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Mechanized forage production of *Leucaena leucocephala* and *L. pulverulenta*

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Abstract

Forage production was measured for *Leucaena leucocephala* and *L. pulverulenta* at 2 sites over a 4-year period using a mechanized procedure for transplanting, cultivating, and harvesting. A silage harvester was modified to cut and chop 1-2 m long shoots and stems 50 cm above ground level. There were 3 harvests per year. Yields ranged from about 1.5 t/ha/yr to 9 t/ha/yr and the crude protein ranged from 11.8% to 23.9%. The protein concentration was lower at higher yields. Yields of 3 t/ha were obtained in 90 days when temperatures were about 30 °C and when 175 mm of well distributed rainfall occurred. Protein contents were higher for *L. leucocephala* than *L. pulverulenta* from 1984 to 1987. There was better survival of the rootstocks of *L. pulverulenta* than *L. leucocephala* from −7 and −9 °C freezes during the 1984–85 winter. This work demonstrates that leucaena can be planted, cultivated and harvested with commercially available equipment and that leucaena has sufficient cold tolerance to be useful in the subtropical United States as a source of high protein animal feed.

Resumen

La producción de forraje de Leucaena leucocephala *y* L. pulverulenta *fue medida en dos localidades durante 4 años, mediante el uso de un procedimiento de trasplante, cultivo y cosecha mecánica. Se modificó un cosechador de ensilaje para cortar y picar rebrotes y tallos de 1-2 m de largo a 50 cm de la superficie del suelo. Se realizaron 3 cosechas por año. Los rendimientos anuales tuvieron un rango de 1.5 t/ha a 9.0 t/ha y la proteína cruda tuvo un rango de 11.8% a 23.9%. La concentración de proteína fue baja cuando los rendimientos de forraje fueron altos. Cuando la temperatura fue de alrededor de 30 °C y cuando la precipitación fue de 175 mm bien distribuidos, se obtuvieron rendimientos de 3.0 t/ha en 90 días. El contenido de proteína de* L. leucocephala *fue mayor que el de* L. pulverulenta *durante 1984 a 1987. La sobrevivencia de los troncos de* L. leucocephala *fue mayor que los de* L. pulverulenta *cuando ocurrió la helada de −7 °C y −9 °C durante el invierno de 1984-1985. Este trabajo demuestra que la leucaena puede ser plantada, cultivada y cosechada con un equipo comercialmente disponible. Asimismo indica que la leucaena tiene suficiente tolerancia al frío como para ser útil en la región sub-tropical de EEUU como fuente rica en proteína para la alimentación animal.*

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Introduction

Leucaena leucocephala and other leguminous shrubs have become important in the tropics where they provide fuelwood, green manure and high protein animal feed (Brewbaker and Hutton 1979). Dijkman (1950) recommended that leucaena be examined in the southern United States but to date this has not occurred. A presumption that leucaena lacks tolerance to freezing weather is probably one of the reasons for its lack of acceptance. Leucaena has been widely used in the tropics as "cut and carry" fodder for animals, but this has not been possible in Australia or the United States due to the lack of a suitable mechanized farming system.

Other work has indicated that leucaena had potential as a fodder plant in southern Texas. While it was killed to the ground level by a −5 °C frost, 90% of the rootstocks resprouted following a more severe −12 °C freeze (Glumac *et al.* 1987). Regrowth from freezing is rapid with growth reaching 4 m within 12 months. Also leucaena was resistant to cotton root rot (*Phymatotrichum omnivorum*) (S. Lyda, pers. comm.) which is the primary reason alfalfa cannot be widely grown in southern Texas.

Our preliminary studies confirmed the findings of Guevarra *et al.* (1978) that leucaena production was enhanced when the cutting height was at least 30 cm. Therefore it was necessary to modify the mechanical harvesting techniques developed by Kinch and Ripperton (1962) to allow for a higher cut. We thus investigated a mechanized transplanting and harvesting system designed around a 3-point-hitch mounted silage harvester which could be set to cut at 50 cm. This mechanized system was used to evaluate the protein and dry matter production of two leucaena species.

Materials and methods

Sites

Two experiments, identical in treatments and design, were conducted on Texas A&I University land at Kingsville and 10 km south in Ricardo (27° 32 'N) on Willacy series — fine sandy loam, mixed hypothermic udic Argiustoll soil. The Kingsville site had been under pasture for 20 years and received a basal application of 176 kg/ha liquid ammonium phosphate (10-15-0, NPK) at planting. The Ricardo site had been row cropped for 20 years and was not fertilized. A thoroughly disked, weed-free planting site was used in both trials.

Treatments and design

There were 2 treatments — *Leucaena leucocephala* (1094) and *L. pulverulenta* (1001). These accessions were chosen on the basis of their superior performance at 9 months of age (Glumac *et al.* 1987). The treatments were replicated 4 times in a randomized complete block design.

Each of the 8 plots at Kingsville was 9 m by 15 m, consisting of 6 rows of 10 trees. The plot size at Ricardo was 12 m x 36 m, with 8 rows of 24 trees. Yield determinations were made on the inner 2 rows at Kingsville and the inner 4 rows at Ricardo. The in-row spacing was 1.5 m. The 1.5 m between-row spacing was critical since this is the distance between the centre of the tractor and the centre of the cutting blades on the harvester.

Procedure

The seeds were hand scarified by cutting and inoculated with *Rhizobium* strain NGR 8 from Nitragin Co. (Milwaukee, WI). The seedlings were grown in deep 3.8 cm × 3.8 cm by 38 cm cardboard containers since these yielded a 25% survival advantage over seedlings raised in dibble tubes (Felker *et al.* 1987). The seedlings were grown in a glasshouse from October until planting.

The Kingsville site was cultivated and alachlor and oryzalin incorporated into the soil at rates of 4.5 and 1.3 kg/ha, respectively, 4 days before planting. The seedlings were transplanted on March 19, 1984 at the Kingsville site and on May 10, 1984 on the Ricardo site. A custom built, heavy duty forestry tree planter, with row markers (Felker *et al.* 1984) was used to plant the seedlings and apply the fertilizer. No water was applied to the seedlings. Weed control at both sites was performed after each harvest with a sweep cultivator pulled behind by a tractor. In addition, during the last two years the pre-emergence herbicide norflurazon was applied once a year at 3 kg/ha a.i. This provided excellent control of *Cynodon dactylon, Sorghum halepense, Cyperus esculentus, Solanum elaeagnifolium* and annual forbs and grasses (Felker *et al.* 1986).

The leucaena was harvested at 50 cm above ground level with a John Deere Model 25 forage harvester attached to a John Deere Model 2940, 80 hp tractor. The harvester was powered from the tractor's PTO shaft and attached to the 3 point hitch. This harvester severed the stems at 50 cm height, chopped the stems into 3-4 mm pieces and blew the chopped forage into a receptacle for weight determination. The 50 cm stubble height did not allow enough clearance to pull a trailer behind the forage harvester. Therefore a 2 m × 2 m platform was affixed to the frame of the forage harvester as shown in Figure 1. Generally 3 harvests were made per year in late spring, summer and fall.

Figure 1. John Deere model 25 silage harvester used to harvest *Leucaena*. In this figure the 3 point hitch was in the highest position.

Samples, of about 300 g, of the chopped material were taken for dry matter and N determination. Samples were stored in a cooler before drying at 45 °C and then ground through a 40 mesh screen. Nitrogen was digested with H_2SO_4 and analyzed colorimetrically using salicylate dichloroisocyanurate (Felker 1977). Samples for the July 16, 1984 harvest were analyzed for N and other forage quality parameters (Table 1) using AOAC (1980) procedures.

During the winter of 1984–85 there were 7 freezing periods. The lowest temperatures recorded were −9 °C with 16 hours below freezing, −7 °C with 44 hours below freezing and −4.5 °C freeze with 10 hours below freezing. *L. leucocephala* stems were killed to ground level whereas the *L. pulverulenta* lost only the leaves and smallest twigs. Nearly all of the *L. leucocephala* rootstocks resprouted the following spring, with the exception of the stems that were knocked over during cultivation. No damage was caused by cultivation when stems were alive and flexible, but when the stems were rigid and dead, cultivation damaged underground portions of the plant.

Results

An analysis of variance for both sites over all years indicated that the Kingsville site had greater dry matter production than the Ricardo site ($P = 0.018$), but that the difference in protein percent between sites was not significant ($p = 0.069$). The fertilizer application at planting may have contributed to the higher dry matter production at the Kingsville site.

In the first year, *L. leucocephala* had greater dry matter and protein concentration at both sites (Figures 2 and 3). In the second year, *L. leucocephala* had significantly ($p = 0.03$) greater production than *L. pulverulenta* only at the Kingsville site. No differences ($P > 0.05$) were found between the species in dry matter production in 1986 and 1987 at either of the sites. Once *L. pulverulenta* became well established, its productivity was not significantly different from *L. leucocephala*. No difference ($P > 0.05$) was found between the species in protein concentration during 1986 or 1987 at the Kingsville site or in 1987 at the Ricardo site. There were significant seasonal differences in yield and protein concentration in all years.

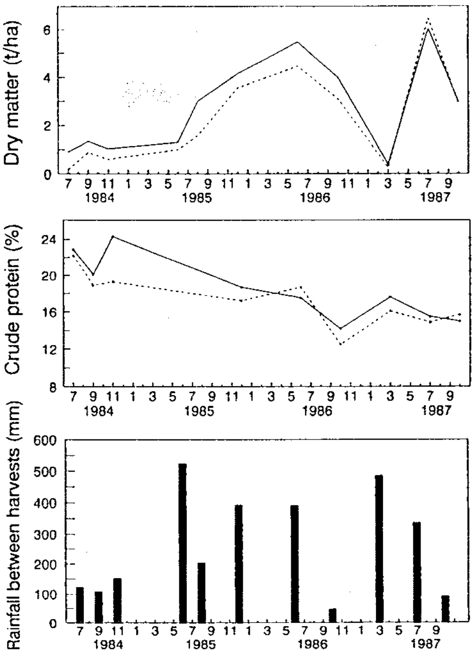

Figure 2. Dry matter production, protein concentration and rainfall between harvests for *L. leucocephala* (1094) (solid line) and *L. pulverulenta* (1001) (dashed line) at the Kingsville site, Texas. The L.S.D. values (P = 0.05) for dry matter production were 0.47, 1.20, 4.29 and 2.39 in 1984, 1985, 1986 and 1987, respectively and for protein concentration were 0.10, 0.68 and 0.37 for 1984, 1986 and 1987, respectively.

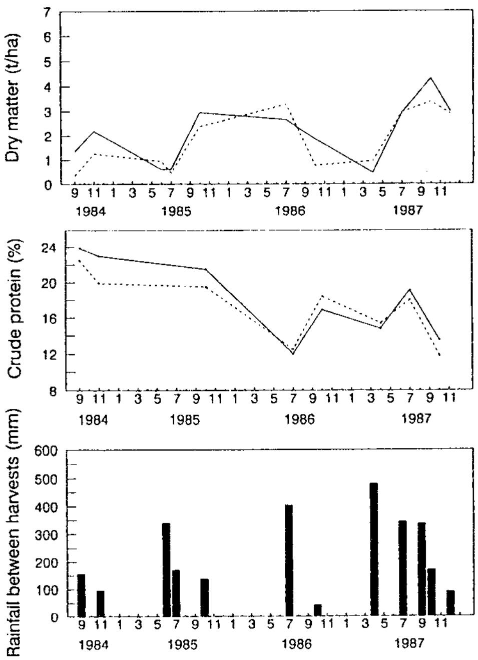

Figure 3. Dry matter production, protein concentration and rainfall between harvests for *L. leucocephala* (1094) (sold line) and *L. pulverulenta* (1001) (dashed line) at Ricardo, Texas. The L.S.D. values (P = 0.05) for dry matter production were 0.78, 0.71, 2.20 and 3.10 for 1984, 1985, 1986 and 1987, respectively and for protein concentration were 0.17, 0.30 and 0.43 for 1984, 1986 and 1987, respectively.

Total annual dry matter production for *L. leucocephala* and *L. pulverulenta* increased from 1984 to 1987 at both the sites (Figures 2 and 3). The annual productivity for *L. leucocephala* for 1984, 1985, 1986 and 1987 was 3.29, 8.46, 9.46 and 9.37 t/ha at Kingsville and 3.53, 4.18, 4.50 and 7.69 t/ha at Ricardo. The annual productivity for *L. pulverulenta* for the same period was 1.65, 6.14, 7.55 and 9.60 t/ha at Kingsville and 1.60, 3.80, 4.04 and 7.25 t/ha at Ricardo.

The protein concentration was highest in the first year at both sites and for both species. The protein concentration was less than 20 percent after the second year's harvest and when the yield was greater than 3 t/ha. The dry matter yield per harvest ranged from about 0.5 t/ha to 6 t/ha. Regressions between dry matter production and percentage crude protein over the 4 year study were negatively correlated for Kingsville ($P = 0.001$) and Ricardo ($P = 0.003$).

One of the best combinations of yield and high protein was obtained from the October 14, 1985 harvest at the Ricardo site. Yield was almost 3 t/ha with a protein concentration of 21 percent. There was slightly less than 3 months between harvests with only 138 mm of rainfall.

Discussion

The low dry matter production during the first year can be attributed to a drought in the first 6 months of 1984 and to the fact that the plants were not fully established. After the first year, *L. pulverulenta* produced more forage at the first harvest after the winter than did *L. leucocephala*. This seems attributable to *L. pulverulenta*'s greater cold hardiness. However in the second and the third harvests of each year *L. leucocephala* produced higher yields than *L. pulverulenta*. The increased forage production with increasing years was not correlated with increasing rainfall. Winter production was obviously more restricted by temperature than by available moisture.

The differences in forage quality between *L. leucocephala* and *L. pulverulenta* are shown in Table 1. *L. leucocephala* and *L. pulverulenta* had similar protein concentration. While *L. pulverulenta* had lower ash and fibre, it had much lower *in vitro* organic matter digestibility and lower energy than *L. leucocephala* (Table 1).

The yields produced by *L. leucocephala* and *L. pulverulenta* in this study are higher than those reported from recent work in Australia but the Texas yields included a higher proportion of stem material. Cooksley *et al.* (1988), examined the forage production of leucaena lines on 6 soil types in a region with about 733 mm rainfall in Australia. After 3 growing seasons the edible dry matter leucaena yield stabilized between 800–900 kg/ha/yr. The leucaena in the Australian trial was not weeded, and may in part explain the lower yield. Felker *et al.* (1986) and Cooksley (1987) have demonstrated a 300 percent increase in growth as a result of weeding leucaena.

Total dry matter yields at the Kingsville and Ricardo sites fall well within the range of total annual forage yields reported for the sub-tropics of 1.5 to 10 t/ha per year (Nitrogen Fixing Tree Association 1985).

The 1.5 m between-row spacing was used to accommodate the forage harvester. In-row canopy closure did not occur until 8–10 weeks after harvest. An in-row spacing of 0.5 to 0.75 m would have been more desirable. The 1.5 m in-row spacing was chosen to reduce the number of seedlings required for transplanting. Even if seedlings cost as little as $0.05 each, $222/ha would be required for seedlings @ 4444 trees/ha. Direct seeding trials are under way to reduce costs of establishment. Since 1 kg of seed containing 15 000 seeds costs about $23, this is much less than the cost of transplanting. If standard equipment for dryland cotton and sorghum with 0.9 m between-row spacing could be combined with in-row spacing of 0.5 m for a population of 22 000 plants/ha, higher production might be possible.

Guevarra *et al.* (1978) examined even higher plant populations (44 000 to 133 000 plants/ha) for forage production and found that the narrowest spacing (0.15 m in-row and 0.5 m between row) gave the greatest forage yield. When used for fuelwood, high plant populations (10 000 to 20 000) were reported to optimize production in the Philippines (Van Den Beldt 1983).

To determine the optimum growth stage for harvesting, the nutritional quality of 7 size fractions of *L. leucocephala* and *L. pulverulenta* were examined by Bassala *et al.* (1991). *L. leucocephala* consistently had higher crude protein than *L. pulverulenta*. New leaves, old leaves and green stem portions (<4 mm diameter) of *L. leucocephala* had 29.4%, 23.9% and 13.0% crude protein, respectively. For *L. pulverulenta* these fractions had 24.8%, 22.5% and 11.5% crude protein, respectively. In our trials the combination of maximum production and best forage yields were obtained when the plants were harvested when they were 1.2 to 1.5 m tall.

Table 1. Feed quality of *Leucaena leucocephala* (1094) and *L. pulverulenta* green chop from the July 16, 1984 harvest

	L. leucocephala Mean + s.e.	*L. pulverulenta* Mean + s.e.	P value
Crude protein (%)	22.9 ± 1.0	22.2 ± 0.5	0.55
Ether extract	4.04 ± 0.3	2.91 ± 0.2	0.02
Crude fibre (%)	18.5 ± 0.4	16.3 ± 0.8	0.05
Ash (%)	9.37 ± 0.2	7.45 ± 0.5	0.01
Organic matter (%)	90.1 ± 0.3	92.6 ± 0.5	0.02
In vitro organic matter (%)	50.2 ± 0.9	31.7 ± 1.4	>0.001
Total digestible nutrients (%)	45.7 ± 0.6	29.3 ± 1.1	>0.001
Digestible energy (kcal/g)	2.01 ± 0.0	1.29 ± 0.05	>0.001
Dry matter (%)	27.8 ± 0.6	31.3 ± 1.1	0.02

P value for significant differences is based on arcsine transformed percentage data using a "T-test" with n = 4.

The percentage of large stems, small stems and leaves in the chopped material was not determined. Using the data of Bassala *et al.* (1991) we estimate that the forage fraction with the lowest protein concentration obtained in this study, that is, 12 percent, had equal amounts of 1.5 to 1.8 cm diameter stems (6% protein), small stems (12% protein) and older leaves (18% protein).

Numerous minor modifications in the silage harvester need to be made before this machine will be acceptable in routine leucaena harvesting operations. Sometimes the spout became clogged so the chopped material could not be blown out. This occurred most frequently when chopping small leafy stems and twigs with high moisture content. Perhaps this could be alleviated by harvesting more slowly, by addition of a blower, or use of a more coarse setting on the chopper.

The forage harvester easily severed and chopped 3 cm diameter stems. However, when the leucaena was not harvested frequently enough, some of the large (6–7 cm diameter) stems caused equipment failure. The pitman arm connecting the severing blades broke once and on two occasions the 90° angle gear box came loose from the frame. Rewelding the gear box to produce a straight line with the PTO shaft at maximum height would avoid this problem.

After four years, the plants gradually developed a sizeable stump but the last harvest was cut at the same level as the first harvest. With the development of a 50 cm wide leucaena hedge it became increasingly difficult to gather the stems into the 15 cm wide opening where the main severing blade was located. A self propelled forage harvester with a 1.5 m to 2 m wide sickle bar cutter would greatly alleviate this problem.

In the United States forage production systems using current leucaena selections will probably be limited to areas in California, Arizona, Texas and Florida that only experience minimum temperatures in the −5 to −10°C range. However leucaena's range could be greatly expanded with crosses that have recently been made at the University of Hawaii that have included *Leucaena retusa* as a source of cold tolerance (J.L. Brewbaker and C. Sorenson, pers. comm.). Recently created hybrids between *L. leucocephala* and *L. pulverulenta* outyielded the *L. leucocephala* cv Cunningham parent by 45% on 5 sites in Australia and also show promise for forage production (Bray *et al.* 1988).

L. leucocephala consistently outyielded *L. pulverulenta* at both sites, although the differences in dry matter production were not significantly different when analyzed for a 4-year period. However, *L. leucocephala* had higher nutritive value for animals than *L. pulverulenta.*

This is the first report of an integrated system for mechanized planting, cultivation and harvesting of leucaena with commercially available one-row equipment. While we consider this only a qualified success, considerable improvements are possible with (1) increased intra-row plant populations, (2) multiple row sickle bar cutters to more effectively harvest hedge type resprouts in old plantings and (3) development of effective direct seeding techniques to reduce the cost and effort of stand establishment.

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