Falvey (1976) also reports that effects of *Leucaena* are usually reversible.

By feeding a ration containing 0.5% mimosine, Crouse *et al.*, (1962) were able to inhibit hairgrowth in mice. They suggested that the toxic action of the mimosine on hairgrowth was due to the inhibition of tyrosine-utilising enzymes. Now mimosine has been implicated in hairloss in cattle (Donaldson *et al.*, 1970, Jones *et al.*, 1976; Holmes, 1976), in sheep (Donaldson *et al.*, 1970, Hegarty, *et al.*, 1964 b; Joshi and Upadhyaya, 1976), in goats (Upadhyaya *et al.*, 1974) and in buffaloes (Letts, 1963). Hegarty *et al.*, (1964) estimated that a daily intake of 0.2 to 0.3g mimosine per kg. bodyweight was sufficient to induce depilation in sheep.

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Hylin and Lichten (1965) induced cessation of oestrus and infertility in rats fed on mimosine. Inclusion of 0.5% mimosine was sufficient to cause irregular and atypical oestrous cycles. They postulated that the action may have been due to interference with the production and release of gonadotrophin. Incorporation of mimosine into the diet of pregnant mice caused abortion (Bindon and Lamond, 1966).

Holmes (1976) observed decreased fertility with Brahman cross heifers grazing *Leucaena*. On contrary, none of the Hawaiian workers have reported any adverse effect of *Leucaena* on the reproduction of cattle (Henke and Morita, 1954; Kinch and Ripperton, 1962). Furr, 1965. Hamilton *et al.*, (1971) also found that *Leucaena* has no effect on oestrus cycle length, conception rate or gestation length in cattle. However, in their trial, calves from cows fed on *Leucaena* had significantly lower mean birth weights.

Bindon and Lamond (1966) observed that birth weights of lambs were lower and neonatal deaths higher from the *Leucaena* fed ewes. Also lambs born had enlarged thyroid glands and were devoid of thymus tissues. Enlarged thyroids in cattle grazing *Leucaena* have been recorded by several workers (Jones *et al.*, 1976; Holmes, 1976.) However, Falvey (1976) observed no significant differences in thyroxine estimation in cattle fed *Leucaena*. Other recorded associated effects of mimosine were mild incoordination and nervous signs (Hamilton *et al.*, 1971,) hyper-activity (Falvey, 1976), temporary blindness (Lyman, 1971), excessive salivation (Jones *et al.*, 1976) and calf mortality (Blunt, 1972), all in cattle.

There are no reports of any ill-effect of *Leucaena* on the milk production of cattle. In Hawaii, dairy cows fed *Leucaena* for five years maintained good yields and produced more milk with a high fat content than that obtained from cows which were kept on Napier grass and concentrates (Henke and Morita, 1954). In Australia, feeding *Leucaena* had no effect on mean yield or composition of milk, but the lactation curve was slightly flattened (Hamilton *et al.*, 1971). In India *Leucaena* sustained milk yield, though there was not any significant rise in milk yield (Narayanan and Sivagnanam, 1962). However, an undesirable flavour has been reported in milk from cows fed *Leucaena* (Henke 1933.)

## LEUCAENA LEAFMEAL TO NON-RUMINANTS

Several workers have shown that *Leucaena*, when properly processed to reduce or eliminate mimosine, could be used in swine and poultry rations. Mimosine could be reduced to 0.2% by soaking and washing the leafmeal three times in 24 hours and drying the leafmeal (Castillo *et al.*, 1964). Washed leafmeal could be used upto 20% in layer rations without any adverse effects

(Vohra, *et al.*, 1972). Feeding pullets with 30% *Leucaena* leafmeal almost caused a complete depression in egg production. This was attributed to mimosine, which was believed to inhibit the development of the ovary (Mateo *et al.*, 1970). However, Castillo *et al.*, 1964, observed poor feathering when leafmeal was added higher than 10%. It was suggested that poor feathering may have been due to interference with the sulphur metabolism.

Surprisingly, in view of its adverse effects on reproductive efficiency in other animals, *Leucaena* in layer rations has been found to have a favourable effect on hatchability of eggs (Mullenax, 1963). This is attributed to its high carotene content.

*Leucaena* meal may constitute as much as 15% of the rations of growing and finishing swine (Iwanaga *et al.*, 1957). Recently, Malynicz (1974) reported that *Leucaena* meal could be incorporated upto 40% level in rations for growing swine. In sows, *Leucaena* reduced the reproductive performance (Semple, 1970).

#### OVERCOMING THE PROBLEM OF MIMOSINE TOXICITY

The high yields of *Leycaena* under adverse conditions, its high feeding value and multifarious uses justify research into ways and means of overcoming the problem of mimosine toxicity.

Research is underway in Hawaii to breed *Leucaena* with a low mimosine content. Considerable variation was found in the 72 strains screened with mimosine levels ranging from 2 to 5% indicating the possibility of breeding low mimosine lines (Brewabaker and Hylin, 1966). Although in 1959, Australian workers believed that selection of low mimosine lines will solve the toxicity problem (Hutton and Gray, 1959) by 1968 Hutton was of the opinion that the breeding of mimosine-free lines for cattle was no longer urgent. Since mimosine is destroyed in the rumen, there is little risk with ruminants particularly if the ruminants become accustomed to it gradually and also if *Leucaena* does not constitute a very high proportion of the diet (Gray, 1969). Joshi and Upadhyaya (1976) reported that when fed in combination with *Setaria* grass at a ratio of 60:40; *Leucaena* had no ill-effects on sheep. Thus, with proper feeding management, there seems to be little problem with this valuable legume.

Mimosine is no longer a serious limitation even with nonruminants. It has been shown now that the toxicity of *Leucaena* could be easily reduced by adding ferrous sulphate, equimolar to mimosine, to the rations (Hathcock *et al.*, 1975; Anon, 1977).

THE POTENTIAL OF *LEUCAENA*

*Leucaena* is not a new crop to Sri Lanka. It occurs in wildstands throughout the country. Its potential value as a cattle feed in Sri Lanka has been reported, as early as in 1929, by Joachim. Hirst (1952) reported a large scale trial in the dry zone, where *Leucaena* was used for goat feeding. He stated that as many as 20 goats can be maintained in an acre of *Leucaena* on very poor grade sloping land unsuitable for cultivation.

The local strain of *Leucaena*, which was introduced long ago as a shade tree and soil improver, is low yielding, early maturing and has a comparatively high mimosine content (Jayawardene, 1975). Although *Leucaena*, to a small extent, is being used for cattle and goat feeding in Sri Lankan villages the crop did not gain much recognition as a fodder during the past probably due to the undesirable features of the local strain. Now with the introduction of the fast growing and high yielding varieties, like the Hawaiian giants and Peru, there should be a change in the outlook on *Leucaena*.

In its favour are its ability to grow in poor soils, rapid natural spreading, its high feeding value and high forage yields. Being deep rooted, *Leucaena* could be expected to give sufficient loppings even under conditions of moisture stress which would normally limit grass growth. Notwithstanding its toxic properties, this tree legume should have a definite future in the dry zone areas to supplement the protein-deficient pasture grasses.

Trials have clearly shown that when *Leucaena* is introduced gradually and fed in a mixed diet there is very little problem as far as ruminants are concerned. Further *Leucaena* appears to have no adverse effect either on the reproductive performance or on the milk production in cattle. Thus in the present context, the greatest potential of *Leucaena* is as a fodder legume for cattle. The breeding of strains low in mimosine may later considerably increase the potential value of the legume for other ruminants and non-ruminants. However, little reliable information is available on the productivity, management and utilization of *Leucaena* under local conditions, which might act as an impediment to the extension of this valuable legume in Sri Lanka. Thus it is suggested that the tempo of research in these lines be stepped up in order to exploit the fullest potential of this forage legume.

ABSTRACT

The agronomic, biochemical and toxicological research concerned with the use of *Leucaena* are reviewed. It is stated that when *Leucaena* is introduced gradually and fed in a mixed diet there is little problem as far as ruminants are concerned. Considering its virtues, this fodder legume should have a future in Sri Lanka, especially in the drier parts as a supplement to the protein-deficient grasses. There is however, an urgent need for work involving all aspects of management and utilization of *Leucaena* under Sri Lankan conditions.

## REFERENCES

- AKAMINE, E. K. (1942). Methods of increasing the germination of the Koa haole seed, *Citc.* 21, *Hawaii Agrric. Exp. Stn.* p 14.
- ANON (1975). Pasture legumes and grasses, Bank of New South Wales, Sydney. p 79.
- ANON (1977). *Leucaena*—The wonder tree, *Asian Livestock*, 2 (7), 8.
- ANDREW, C. S.; HUTTON, E. (1974). Effect of pH and calcium on the growth of tropical pasture legumes, *Proc. 12th Int. Grassld Cong.* p 21.
- ARNOLD, H. C. (1934). A promising fodder, *Rhodesia Agric. J.* 31, 593.
- BINDON, B. M.; LAMRND, D. R. (1966). Examination of tropical legumes for deleterous effects on reproduction, *Proc. Aust. Soc. Anim. Prod.*, 6, 109.
- BLUNT, C. G. (1972) Cited by JONES, R. J. The place of legumes in tropical pastures, *Aspac Tech. Bull.* 9.
- BREWBAKER, J. L.; HYLIN, J. W. (1965). Variation in mimosine content in *Leucaena* species and related mimosaceae, *Crop. Sci.*, 5, 348.
- CASTILLO, L. S., AGLIBUT, F. B.; GERAPACIO, A. L.; GLORIA, L. S.; GATAPIA, A. R. (1964). *Leucaena* for poultry and livestock, *Phil. Agric.*, 47, 393.
- CHANDOLA, R. P.; KHAN, M. A. Q.; TYAGI, P. C.; CHATURVEDI, Y. C. (1973). Effect of seed treatment on germination of white pop nac. *Rajasthan J. Agric. Sc.*, 4, 34.
- CROUNSE, R. G.; MAXWELL, J. D.; BLANK, H. (1962). Inhibition of growth of hair by mimosine, *Nature* 194, 694.
- DE WIT, H. C.D. (1961). Typification and correct name of *Leucaena glauca* (L) Banth., *Taxon*, 10, 50.
- DIJKMAN, M. J. (1950). *Leucaena*—A promising soil erosion control plant, *Econ. Bot.*, 4, 337.
- DONALDSON, L. E.; HAMILTON, R. I.; AMBOUTNE, L. J.; LITTLE, D. A. (1970). Assessing *Leucaena leucocephala* for deleterious effects in cattle and sheep. *Proc. 11th Inr. Grassld Cong.*, p780.
- ESQUIVEL, S. C. (1965). Factors affecting legume nodulation in the tropics. *Turrialba*, 15, 252
- FALVEY, L. (1976). The effects of *Leucaena* on cattle in the Northern Territory. *Aust. Vet. J.*, 52, 243.
- FARINAS, E. C. (1951). Ipil-ipil the 'Alfalfa' of the tropics, its establishment, culture and utilization as a fodder crop. *Phil. J. Anim. Ind.*, 12, 252.
- FAO. (1959). Tabulated information on tropical and sub-tropical grain legumes. Rome.
- FURR, R. D. (1965). Pasture performance of grade Hereford cattle compared to crossbred steers on Guinea grass/Koa haole, *Hawaii Fm Sci.*, 14, 4.
- GRAY, S. G. (1962). Hot water seed treatment for *Leucaena glauca*, *Aust. J. exp. Agric. Anim. Husb.*, 2, 178.
- GRAY, S. C. (1969). Breeding *Leucaena leucocephala* for Queensland, *Trop. Grasslds*, 3, 79.
- GUZMAN, M. R. De; ALLO, A. V. (1975). Pasture production under coconut palms, *ASPAC tech. bull.*
- HAMILTON, R. I.; DONALDSON, L. E.; LAMBOURNE, L. J. (1971). *Leucaena* as a feed for dairy cows, *Aust. J. Agric. Res.*, 22, 681.
- HATHCOCK, J. N.; LABADON, M. M.; MATEO, J. F. (1975). Effects of dietary protein level and ferrous sulphate on toxicity of *Leucaena* to chicks, *Nut. Rep. Intern.*, 11, 55-63.

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- HEGARTY, M. P.; COURT, R. D.; SCHNICKEL, P. G. (1964 a). Reaction of sheep to the consumption of *Leucaena glauca* and its toxic principle mimosine *Aust. J. Agric. Res.* 15, 153.
- HEGARTY, M. P.; COURT, R. D.; THORNE, P. M. (1964 b). The determination of mimosine in biological material, *Aust. J. Agric. Res.*, 15, 168.
- HENKE, L. A. (1933). Value of Koa haole as a feed for dairy cattle, Cited by *Nut, Abst.*, 4, 2969.
- HENKE, L. A.; MARUYANA, C.; QUISHBERRY, J. H.; WILLET, E. L. (1964). A reprint concerning animal husbandry, *Rep. Univ. Hawaii*, pp. 36.
- HENKE, L. A.; MORITA, K. (1954). Value of Koa haole as a feed for dairy cows, *Circ.* 44, *Hawaii Agric. Exp. Stn.*, pp 14.
- HILL, G. D. (1970). Studies on the growth of *Leucaena*, I. Effect of weeding and N fertilizers, *Papua New Guin. Agric. J.*, 22, 69.
- HILL, G. D. (1971)a. *Leucaena leucocephala* for pastures in the tropics, *Herb. Abst.*, 41, 111.
- HILL, G. D. (1971 b). Studies on the growth of *Leucaena*, II. Effect of lime, *Papua New Guin. Agric. J.* 22,, 69.
- HIRST, H. (1952). Furthering the supply and consumption of livestock produce in Ceylon, *Trop. Agriculturist*, CVIII, 221.
- HOLLAND, T. H. (1931). Green manuring of Tea, Coffee and Cacao, *A manual of green manuring*, Hohnson and Co., Colombo.
- HOLMES, J. H. G. (1976). Growth of Brahman cross heifers grazing *Leucaena*, *Proc. Aust. Soc. Anim. Prod.*, 11, 453.
- HUTTON, E. M. (1968). Australia's pasture legumes, *J. Aust. Inst. Agric. Sci.*, 34, 203.
- HUTTON, E. M.; BONNER, I. A. (1960). Dry Matter and protein yields in four strains of *Leucaena glauca* Benth., *J. Aust. Inst. Agric. Sci.*, 26, 276.
- HUTTON, E. M.; GRAY, S. G. (1959). Problems in adopting *Leucaena glauca* as a forage for Australian tropics, *Emp. J. Exp. Agric.* 27, 187.
- HYLIN, J. W.; LIGHTON, I. J. (1965). Production of reversible infertility in rats by feeding mimosine, *Biochem. Pharmac.* 14, 1167.
- IWANAGA, I. I., OTAGAKI, K. K.; WAYMAN, O. (1957). Dehydrated Koa haole in rations for growing and finishing swine, *Proc. West Sec. Amer Soc. Anim. Prod.* 1-4.
- JAYAWARDENE, A. B. P. (1975). Research note—Preliminary evaluation of some forage introductions, *Anim. Prod. & Health Bull.*, 9, 101.
- JOACHIM, A. W. R. (1929). Analysis of *Leucaena glauca* hay, *Trop. Agriculturist*, 72, 279.
- JONES, K. J. (1972). The place of legumes in tropical pastures, *ASPAC tech. bull.*: 9, pp 69.
- JONES, R. J.; Blunt, C.G.; HOLMES, J. H. G. (1976). Enlarged thyroid glands in cattle grazing *Leucaena* pasture,, *Trop. Grasslands*, 10, 1113.
- JOSHI, D. C., UPADHYAYA, V. S. (1976). *Leucaena leucocephala*—An evergreen protein-rich tree fodder and the possibility of using it in the dietary of animals, *Indian Vet. J.*, 53, 606.
- KINCH, D. M.; RIPPERTON, J. C. (1962). Hoa haole—Production and Processing, *Bull.* 129, *Hawaii, Agric. Exp. Stn.*, pp. 58.
- LETTS, G. A. (1963). *Leucaena glauca* and ruminants, *Aust. Vet. J.*, 39, 287.
- LYMAN. (1971). Cited by Hamilton *et al*, *Aust. J. Agric. Res.*, 22, 681.
- MALYNICZ, G. (1974). The effect of adding *Leucaena* meal to commercial rations for growing pigs, *Papua New Guin. Agric. J.*, 25, 12.

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- MATEO, J. P.; LABADAN, M. M.; ABILAY, T. T.; AANDY, R. (1970). Study of paired feeding of pullets using high levels of ipil-ipil leaf meal, *Phil. Agric.*, 54, 312.
- MENDOZA, R. C. (1975). Ipil-ipil; its culture and management, *Pasture Newsletter (Phil.)* 3,1.
- MULIENAX, C. H. (1963). Observations on *Leucaena glauca*, *Aust. Vet., J.*, 39, 88.
- NARAYANAN, S. S.; SIVAGNANAM, L. (1962) A leguminous thornless quick growing hedge plant—*Leucaena glauca*, *Madras Agric., J.*, 49, 110.
- NORRIS, D. C. (1967). The intelligent use of inoculants and lime pelleting for tropical legumes, *Trop. Grasslands*, 1. 107.
- OAKES, A. J.; SKOV, O. (1962). Some woody legumes as forage crops for dry tropics, *Trop. Agric. (Trinidad)*, 39, 281.
- OWEN, L. N. (1968). Hair loss and other toxic effects of *Leucaena glauca*, *Vet. Rec.*, 70, 454.
- PARK, M. (1931). Fungus diseases and green manuring, *A manual of green manuring*, Johnson & Co., Colombo.
- RAMDEO, K. D. (1971). Studies on seed coat dormancy in *Leucaena glauca* Benth., *Jap. J. Ecology*, 21, 14.
- SEMPLE, A T. (1970). *Grassland improvement*, Leonard Hill Books, London. pp. 400.
- SPRAGUE, H. B. (1975). The contribution of legumes to continuously productive agricultural systems for the tropics and subtropics, *US AID tech. bull:* 12.
- TAKAHASHI, M.; RIPPERTON, J. C. (1949). Koa haole—its establishment, culture and utilization as a forage crop, *Bull, 100. Hawaii, Agric. Exp. Stn.*, pp 56.
- TJIO, J. H. (1949). The somatic chromosomes of some tropical plants, *Hereditas*, 34, 135.
- UPADHYAYA, V. S.; REKIB, A.; PATHAK, P. S.; (1974). Nutritive value of *Leucaena leucocephala*, *Indian Vet., J.*, 51, 534.
- VENKATARAMAN, L. (1948). Effect of heat and cold treatment on the germination of *Leucaena glauca* Benth., *Madras Agric. J.*, 35, 179.
- VOHRA, P.; HERRICK, R. B.; WILSON, W. I.; SIOPES, T. D. (1972). The use of ipil-ipil in the diets of laying chickens and quails, *Phil, Agric.*, 56, 104.
- WHYTE, R. O.; NILSSON-LEISSNER, G; TRUMBLE, H. C. (1953). Legumes in agriculture, *FAO studies No: 21*, Rome, p. 367.
- YABES, S. I. (1977). Ipil-ipil: The wonder tree. *Phil Council for Agric. and Resources Res.*, Laguna, p. 16.