MANAGEMENT OF *Leucaena leucocephala* (Lam.) de Wit FOR MAXIMUM YIELD AND NITROGEN CONTRIBUTION TO INTERCROPPED CORN

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ABSTRACT

The performance of the Hawaiian type (K341) of L. leucocephala (Lam.) de Wit was compared with that of a Salvador type (K8) in field experiments at North Kohala, Hawaii (130 m elevation, Typic Ustropepts). In a second experiment, leucaena (K8) was intercropped with corn (H610) to study their relative yields and the nitrogen contribution of leucaena to intercropped corn.

Spacing, cutting regimes and climatic factors significantly affected the morphological development and yield of both varieties. Growth rate and yields were higher during periods of high solar radiation and night temperature values. The early flowering habits of K341 coupled with more lateral branching resulted in a shrubby type of growth; while the apically dominant K8 assumed a single-shoot type of growth. The flowering of K341 was enhanced at the lower planting densities. The faster rate of growth of K8 contributed to its more rapid increased interception of sunlight than K341 as both approached the cutting stages. At harvest, the light interception was about identical at 96 percent.

The total annual dry matter yields were 17.8 t/ha for K341 and 15.2 t/ha for K8. These yields consisted of 12.0 tons of forage fraction (leaves + succulent stems) for K341 (513 kg N/ha/yr) and 9.9 tons of forage fraction for K8 (429 kg N/ha/yr). The remainder was hard stem. Yields decreased with frequent cutting and wider plant spacing. However, the percent forage fraction was higher under more frequent cutting and wider plant spacing. Therefore, dense planting (15 cm x 50 cm) and cutting at approximately 1 m height at harvest

were desirable management practices considering the forage yield, the percentage forage fraction, and the average cutting frequency (3-month interval).

Nitrogen and mimosine contents of the forage fraction and stem on a dry weight basis were similar in all treatments. Forage fraction contained 4.30 percent nitrogen and 6.6 percent mimosine. The stems contained 1.5% N and 0.92% mimosine. Crude protein in the forage fraction and stem was comprised of about 24 percent and 10 percent mimosine, respectively.

Based on forage fraction, K341 produced nearly 600 kg N/ha/yr while K8 produced about 500 kg N/ha/yr. The differences in the N yields among treatments were due to differences in dry matter yields.

Unlike tillering grasses, leucaena was not able to compensate for the wider spacing by producing more stems. Therefore, optimum density at planting was critical in leucaena for maximum yield production.

Stem diameter was similar for both varieties at harvest (8.2 mm overall average). Delayed cutting and wider plant spacing resulted in larger stem diameters.

Forage production of leucaena was about 1/2 - 2/3 that of alfalfa. Weed control was more of a problem with leucaena than with alfalfa. However, leucaena production involved easier agronomic management than alfalfa because of less frequent harvests, greater harvest flexibility, freedom from disease infestations and longevity of stand.

When leucaena was intercropped with corn, it made excellent growth, with yields on a unit area basis comparable to the monocropping experiment. The amount of leucaena plant material produced and added to the corn increased with delayed cutting, with double rows of leucaena and to a small degree, with decreased corn plant density. Percent nitrogen in the leucaena plant material decreased with delayed cutting because of the increased proportion of stem compared to forage fraction. The amount of leucaena-N applied to each corn crop varied from about 60 to 180 kg/ha.

In the first corn crop, the yields of corn grain and stover were not influenced by the application of either urea or leucaena forage. This was due to residual soil nitrogen from a previous sorghum experiment and to the limited quantities of leucaena added to the soil. The grain yields of corn intercropped with a single row of leucaena cut at seedling (3.40 t/ha) or tasseling (3.56 t/ha) stage were comparable to the grain yields of the check plot (3.45 t/ha).

The nitrogen content of the ear leaf samples of intercropped corn ranged from 2.3 - 2.7% with no differences due to treatments. This was similar to the ear leaf samples from the check plots which ranged from 2.42 - 2.9% nitrogen.

In the second crop of corn, there was a significant response to both urea and leucaena forage application. Yields of corn seedlings, grain and stover in the corn-leucaena intercrop were generally higher than in the check. Corn seedlings yielded from 2.70 - 4.36 g/plant with leucaena-N compared to 1.48 - 1.86 g/plant in the check treatment. The grain yields of corn intercropped with leucaena averaged 2.39 t/ha - 23 percent higher than the check. Grain yields were higher when leucaena was cut at the early stage of corn than at later stages of growth because in the former, the nitrogen could not be effectively utilized by the corn.

Yields of corn grain and stover from corn intercropped with double rows of leucaena were lower than corn from single leucaena row treatments on a field area basis, but double-leucaena-row treatments yielded higher on a corn area basis. Higher grain and stover production were obtained with close corn spacing (15 cm) than wide spacing (30 or 45 cm). The effects of various treatments on the Ncontents of the plant samples were similar to their effects on grain yields.

Nitrogen content of the seedlings, leaf and whole plant samples increased with increasing rates of urea and leucaena forage application. In the urea-N treatments, plant spacing had a limited influence on the N content of the seedlings; a greater influence was observed at the later stage of plant growth. In the corn-leucaena intercrop, the nitrogen content of the corn plant tissue increased consistently under lower planting density. The nitrogen contribution of leucaena forage were estimated on the basis of: (1) the level of N nutrition in the corn plant tissue samples, (2) the weight of corn seedlings, and (3) grain yields. The equivalent urea-N levels in the intercropped corn were as follows: corn plant tissue samples, 9 - 28 kg N/ha; weight of seedlings, 32 - 58 kg N/ha; and grain yield, 0 - 12 kg N/ha. The efficiency of leucaena in supplying nitrogen to corn was about 38 percent of that of urea, based on the grain yield.

Corn spacing accounted for most of the variation in yield in the leucaena treatments (r^2 = 82%), but there was an improvement in the coefficient of determination when leucaena-N data were added to the spacing data (R^2 = 88%).

The total fresh forage production in corn-leucaena intercrop and in corn alone fertilized with 75 kg N/ha from urea was comparable, at

24 t/ha. This yield was twice the fresh forage yield of corn under zero nitrogen plot.

Percent crude protein and crude protein yield of the forage were significantly higher in the corn-leucaena mixed forage compared to corn forage without leucaena. Percent crude protein of the corn-leucaena ranged from 15.9 to 21.98% while under zero nitrogen and 75 kg N/ha treatments, the maximum percent crude protein concentrations were 9.90% and 12.07%, respectively. Crude protein yield in the corn-leucaena treatment was 1.44 t/ha, twice the yield under 75 kg N/ha and three times the yield under zero nitrogen plot.

Leucaena contributed significantly to reducing the nitrogen requirement of the intercropped corn. In addition to nitrogen, leucaena forage undoubtedly contributed other nutrients to corn. Forage nutrient values increased considerably when leucaena was mixed with the corn.

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CHAPTER I. INTRODUCTION

The shortage and ever increasing prices of food commodities have put greater pressure on research organizations to launch research programs aimed at improving the efficiency of farm inputs used for food production. However, increased crop production is limited by several factors including the high cost and short supply of industrial fertilizer, particularly the widely used nitrogen. In animal production, the increase in costs of sea products as sources of protein in animal feed has resulted in increased demand for plant protein.

Legumes hold great potential as sources of high-protein food and feed, and have thus received considerable attention from research organizations. They are also beneficial in various systems of crop and soil management because of their ability to fix significant amounts of nitrogen.

Leucaena leucocephala (Lam.) de Wit is a tropical legume which has spread over a wide range of topography and climatic conditions in the tropics. Large areas of leucaena are cut on a regular basis for fuel. If the non-woody portions are returned to the soil, considerable quantities of nitrogen are added to the system. Utilization of the nitrogen fixed by leucaena by means of multiple cropping or intercropping has a potential value for food crop systems. However, the productivity of leucaena under intensive management is not well defined. Knowledge about its agronomic management can therefore contribute to our understanding of how to exploit this productive legume in food production systems.

CHAPTER II. REVIEW OF LITERATURE

Leucaena leucocephala (Lam.) de Wit: Description, Use and Culture

Botanical and varietal description. Since 1842, *Leucaena leucocephala* (Lam.) de Wit was known as *Leucaena glauca* (L.) Benth. However, in 1961 its name was changed to *Leucaena leucocephala* (Lam.) de Wit (de Wit, 1961 and Everist, 1963). Recently, Gillis and Stearn (1974) stated that the correct name was *Leucaena latisiliqua* (L.) Gillis. However, de Wit (1975) reiterated that the correct name is *Leucaena leucocephala* (Lam.) de Wit, and taxonomists at the Arnold Arboretum at Harvard University agreed that probably de Wit is correct.[1]

Matthews (1914); Lyman, Rotar and Bown (1967); and Oakes and Skov (1967) outlined the agronomic features of leucaena. In 1972, Brewbaker, Plucknett and Gonzalez classified the cultivars of leucaena in the Hawaii collection into general types, the "Hawaiian" type and the "Salvador" type. The Hawaiian type is an aggressive weedy shrub that grows up to 30 feet. It is highly branched and flowers abundantly. The Salvador type is arboreal, growing up to 50 feet tall in 6 years. It has bigger seeds, pods, flowers, leaves, leaflets, trunks and branches than the Hawaiian type. Salvador type tends to flower only once a year, in the spring, whereas Hawaiian type flowers whenever moisture permits (Brewbaker, 1975).

This member of the Mimosaceae family has its origin in Central America and has spread and naturalized widely in the tropics. This

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[1] Personal communication from Dr. Edward E. Terrell, USDA, Beltsville, Maryland, January 9, 1976.

legume is known in different countries by various local names. It is known in the Philippines as ipil-ipil, Santa Elena, agho, datels and comcompitis (Matthews, 1914). In Hawaii, it is called haole koa or koa haole (Henke and Morita, 1954), while in Mauritius it is called acacia. In India, it is known as wild tamarind and koo babool [Narayanan and Sivagnanam, 1962; Deb Roy, Pathak and Patel (unpublished paper)]. Mullenax (1963) reported that in Bahamas Islands, Indonesia and Australia, it is called jumbay, lamtoro and cow bush, respectively. In Fiji, it is known as vaivai (Patridge and Ranacou, 1973). "Leucaena" will be adopted as the common name for Leucaena leucocephala (Lam.) de Wit in the discussion.

Extensive literature review on description, culture and utilization of this legume was published by Oakes (1968). Gray (1968) and Hill (1971a) made research reviews concerning its use as a pasture species. A brief general review on leucaena was also made by Purseglove (1974).

Economic importance. Leucaena has multiple uses. The plant serves as a wind break, as a shade tree for coffee and cacao and for erosion control (Dijkman, 1950). Its hard trunk, which grows to an average basal diameter of 22 cm and twigs make excellent firewood and are good sources of charcoal (Matthews, 1914; Takahashi and Ripperton, 1949; Brown, 1954; Brewbaker, 1975). Matured stems with their hard red core are used for construction and fence posts.

Commercially, mature seeds are made into fancy bracelets, necklaces and draperies. The large flowers of the Salvador type produce large pods and seeds that average 8,000 per pound, versus 12,000 per pound of the Hawaiian type, and might be attractive to seed lei makers (Brewbaker, 1975).

The young shoots, leaves and pods have been used for human and animal food (Takahashi and Ripperton, 1949; Farinas, 1951; Sen, 1956; Anslow, 1957; Hutton and Gray, 1959; Kinch and Ripperton, 1962). In 1972, Brewbaker, Plucknett and Gonzalez reported that leucaena apparently constituted a significant protein supplement to the human diet in several areas of Southeast Asia and Central America.

Moreover, its seeds contain a relatively large amount of galactomannans, a highly viscous gum which can be useful as an effective thickening agent or emulsion stabilizer at low concentration (Morimoto and Unrau, 1962).

Matthews (1914) and Narayanan and Sivagnanam (1962) showed that leucaena can help improve the physical condition and fertility of the soil by plowing the leaves and twigs into the soil.

Leucaena is widely used primarily for pasture (Lyman, Rotar and Bown, 1967). However, it is not very suitable for hay making as the leaves are quickly shed once the stems are cut (Cooksley, 1974). Its value as animal feed is sometimes reduced due to the high level of mimosine (1 to 7 percent) in the leaves. Henke and Morita (1954), Jones (1973a), and Partridge and Ranacou (1974) reported favorable results on feeding leucaena to cows. Hegarty and Court (1972 and 1973) also reported no symptoms of mimosine toxicity to dairy cows fed with leucaena. There was no trace of mimosine in the blood of cows. They suggested that this and other evidence indicated that practically all the mimosine ingested was being degraded to 3,4 dihydroxy pyridine in the rumen. This metabolite of mimosine was detected in most of the biological fluids from these cows. In the Bahamas, ruminants fed almost entirely with leucaena did not show symptoms of ill effects

(Mullenax, 1963). On the other hand, unfavorable biological effects of feeding leucaena to animals were pointed out in many papers. Stobbs and Fraser (1971) observed that Jersey cows grazing on leucaena produced tainted milk. Alopecia, growth inhibition, cataracts, decreased fertility and mortality were shown to occur in animals fed mainly with leucaena (Hegarty, Schinckel and Court, 1964; Joshi, 1968; Labadan, et al., 1969; Wayman, Iwanaga and Hugh, 1970; Hatcock, Labadan and Mateo, 1975). However, Cooksley (1974) showed that ruminants were able to detoxify mimosine far more readily than monogastric animals such as pigs and horses. Furthermore, Cooksley noted that mimosine content in the plant varied throughout the year and the growing young leaves contained the highest levels. The side effects from mimosine can be reduced or eliminated by careful management, and the overall benefits of the plant outweigh its disadvantages. These undesirable effects to animals were attributed to the presence of the biologically active amino acid, mimosine. However, Hathcock and Labadan (1975) contended that in addition to mimosine, leucaena contains one or more toxic substances which account for a significant proportion of its total toxicity to chicken embryo.

Environmental adaptation. Leucaena is tolerant to a wide range of climatic and soil conditions. In Hawaii, it thrives in naturalized stands from sea level up to 300 meters in areas receiving 60 to 160 cm annual rainfall. Planted stands grow up to nearly 1500 meters under 400 cm annual rainfall (Takahashi and Ripperton, 1949). In Indonesia, naturalized stands thrive up to 400 meters (Dijkman, 1950).

Leucaena resists drought and high temperature by entering a dormant stage in which only a few leaves at the apical tip of the plant remain (Kinch and Ripperton, 1962). Undoubtedly, its deep and fast growing taproot and xerophytic leaf movement also contribute to its drought tolerance (Dijkman, 1950; Oakes and Skov, 1967).

Leucaena is the only tropical legume that has shown the ability to survive and produce on the heavy clay soil in the low rainfall section of the Burnett region in Queensland (Cooksley, 1974).

One feature common to all reports on leucaena is its ability to flourish on soils with alkaline pH and to grow on rocky soils with little topsoil. In a list of 23 legumes used in tropical pastures, Hutton (1970) cited leucaena as one of the three legumes that might respond to lime. The other two legumes were white clover and lucerne. Under continuous function design experiments in Hawaii (Fox, 1973), dry matter yields of leucaena were highly correlated ($r = 0.98$) with increased soil pH (pH 5 to 7).[2]

<u>Dormancy and seed germination</u>. Genetic and environmental factors influence the germination of seeds. The microenvironmental factors surrounding the seeds are critical for germination. A genetic factor influencing the dormancy behavior of leucaena seeds is associated with the thick, tough, waxy layered seed coat that is impermeable to water.

Studies on the germination of leucaena seeds conducted in soil flats in the greenhouse showed that maximum germination of seeds under optimum condition may vary from one to four years. The seeds can be kept viable at ordinary storage conditions for as long as 10 years (Akamine, 1952).

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[2] Personal communication from Dr. Robert L. Fox, University of Hawaii, College of Tropical Agriculture, April 6, 1976.

Ninety percent seed germination was obtained by mechanical and sulfuric acid scarification. Soaking the seeds for 10 minutes in water kept at 70°C gave a germination of 70 percent. The untreated seeds gave only about 10 to 15 percent germination (Akamine, 1942). Venkataratnam (1948) obtained similar results with hot water treatment.

Takahashi and Ripperton (1949) recommended acid treatment of seeds. However, Gray (1962) suggested seed immersion in hot water at 80°C for 2 minutes. He found that treated seeds which were dried and stored retained full viability for 15 months.

Seed inoculation with *Rhizobium*. Trinick (1965) found that in Papua-New Guinea, where other legumes grew and nodulated vigorously without inoculation, leucaena responded to inoculation. This suggested that leucaena was very specific in its *Rhizobium* requirement. He obtained nodulation of leucaena only with rhizobia from tropical legumes which were fast growing, acid producing and which had similar cultural characteristics to the leucaena root-nodule bacteria. Galli (1958) and Cooksley (1974) observed the high *Rhizobium* strain specificity of leucaena. Further study by Trinick (1968) showed that *L. leucocephala*, *Mimosa invisa*, *Mimosa pudica*, *Acacia farnesiana* and *Sesbania spp*. have the properties of a cross inoculation group of plants.

In Australia, Norris (1965 and 1973) found that *Rhizobium* strains isolated from leucaena were consistently of a fast-growing, acid producing type. He considered this as an evidence that leucaena was adapted primarily to alkaline soil and suggested the use of lime-pelleting of seed or application of lime on soils. Similarly, Wu (1964) observed increased yields and nitrogen contents of leucaena by liming and inoculation of effective rhizobia.

Weed control. Critical periods of weed control in cultivated leucaena fall into two phases: (1) weed control during the initial seedling growth and (2) weed control in the early regrowth of the ratoon crop. Although studies on weed control have been limited, results indicated that either herbicide or handweeding considerably increased the yield of leucaena (Kinch and Ripperton, 1962; Hill, 1970). In pot trials in which one leucaena seed was sown with 1 to 8 Eleusine indica seeds per pot, dry weight of leucaena was only 18 to 27 percent of the control (Jones, 1970).

Studies on the response of seedlings of pasture species including leucaena to pre-emergence and post emergence herbicide application showed that leucaena is resistant to the toxic effects of a wide range of herbicides (Nicholls, Plucknett and Burrill, 1973). However, Jones (1973b) found that some herbicides, notably karbutilate and atrazine had adverse effects on plant numbers and growth of leucaena.

Factors influencing persistence, yield and quality of forage. Studies by Takahashi and Ripperton (1949) on the period of establishment indicated that neither the persistency nor the overall yield was affected by the length of period of establishment. However, the shorter period of establishment was recommended because of the ease of harvesting of the crop and the better quality of forage obtainable from younger crops.

In addition, Takahashi and Ripperton found that lower cutting levels produced higher yields. There was a progressive decrease in yield as the height of cutting was increased. Best forage yield was usually obtained when the plants were harvested at 120 to 150 cm tall or approximately 4 months old and a few of the more advanced plants were in the full-bloom stage. When cut every two months, leucaena was entirely vegetative. When cut at 3 months interval it was at bud or early bloom stage. At 4 months cutting interval, leucaena was at early podding stage.

Yield of dry matter. Yield trials on leucaena cultivars have been conducted in various countries. In Sanford, Queensland, the mean forage dry matter yield of Peru, El Salvador and Guatemala strains was 2.0 t/ha/harvest with 28 percent protein. The average forage dry matter yield of Hawaiian strain was 374 kg/ha/harvest containing 30 percent protein. It showed that the Salvador strains yielded five times more of forage than the Hawaiian strain. There was no significant difference between strains with respect to proportion of leaf fraction which ranged from 69 to 84 percent by weight (Hutton and Bonner, 1960). Hutton and Bonner concluded that the dry matter and protein production at Sanford was better than that of good crops of irrigated lucerne in Southern Queensland and was comparable with the yield from high quality clover, rye grass pasture in New Zealand.

Studies by Oakes and Skov (1967) in the Virgin Islands showed that dry matter yield of Salvador type was about 50 percent higher than Hawaiian type. The average yield of four strains of Salvador type was 15.8 t/ha/yr of dry matter. The average dry matter yield of four strains of Hawaiian type was 10.6 t/ha/yr.

Under a six-week grazing cycle of leucaena over a nine-month period in New Guinea, Peru strain produced an estimated yield of 12.0 t/ha of dry matter. Yield responded markedly to increased rainfall (Hill, 1971c).

Yield trials of six strains of leucaena in Fiji showed K8, a Salvador type, as the highest yielder, producing 21.5 t/ha/yr of total dry matter when harvested 4 to 5 times a year (Partridge and Ranacou, 1973). The ratio of leaf to fine branches by dry weight was approximately 65:35 with no significant differences between strains.

In Hawaii, Takahashi and Ripperton (1949) conducted experiments on the kinds of planting materials and period of cutting leucaena. Using the naturalized Hawaiian cultivar, the best green whole forage yield was obtained from plantings which were cut at two months interval. The yield was 56.1 t/ha/yr which was equivalent to 14.0 t/ha/yr of dry forage based on an assumed 25 percent moisture.

In recent advanced yield trials in Hawaii, Brewbaker, Plucknett and Gonzalez (1972) showed that Salvador types yielded two and one half times as much forage as the Hawaiian types. Superior varieties of Salvador type were K8, K28 and K67 which gave average dry forage yields of 30.0 t/ha/yr. Hawaiian type produced an average dry forage yield of 12.3 t/ha/yr.

Protein and mimosine contents. Kinch and Ripperton (1962) reported the protein content of leucaena whole forage as 22 percent (3.52% N) and 30.2 percent (4.83% N) for the leafy fraction. Other studies by Anslow (1957); Chou and Rose (1965); Upadhyay, Rekeb and Pathak (1974) showed the protein contents of dehydrated leaves to be 24.56 percent (3.93% N), 23.38 (3.74% N), and 21.45 percent (3.43% N), respectively.

There was a small variation between crude protein levels at different harvesting dates but no seasonal pattern was apparent. Partridge and Ranacou (1973) found 33 percent (5.28% N) crude protein in the leaves and 13 percent (2.08% N) in the fine branches. Studies by Singh and Mudgal (1967) showed that the crude protein content of leucaena varied from 18.90 percent (3.02% N) to 24.57 percent (4.41% N). This variation was considered to be possibly due to climatic or edaphic factors or stage of maturity of the plants at harvest.

Studies were made by Takahashi and Ripperton (1949) on the effects of cutting intervals on the protein content of the leaves, stems and whole forage of leucaena. Cuttings were done at 2, 3, and 4 months intervals. Their results showed that the protein contents of the leaves, stems and whole forage increased considerably as the cutting intervals were shortened. The percentage of protein in the leaves was about 3 times that of the stems.

Oakes and Skov (1967) found 15.4 percent (2.46% N) protein in the dry matter of Salvador strain and 15.7 percent (2.51% N) in Hawaiian strain, a negligible difference.

Leucaena contains the amino acid mimosine, β[-N-(3-hydorxypyridone - 4)]- σ -aminopropionic acid, in the free form. This compound is believed to limit the nutritional usefulness of the plant (Bickel and Wibaut, 1946; Matsumoto, Smith and Sherman, 1951). Lin and Ling (1961) made a detailed study on the chemical and physical properties of mimosine.

Mimosine occurs in highest concentration in the young actively growing leaf. A typical analysis of the Peru cultivar gave the following mimosine contents on a dry weight basis: vegetative apical shoots, 6.8 percent; first leaf, 3.2 percent; fifth leaf, 1.4 percent, and tenth leaf, 0.9 percent (Hegarty and Court, 1972). This finding closely agreed with the conclusion of Takahashi and Ripperton (1949) and Gonzalez (1966). Kinch and Ripperton (1962) obtained mimosine contents of 3.56 percent for dehydrated whole forage, 4.56 percent for leafy fractions and 0.95 percent for stems. In later studies by Brewbaker and Hylin (1965), 72 strains of the genus leucaena showed mimosine concentration which ranged from two to five percent. Brewbaker, Plucknett and Gonzalez (1972) showed that the mimosine content of Salvador type was comparable to that of Hawaiian type. They obtained 4.32 percent for K8 (Salvador type) and 4.42 percent for K65 (Hawaiian type). Their studies indicated that the mimosine content was concentrated in the leafy portion of the plant.

Environmental factors influence the mimosine content of the plant. Cooksley (1974) reported that mimosine content in the plant varies throughout the year.

Studies have been conducted to minimize the undesirable effects of mimosine in leucaena-fed animals. Addition of ferrous sulfate in a mixed ration containing ground leucaena was effective in reducing the toxic effects of mimosine (Wayman, Iwanaga and Hugh, 1970). Heating the forage to $\geqslant 70^{\circ}C$ in the presence of moisture from 24 to 72 hours was also effective in reducing the amount of mimosine in leucaena leaves (Matsumoto, Smith and Sherman, 1951; Ross and Springhall, 1963).

To get a permanent solution to the mimosine problem in leucaena, cytological and biochemical studies in the genus leucaena were initiated in Hawaii in relation to the breeding of low mimosine and high yielding types of _L. leucocephala_ (Lam.) de Wit (Gonzalez, Brewbaker and Hamil, 1967).

An advanced bred line (Guatemala x Peru) developed in Australia has consistently outyielded the commercial Peru cultivar. A back-crossing program is in progress between this high yielding line and selections from another *Leucaena* species, which is low in mimosine (Hutton, 1973).

Status of research work on leucaena. Agronomic research on leucaena has been sporadic. In spite of its wide geographical distribution and widely accepted potential as productive source of nutritive forage, there are very few available references concerning the agronomic management of leucaena.

However, the literature concerning the use of leucaena forage for poultry and livestock feed and biochemical studies on mimosine is extensive.

The use of leucaena forage is mainly for animal feed. There is no available literature concerning extensive use of leucaena as source of nitrogen for the production of food and feed crops. Under the present condition of limited inorganic commercial nitrogen supply in most of the developing countries, the use of leucaena for low-productive-input-agriculture seems promising.

Intercropping Legume and Non-legume Crops

Intercropping as a type of intensive cropping. Intercropping is the growing of two or more crops simultaneously in alternate rows. This basic definition of intercropping is not being followed literally because the arrangement of the crops in the intercropping system depends more on the objectives of intensive cropping. Intercropping is practiced primarily to increase land productivity through efficient utilization of space, soil fertility, soil moisture, solar radiation and other environmental growth factors. Also, intercropping of legumes and grasses is practiced so that grasses can take advantage of nitrogen that can be provided by legume N-fixation. There are also a number of other objectives which may be important bases for intercropping systems, such as distribution of risk, reduced insect damage, etc. depending on the situation.

Observations on intercropping leucaena with pasture grasses. Guinea grass and green panic grass are the two grasses most commonly grown with leucaena. Guinea grass has regrowth characteristics comparable with the regrowth cycle of leucaena (Lyman, Rotar and Bown, 1967). The system of interplanting leucaena and guinea grass in rows is regarded as one of the best combinations for the moderately dry lowland pasture of Hawaii, and has been in use in Hawaii for many years (Takahashi, 1956).

The growth of a pure stand of nadi blue grass (*Dicanthium caricosum*) under grazing in Fiji was compared with the same grass growing between the rows of leucaena. The study revealed that nadi blue grass was thicker in the latter after several periods of grazing. Partridge and Ranacou (1974) concluded that nitrogen supplied by the legumes was one of the reasons for the thicker growth of grass in the leucaena mixture.

General observations on intercropping leguminous and non-leguminous crops. Intercropping a non-legume with a legume crop has been a traditional practice of farmers in sub-tropical and tropical countries.

However, it has often been observed that the yields of both crops are reduced when intercropped, compared with yields when they are grown alone, although the combined yield may be higher than either crop grown separately (Dalal, 1974). Studies of intercropping of castor beans with soybean or groundnuts, corn or sorghum with groundnuts resulted in lower yields of each crop; however, the total yields of the two intercrops were higher than the yield of each crop in single cropping (Evans, 1960; Evans and Sreedharan, 1962). Agboola and Fayemi (1971) observed that the yield of legumes was usually more depressed in mixed cropping than that of non-legumes. Decreases in yields of legumes and non-legumes grown together can be minimized by selecting crops of widely different growth habits. Enyi (1973) reported that intercropping corn with either beans or cowpeas had more adverse effect than pigeon peas on grain yield of corn. He attributed this to the fact that high rates of nutrient absorption by the two legumes coincided with uptake by the corn, whereas in pigeon peas the greatest nutrient demand occurred after the corn was harvested. Similar observations on corn-pigeon peas intercropping were noted by Dalal (1974).

By way of contrast, Kurtz, Appleman and Bray (1946) observed in corn-clover experiment that when no nitrogen was applied, the corn growing in association with the red clover showed advanced symptoms of nitrogen deficiency, bore small ears and gave low yield. Evidently the two crops were competing strongly for limited supplies of water or nutrients during the same time period.

Experiments on interplanting of corn with nine different tropical legumes in the rain forest zone of the western state of Nigeria at Ibadan indicated that *Phaseolus lunatus* and *Mucuna utilis* lowered corn yield. These legumes were fast growing and climbed over the corn plants. Calopogonium mucunoides, Vigna sinensis and Phaseolus aureus had much less effect on corn and were themselves tolerant to corn shade. In this experiment, high yields of corn were maintained during the four growing seasons in both the fertilized control plots and those interplanted with different legumes without fertilizer, whereas the yield of corn in plots with neither legume nor fertilizer was reduced to half of the yield of the first corn crop (Agboola and Fayemi, 1971).

Syarifuddin, Effendy, Ismael and McIntosh (1974) found that in intercropping vegetable legumes with corn, the yield of legumes decreased. However, the high yield of corn compensated for reduction in yields of legumes.

Transfer of legume fixed-N to associated non-legume crops. In Finland, Virtanen and Hausen (1937) conducted extensive experiments that provided proof that leguminous plants were able to excrete nitrogen into the substrate in which they were growing and the nitrogen may be used by non-leguminous plants in association. Similar results were observed by Walker, Orchiston and Adams (1954). They added that under the same growing conditions, legumes appeared to transfer to grasses half of the N fixed in a form readily absorbed by grasses.

Wilson and Wyss (1937) observed on mixed crops of peas and barley under controlled light intensity that 30 to 40 percent of the nitrogen fixed by peas was excreted to the companion crop of barley. On peas and potato combination, 3 to 13 percent of the N fixed by peas was transferred to potatoes. They did not observe N excretion in soybeans under ordinary growing conditions. However, with drastic shading and low temperature, soybean transferred 35 to 60 percent of the N fixed to the companion crop of barley. Some experiments however were not successful in showing that leguminous plants were able to excrete nitrogen into the substrate (Ludwig and Allison, 1937; Nowotnowna, 1937).

Wilson and Wyss (1937) offered the following explanations of the discrepancies among studies of excretion of N fixed by legumes.

(1) If the environment was unfavorable for photosynthesis, fixation of nitrogen by legumes was poor and little or no excretion occurred.

(2) If the environment was highly favorable for photosynthesis, carbohydrate formation in the plants proceeded rapidly, and the nitrogen fixed was readily converted into relatively inert forms, e.g. protein in new tissue.

(3) Under certain environmental conditions, carbohydrate synthesis in the legume was sufficiently high and insured a fairly rapid rate of fixation, but it was not high enough to use all the nitrogen fixed in the formation of new tissues. Under these circumstances N compounds accumulate in the nodules, and if there were intimate contacts with the roots of other species or with highly adsorptive surfaces, part of the excess N was excreted. The net effect of the excretion was to maintain a carbohydrate nitrogen balance in the plant.

Whitney and Kanehiro (1967) observed in the study of the pathways of nitrogen transfer in some tropical forage legume grass association that small quantities of amino acids, ammonia and nitrate were released from legume root systems following severe defoliation. Analyses of solutions in which plucked leaves had been shaken showed that very little N could be leached from intact legume leaves. Whitney (1976, "in press") suggested that the major pathway of N transfer under grazing would probably be through the trampling of legume leaves by grazing animals and subsequent recycling of leaf-N.

Whitney (1970) conducted an experiment on cutting frequency and height on the N economy of D. intortum mixtures with pangola or kikuyu grass. Intensive cutting reduced N fixation rates and cutting interval was more important than height of cut. Significant transfer of N to the grass occurred only under the most lenient cutting regime where about 19 percent of the N fixed was apparently recovered in the grass fraction.

It seems reasonable to conclude that significant transfer of nitrogen from a legume to an associated crop will occur by excretion only when the legume is vigorously photosynthizing, but is restricted in its growth due to cool temperature or other causes. Nitrogen is also lost from legumes when they are severely defoliated. However, most nitrogen transfer is probably due to bacterial decomposition of legume tissue - roots, nodules and aerial parts.

CHAPTER III. GENERAL MATERIALS AND METHODS

Site and Location

The experiments were conducted at the Kohala Feed and Forage Research experimental field of the Hawaii Agricultural Experiment Station at Hawi, Hawaii (Appendix Figure I). In previous years the field had been planted to irrigated sugarcane. The experimental site is located at approximately 20°14'N latitude and 155°52'W longitude at about 130 m elevation. The Hawi soil series is a member of the fine, halloysitic, isohyperthermic family of the Typic Ustropepts (formerly low humic latosols). The soil is a well-drained silty clay, nearly level to moderately sloping (Sato, et al., 1973). Appendix Tables I and II show the general description of the soil profile and the chemical and physical properties of Hawi soil series (Gardiner, 1967).

Climate

Solar radiation, temperature, rainfall and pan evaporation data were obtained from the Kohala Sugar Company main observatory at Hawi, about one kilometer from the experimental plot. Appendix Figure II shows the monthly rainfall and pan evaporation during the conduct of the experiments. Two pronounced rainfall distributions were recorded; dry from April to September and wet from October to March. The average precipitation during the dry period was 5.6 cm/month while pan evaporation was 22.9 cm/month causing a monthly deficit of 17.3 cm (4.3 cm/week). During these six months, the crop was irrigated with about 5 cm of water a week. From October to March, the monthly precipitation of 18.0 cm was about equal to the 18.9 cm of monthly pan evaporation. However, precipitation exceeded pan evaporation in January and February.

The seasonal fluctuations of solar radiation and temperature followed a similar trend (Appendix Figure III). This trend was inversely related to rainfall distribution. The average light intensity during the months of April to October was 554 ly/day. From November to March the light intensity was 435 ly/day.

Average monthly night temperature was computed according to the formula of Went (1957): viz

$$\text{Night T} = \text{Min. T} + \tfrac{1}{4}\,(\text{Max. T} - \text{Min. T})$$

The average night temperature varied from 8.9C to 22.4C, with the lowest temperature observed during the months of January, February and March and the highest in August, September and October.

Cultural Practices

Previous crop and soil fertility treatment. Prior to the leucaena experiment, a sorghum irrigation experiment was conducted in this field in 1973. The experiment was fertilized with (in kg/ha) N-100, P-220, K-220, Mg-55, Cu-11, B-11, Zn-11, and Mn-22, and limed with $CaCO_3$ at 2000 kg/ha.

All sorghum residues were removed from the field. The field was plowed, rotovated and soil samples were taken to plow depth. Soil analyses showed the following: pH 5.5 (water), 39 ppm P (Modified Truog), and exchangeable cations of 180 ppm K, 1240 ppm Ca, and 330 ppm Mg.

Seed treatment of leucaena. Dormancy of the seeds was broken by soaking them in water at 80°C for two minutes, and then air drying them. The seeds were inoculated with "Nitragin" *Rhizobium* inoculant before planting.

Weed control. Weeds were controlled during the establishment and early regrowth periods by applying paraquat herbicide in a directed spray.

Irrigation. Irrigation was done every 1 to 2 weeks with overhead sprinklers which delivered 1.5 cm water/hr. Irrigation was scheduled according to the amount of weekly precipitation (Appendix Figure II) and soil conditions.

Analysis of Plant Tissue Samples

Drying and grinding. Samples of forage and stem fractions of leucaena and plant and leaf samples of corn were dried in a forced-draft oven at 65°C. After the samples were dried, they were ground in a Wiley mill with a 0.4 mm sieve. Ground samples were stored in plastic bags for nitrogen and mimosine analyses.

Nitrogen and mimosine analyses. Total nitrogen in the plant samples was determined by the semi-micro Kjeldahl method (Yoshida, Forno and Cock, 1971). Analysis of mimosine was done following the colorimetric method of Matsumoto and Sherman (1951).

CHAPTER IV. YIELD AND GROWTH CHARACTERISTICS OF LEUCAENA AS INFLUENCED BY VARIETY, INTRA-ROW PLANT SPACING AND CUTTING REGIMES

For intensive production of leucaena, it is important to understand the growth behavior of varietal types, and the optimum plant population that will result in minimum negative intraspecies plant competition and maximum yield production.

This experiment was conducted (1) to compare the growth behavior and yield potential of two distinct varietal types of leucaena and (2) to determine the plant spacing and height of plant at harvest for maximum crop production.

Materials and Methods

The experiment was conducted from March 27, 1974 to August 11, 1975. The same fertilizer treatments used for the sorghum experiment were reapplied prior to establishing the leucaena experiment, except that nitrogen was omitted. Fertilizer was not applied on the regrowth crops of leucaena. A general view of the field experiment is shown in Appendix Figure IV.

Two cultivars of leucaena, K341 and K8 (PI 263695) were used. K341 is a Hawaiian type naturalized in Hawi and designated as "Kohala." K8 is a high yielding Salvador type, originating from Mexico (Brewbaker, Plucknett and Gonzalez, 1972). K8 is also known as "Hawaiian Giant" (Brewbaker, 1975).

Plots were arranged in a factorial split plot design with leucaena cultivars as main plots, cutting regimes as sub plots, and intra-row plant spacing as sub-sub plots. The experiment was replicated four times (Appendix Figure V). Cutting regimes involved harvesting when plants reached average heights of (1) 55 cm, (2) 105 cm, and (3) 155 cm (Appendix Figure VI). Plants were cut at 2.5 - 5.0 cm above the ground surface (Appendix Figure VII).

Intra-row plant spacings were (1) 15 cm, (2) 30 cm, and (3) 45 cm corresponding to populations of about 133,000, 66,000, and 45,000 hills per hectare, respectively. Sub-sub plots consisted of 4 rows, 50 cm apart and 5 m long. Harvest data were obtained from the middle 4 m of the two inner rows.

Inoculated seeds were planted using hand corn planters at the rate of two to three seeds per hill. Growth development was observed. Routine weed control and irrigation were carried out as needed.

When the desired plant height was attained, all plants in the treatment were cut, bundled, and immediately separated into forage and stem fractions (Appendix Figure VIII). The forage fraction consisted of the leaves plus the green, soft portion of the stems, while the stems were mainly the hard-brownish section of the stems. Measurements were also taken during one or more growth periods of: (1) weekly increase in plant height, (2) stem diameter at harvest (>5 mm), (3) number of stems (>5 mm) at harvest, (4) percent light interception, (5) percent flowering at harvest, and (6) nitrogen and mimosine contents.

Plant height was measured from ground level to the tip of the growing bud of four randomly selected plants. Stem diameter was measured in the middle portion of the brown stem. Stems with distinct flower buds were counted. Percent light interception was calculated as the amount of light at ground level inside the plot yield area as a fraction of that measured above the crop canopy. Measurement was done at about ten o'clock in the morning.

Results and Discussion

Seedling establishment and regrowth cycle. The pattern and rate of growth of the plant and regrowth crops were measured (Figure 1). The plant crops of leucaena seemed to have three readily identifiable phases of growth. They were (1) the seedling establishment phase (A), (2) the lag vegetative phase (B), and (3) the active vegetative phase for K8 and/or active vegetative-reproductive phase for K341 (C). The seedling establishment phase lasted for about five weeks after planting. Management of water, weed control and fertilization were particularly critical during the seedling establishment phase. During this period, K341 and K8 both grew at about 0.30 cm/day. The lag vegetative phase covered the next three to four-week period. The rate of growth of K8 became distinctly faster than K341. During this phase K8 produced a few apically dominant stems which rapidly increased in height. K341 increased in height less rapidly, but had a bushier habit (Figure 2). The average rate of growth of K341 and K8 was 0.80 cm/day. The active vegetative phase (for K8) or the active vegetative-reproductive phase (for K341) was the stage of accelerated linear growth. K8 increased in height at the rate of 3 cm/day, twice the rate of K341. The early flowering habits of K341 plus more lateral branching seemed to contribute to its slower rate of increase in height compared to the apically dominant K8. As in Gonzalez's experiments (1966) K8 did not flower during the period of the experiment.

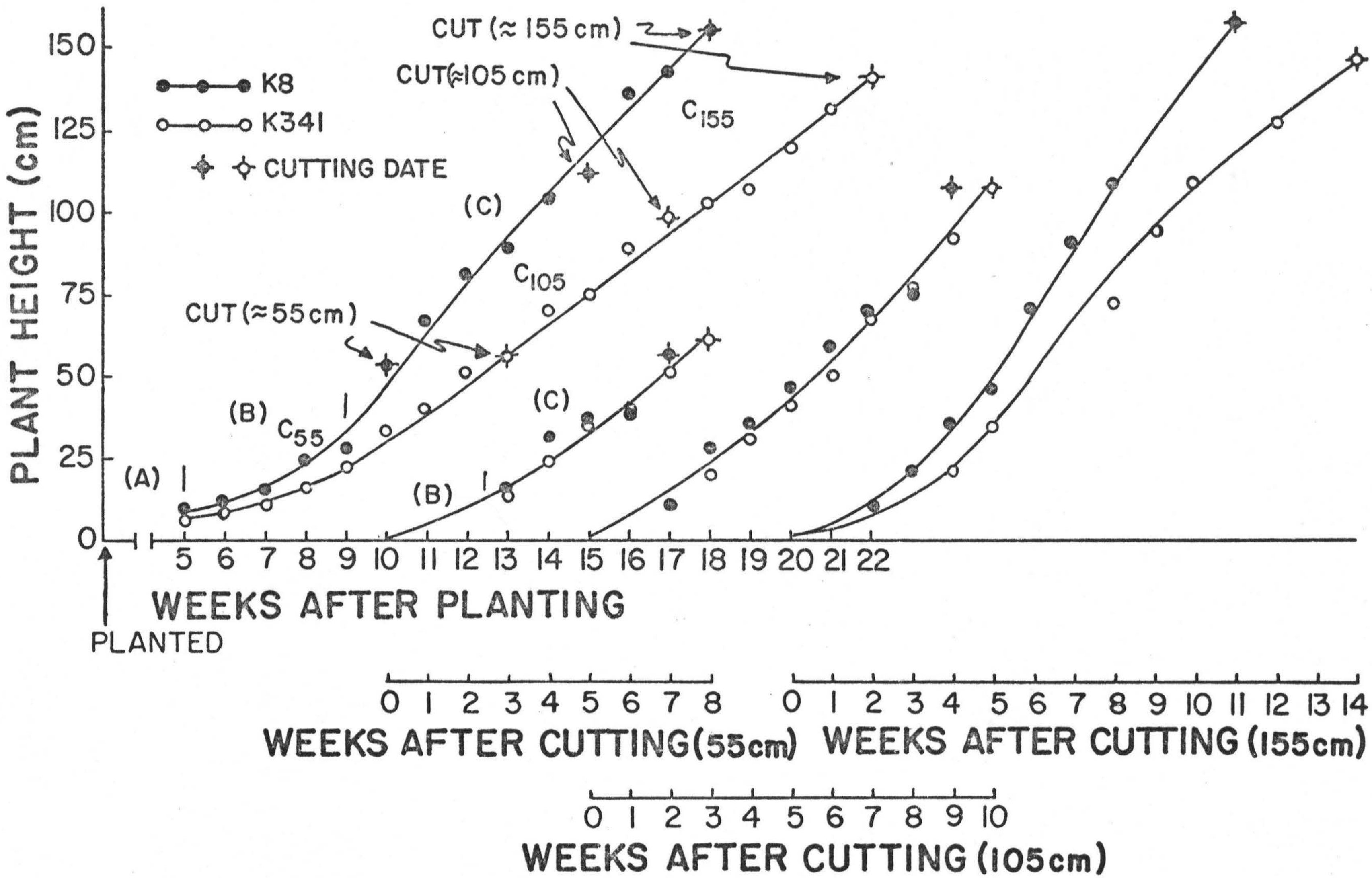

Figure 1. Weekly growth rates of the plant and regrowth of leucaena.

K8

K341

Figure 2. Two-month old K8 and K341; note the more prominent elongating shoots of K8.

The growth pattern of the ratoon crops included a lag vegetative phase and an active vegetative or active vegetative-reproductive phase. When K8 and K341 were cut at 55 or 105 cm, their regrowth patterns were nearly identical, but when they were cut at 155 cm, K341 was slower to recover and resume growth than K8. The difference in the rate of regrowth between the two varieties after cutting at an attained height at 155 cm can possibly be related to their flowering habits. When K341 was allowed to grow to 155 cm height, the plants flowered heavily before cutting. The flowering plants would be expected to translocate more photosynthates and nutrients to the seeds with consequent deprivation of the roots. This would be similar to that described in soybean by deMooy, Pesek and Spaldon (1973). Furthermore, possible reduction in downward flow of photosynthates may restrict N fixation by nodule bacteria and uptake of the major nutrients at the stage when the plant needed appreciable quantities of N, P and K. Thus, when K341 was allowed to flower, the subsequent regrowth from harvested plants was slower, probably due to lower levels of carbohydrates, proteins and nutrients in the basal stems and roots.

Unlike alfalfa, leucaena does not produce vegetative buds at the base of the plant before cutting, and therefore is slow to recover after each cutting.

Rate of increase in height in relation to climatic factors. Crops at plant height of 55 cm, 105 cm, and 155 cm were cut at an average of 76, 100, and 126-day intervals for K341, and 65, 91, and 115-day intervals for K8. In general, K8 attained the desired height about 10 days earlier than K341.

The growth rate of leucaena at 55 cm height at cutting followed the seasonal pattern of solar radiation and night temperature as shown in Figure 3. A faster rate of growth was observed when solar radiation and night temperature were higher. Similarly the rate of growth decreased when solar radiation and night temperature were low. The average rates of growth for K341 and K8 (cut at 55 cm) were 0.73 and 0.87 cm/day, respectively. The growth peak for K341 occurred during September and October at 0.96 cm/day. However, K8 grew at the rate of 1.0 cm/day from May to the middle of November. The correlation coefficient for the relationship between night temperature and growth rate were similar: $r = 0.94$ and $r = 0.86$ for K341 and K8 respectively (Figure 4). The correlation between solar radiation and growth rate was lower for K341 ($r = 0.66$) than K8 ($r = 0.98$). It appeared that the growth rate of K341 was closely related to average night temperature, while the K8 growth rate was more closely related to solar radiation levels. The relationship between solar radiation and night temperature values and growth pattern at the 105 and 155 cm cutting heights were similar to 55 cm height.

Light interception and vegetative development. Light interception measurement were based on the amounts of blue and red sunlight passing through the crop canopies. Figure 5 shows percent light intercepted by the plant crops of K8 and K341 as they approached the cutting stage. Ten weeks after planting, K8 intercepted 35 percent more sunlight than K341. The difference in the amount of light intercepted by the two varieties decreased as plant growth progressed, e.g., 20 percent on the 11th week and 10 percent on the 12th week. Light interception at cutting time was nearly identical, 96.6 percent for

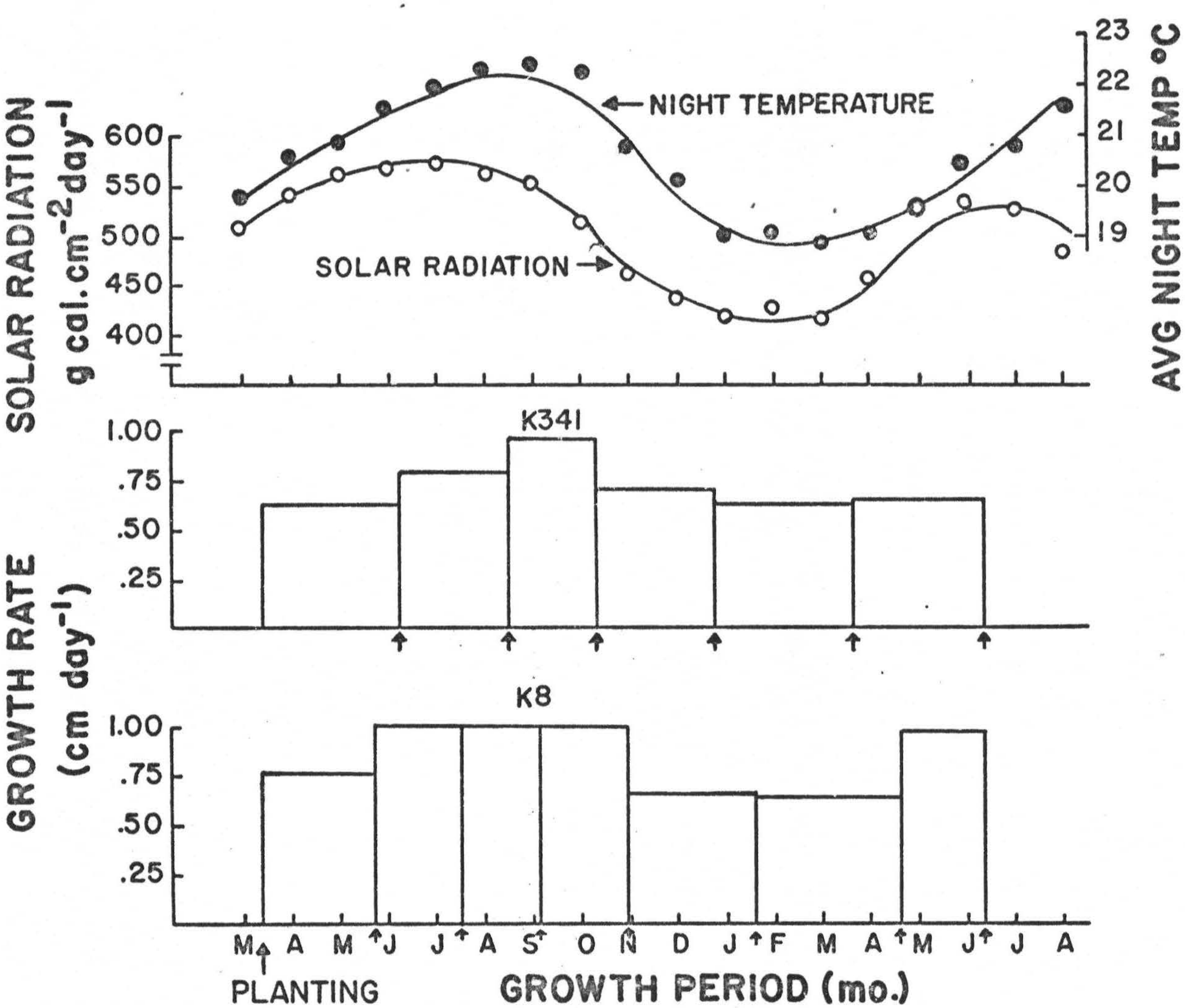

Figure 3. The effects of night temperature and solar radiation on the rate of growth of leucaena at 55 cm height at cutting. Avg of three spacings and four replications; ↑ indicates time of cutting.

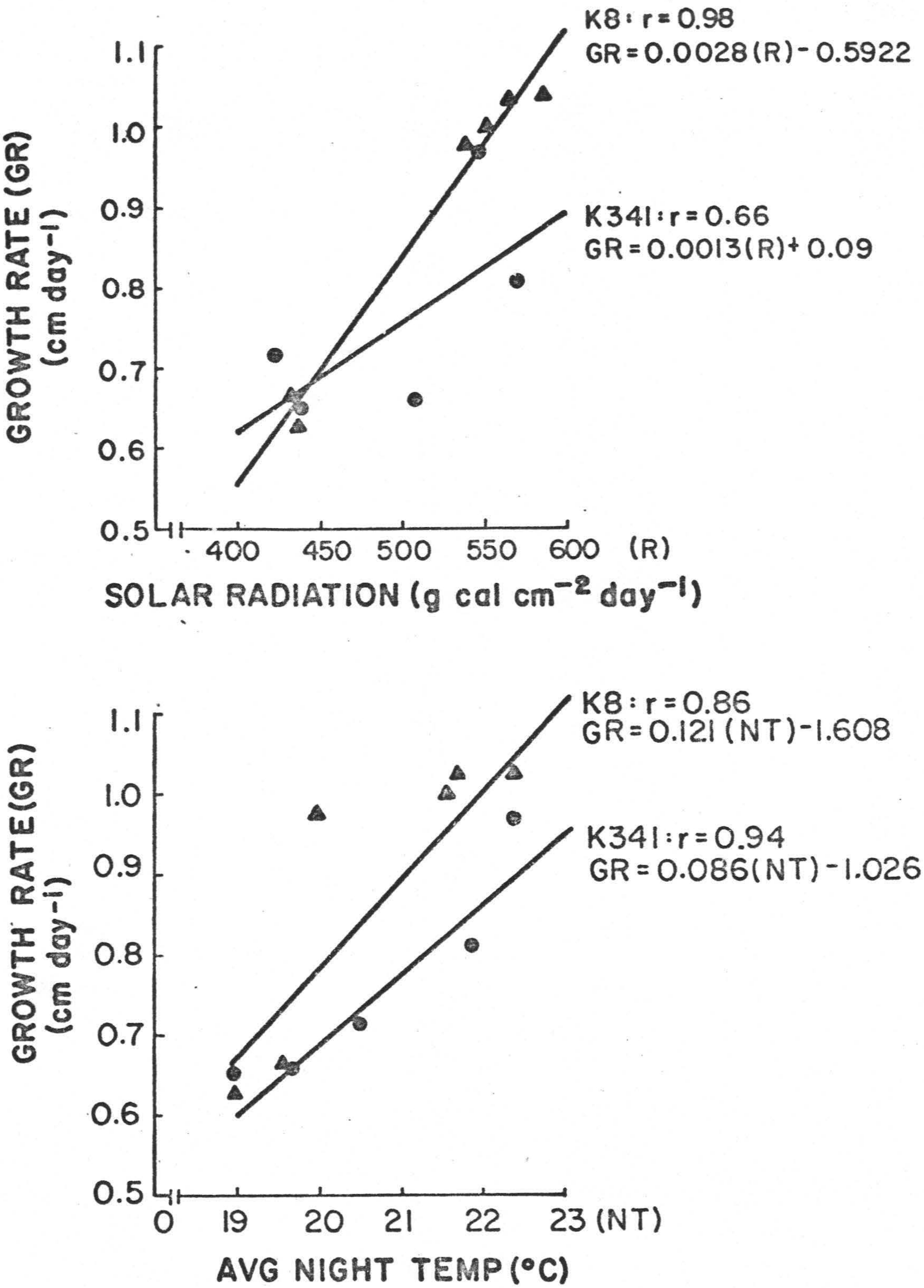

Figure 4. Correlation of growth rate of plant height with the avg night temperature and solar radiation at 55 cm height at cutting (● K341, ▲ K8).

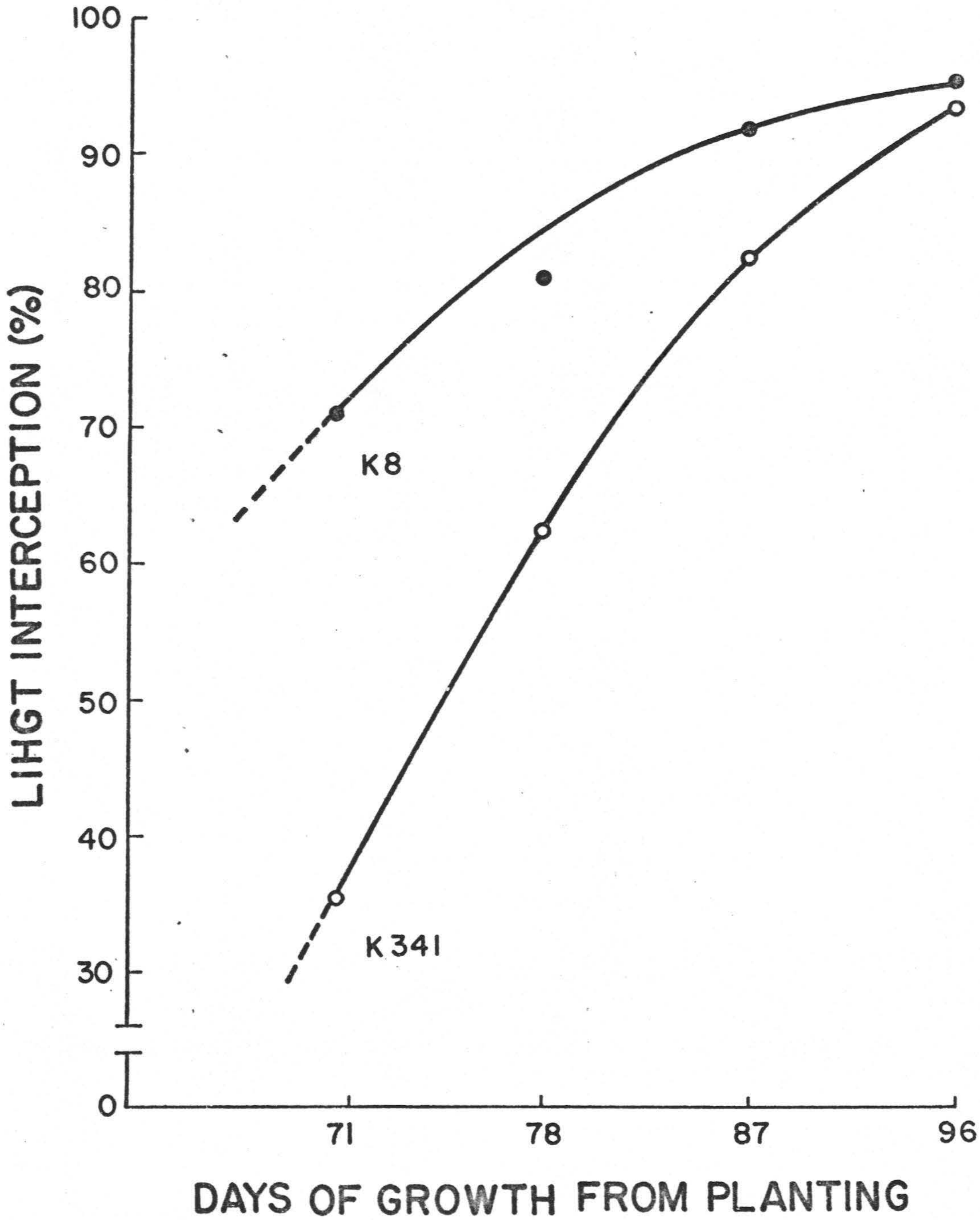

Figure 5. Percent light interception of K8 and K341 canopies during the active vegetative growth phase (June 6 to July 1), crop was planted on 27 March 74.

K341 and 96.3 percent for K8. There were no significant differences in the amount of light intercepted by the various intra-row spacing treatments. During the experiment, the average light interception at harvest for 55, 105, and 155 cm height of cutting was 94.8, 96.4, and 98.2 percent, respectively (Table 5).

Higher light interception of K8 at the vegetative growth stage showed that it has the ability to more rapidly produce photosynthetic surface area than K341. This characteristic of K8 is related to its rapid upright growth. K341 exhibits less dominant upright growth and a tendency to produce more lateral branches (Figure 6). The ability of a cultivar to grow rapidly, both upright and laterally, is an important plant attribute for efficient utilization of sunlight. This allows the plant to effectively compete with weeds and to reduce surface soil evaporation and soil erosion.

Dry matter yields. Plant height was used as a criterion for cutting leucaena. This basis of cutting resulted in differences in harvesting frequency and in the total number of growth periods among height treatments and between the two varieties of leucaena. For more realistic comparisons of yields, data were expressed on the basis of yield per year.

Averaging overall treatments, the total dry matter yields were 17.8 t/ha/yr for K341 and 15.2 t/ha/yr for K8. These yields consisted of 12.0 tons of the forage fraction (FF) and 5.8 tons of the stem fraction (SF) for K341, and 9.9 tons of FF and 5.3 tons of SF for K8 (Table 1).

Figure 6. Comparison of the leaf density on the stems of K8 and K341.

Table 1. The effects of plant height at cutting and intra-row spacing on dry matter yields and percent forage fraction of K341 and K8. Avg of four replications.

Avg height at cutting	Avg cutting interval[+]	Intra-row spacing	Annual DM Yield: Forage fraction	Annual DM Yield: Stem fraction	Annual DM Yield: Total yield	Forage/ total yield
cm	days	cm	t/ha	t/ha	t/ha	%
Variety K341 (Kohala)						
55	76	15	12.2	3.1	15.3	80
		30	10.8	2.9	13.7	80
		45	9.5	2.2	11.7	82
		Mean	10.8	2.7	13.5	81
105	100	15	12.9	6.7	19.6	66
		30	12.3	5.5	17.8	69
		45	12.0	5.1	17.1	70
		Mean	12.4	5.8	18.2	68
155	126	15	13.0	9.2	22.2	59
		30	14.0	10.1	24.1	58
		45	11.5	7.3	18.8	62
		Mean	12.8	8.9	21.7	60
		Variety Mean	12.0	5.8	17.8	70
Variety K8 (Hawaiian Giant)						
55	65	15	9.2	2.9	12.1	76
		30	7.7	2.2	9.9	79
		45	6.8	2.0	8.8	77
		Mean	7.9	2.4	10.3	77
105	91	15	11.5	5.6	17.1	67
		30	10.2	4.8	15.0	68
		45	10.1	4.5	14.6	69
		Mean	10.6	5.0	15.6	68
155	115	15	11.7	9.6	21.3	55
		30	11.3	8.1	19.4	59
		45	10.8	8.1	18.9	58
		Mean	11.3	8.6	19.9	57
		Variety Mean	9.9	5.3	15.2	67

[+]All treatments were harvested over a 455-502 day period (4-7 total cuts)

These findings did not agree with the previous reports that "Salvador types" of leucaena yielded higher than the "Hawaiian types." Apparently, K8 was not well adapted to the intensive management practiced in this experiment since yields were significantly lower than the 30 t/ha/yr reported by Brewbaker, Plucknett and Gonzalez (1972) under different management.

The yield under more frequent cutting was lower than under less frequent cutting. However, total dry matter yields under less frequent cutting contained a lower percentages of forage. The data seemed to indicate that planting at 15 cm apart and cutting when the plants reached about 1 m height resulted in yields nearly as great as when the plants were cut at a later stage. At this stage, stem content was not excessive, but was somewhat higher than in plants cut at 55 cm attained height. However, the increased steminess may be compensated by the benefits derived in cutting less frequently.

The lower DM yields at more frequent cutting than at less frequent cutting seemed to be related to the vegetative phases of growth. More frequent cuttings per year resulted in more periods of the lag vegetative phase, thus the rate of DM yield production per unit time was decreased. According to Whiteman and Lulham (1970), a severe check in growth such as close cutting resulted in mobilization of sugars and amino acids from the roots to support the development of new leaves. As a result, root growth and N fixation are reduced, further limiting the growth of legumes under frequent cutting.

Yields of both varieties were also significantly reduced as planting density was reduced by increasing intra-row plant spacing

(Figure 7 and Table 2).

Most of the increase in the total yield of dry matter under infrequent cutting was comprised of the stem fraction. As height at cutting was increased from 55 to 155 cm, the annual yield of forage fraction increased by 28 percent; however, the annual yield of stem fraction increased by 240 percent. This was apparently due at least in part to shading of lower leaves by the taller plants, resulting in considerable leaf shedding from the lower portions of the plants. This is also shown in the percentage of forage fraction in leucaena cut at different attained heights; 79, 68, and 59% for 55, 105, and 155 cm height, respectively (Table 2).

Under certain agricultural management, less frequent harvest may be advantageous in terms of saving expenses in harvesting and processing operations. For forage production, a variety of leucaena that will produce high total dry matter yields with low percentage of stem even under infrequent cutting will be desirable.

As plant spacing increased, yields of both forage and stem fractions decreased. However, percent forage fraction increased as spacing increased, apparently due to improved light transmission to the lower portion of the plants resulting in minimum leaf shedding especially under less frequent cutting.

<u>Percentage nitrogen and nitrogen yield of dry matter</u>. The nitrogen content of forage fraction averaged 4.27% for K341 and 4.31% for K8. Nitrogen content of the stems averaged 1.52% and 1.43%, respectively. Overall nitrogen percentages were not influenced by variety, plant spacing or cutting interval except that stems declined in N content

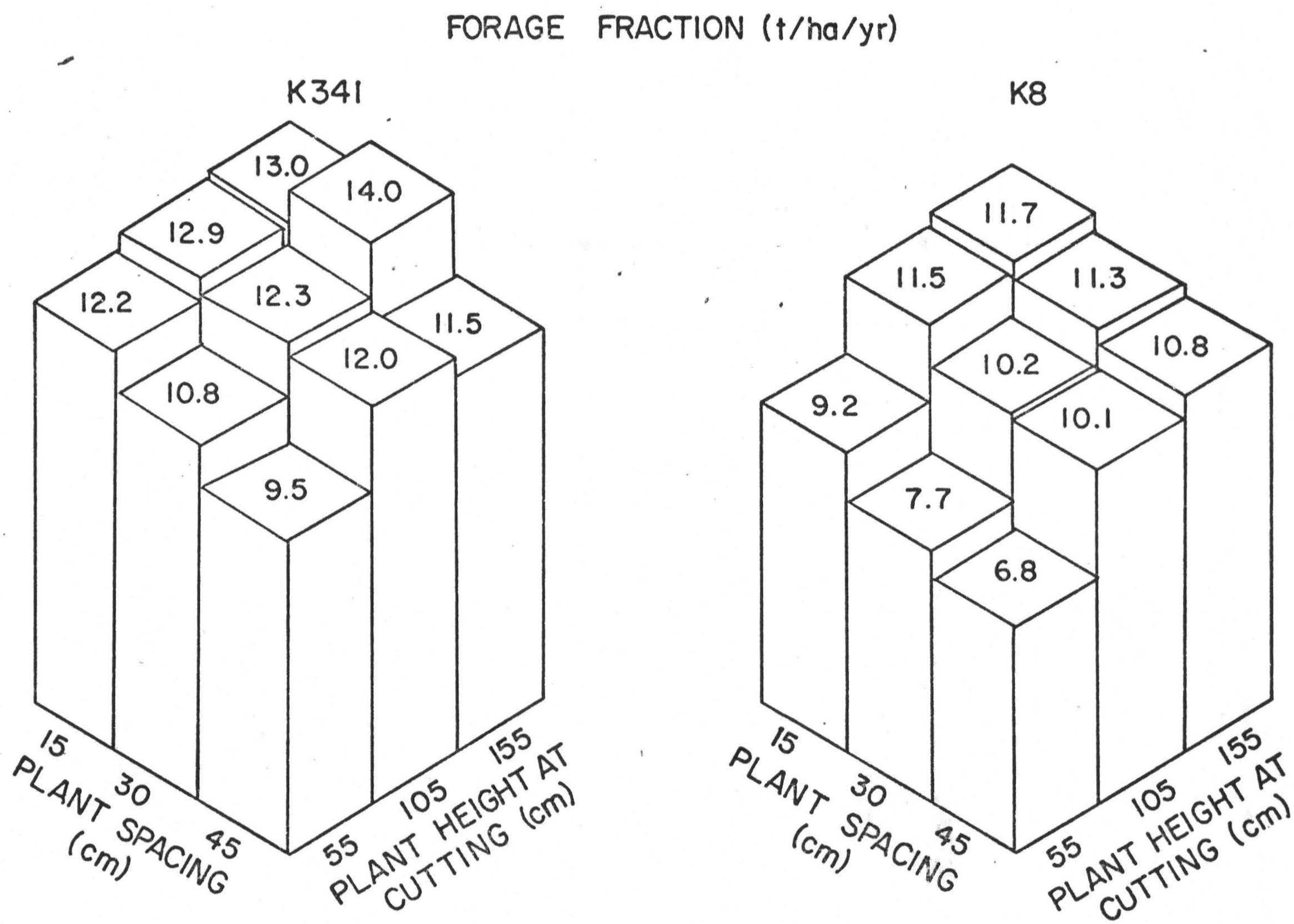

Figure 7. The effects of plant height at cutting and intra-row spacing on dry matter yields per year of forage fraction of K341 and K8. Avg of four replications.

Table 2. Analysis of treatment effects of variety, height at cutting, and plant density on production of dry matter and nitrogen content of leucaena under intensive management

Treatment variables	Annual DM yield		Percent forage	Percent nitrogen		Annual nitrogen yield	
	Forage fraction	Stem fraction	fraction	Forage fraction	Stem fraction	Forage fraction	Stem fraction
	t/ha		%			kg/ha	
Variety							
K341	12.0 a	5.8 a	70 a	4.27 a	1.52 a	513 a	84 a
K8	9.9 b	5.3 b	67 b	4.31 a	1.43 a	429 b	72 a
Height at cutting							
55 cm	9.35 c	2.55 c	79 a	4.39 a	1.62 a	410 c	40 c
105 cm	11.50 b	5.40 b	68 b	4.18 a	1.48 a	482 b	79 b
155 cm	12.05 a	8.75 a	59 c	4.30 a	1.32 a	521 a	115 a
Intra-row spacing							
15 cm	11.75 a	6.18 a	67 c	4.32 a	1.49 a	507 a	88 a
30 cm	11.05 b	5.60 b	69 b	4.24 a	1.49 a	467 b	79 b
45 cm	10.12 c	4.87 c	70 a	4.30 a	1.45 a	439 c	67 c

Means in the same column of pair or triplet followed by the same letter are not significantly different at the 5% level (Bayes LSD).

as harvesting interval increased (Tables 2 and 3).

The fact that the percentage of nitrogen in the forage fraction remained constant under a wide range of harvesting periods could be very advantageous since it would allow flexibility in harvesting without sacrificing the nutrient value of the forage.

On the average, K341 produced nearly 600 kg N/ha/yr while K8 produced about 500 kg N/ha/yr based on the forage fraction (Tables 2 and 3). In the best treatments, the total nitrogen yields (stem + forage) were 715 kg N/ha for K341 and 625 kg N/ha for K8. The forage fraction averaged about 85 percent of the total nitrogen yields in both varieties. In general, as in the case of Dm yields, N yield per year increased with height at cutting and decreased with increasing width of intra-row spacing.

The differences noted in N yields among treatments were primarily due to differences in dry matter yields.

Plant characters at harvest. Characters of K8 and K341 as influenced by various management variables are presented in Tables 4 and 5. The number of stems counted per hectare was not significantly affected by variety or height at cutting. However, in general, the number of stems per hectare was positively correlated with plant spacing. It can be seen that unlike most tillering plants, leucaena was not able to compensate for wide spacing by producing more stems. As a result, the selection of the optimum spacing or planting density is very important in maximizing dry matter yield and percent forage fraction.

Furthermore, with increase in attained height at cutting, stem diameter increased significantly. The average stem diameters for

Table 3. The effects of plant height at cutting and intra-row spacing on the percent nitrogen and nitrogen yield of K341 and K8. Avg of four replications.

Avg height at cutting	Avg cutting interval	Intra-row spacing	Percent nitrogen: Forage fraction	Percent nitrogen: Stem fraction	Annual N Yield: Forage fraction	Annual N Yield: Stem fraction
cm	days	cm	%		kg/ha	
Variety K341 (Kohala)						
55	76	15	4.52	1.63	547	49
		30	4.46	1.63	485	46
		45	4.40	1.59	417	34
		Mean	4.46	1.62	483	43
105	100	15	4.13	1.54	532	102
		30	3.97	1.60	488	89
		45	4.17	1.50	498	76
		Mean	4.09	1.55	506	89
155	126	15	4.37	1.45	563	131
		30	4.20	1.37	581	134
		45	4.19	1.36	509	96
		Mean	4.25	1.39	551	120
	Variety Mean		4.27	1.52	513	84
Variety K8 (Hawaiian Giant)						
55	65	15	4.26	1.60	388	46
		30	4.31	1.61	329	36
		45	4.34	1.63	392	33
		Mean	4.31	1.61	336	38
105	91	15	4.35	1.45	507	76
		30	4.26	1.42	439	66
		45	4.21	1.36	430	62
		Mean	4.27	1.41	459	68
155	115	15	4.30	1.27	505	121
		30	4.26	1.28	481	105
		45	4.52	1.25	488	102
		Mean	4.36	1.26	491	110
	Variety Mean		4.31	1.43	429	72

Table 4. The effects of plant height at cutting and intra-row spacing on stem count, stem diameter, flowering and light interception of K341 and K8. Avg of four replications.

Avg height at cutting	Avg cutting interval	Intra-row spacing	Stem count per ha	Stem diameter	Flowering stems	Light interception
cm	days	cm	thousand/ha	mm	%	%
Variety K341 (Kohala)						
55	76	15	362	6.3	6	97.2
		30	258	7.1	19	94.1
		45	193	7.4	39	94.1
		Mean	271	6.9	21	95.1
105	100	15	355	7.5	16	96.4
		30	234	8.6	42	96.8
		45	180	9.7	48	96.6
		Mean	256	8.6	35	96.6
155	126	15	390	8.2	4	98.7
		30	278	9.4	15	98.4
		45	167	11.4	41	96.9
		Mean	278	9.7	20	98.0
	Variety Mean		268	8.4	25	96.6
Variety K8 (Hawaiian Giant)						
55	65	15	338	5.4	0	93.5
		30	247	5.9	0	94.9
		45	194	6.4	0	94.7
		Mean	260	5.9		94.4
105	91	15	314	7.4	0	97.4
		30	206	8.1	0	96.2
		45	183	8.9	0	94.8
		Mean	234	8.1		96.1
155	115	15	305	9.2	0	99.0
		30	198	9.8	0	98.8
		45	147	10.9	0	97.6
		Mean	217	10.0		98.5
	Variety Mean		237	8.0		96.3

Table 5. Analysis of treatment effects of variety, height at cutting, and plant density on the characteristics of leucaena at harvest when grown under intensive management.

Treatment variables	Stem count	Stem diameter	Light interception	Percent mimosine	
				Forage fraction	Stem fraction
	thousand/ha	mm	%		
Variety					
K341	268 a	8.4 a	96.6 a	6.39 a	0.85 a
K8	237 a	8.0 a	96.3 a	6.93 a	0.99 a
Height at cutting					
55 cm	266 a	6.4 c	94.8 a	6.46 a	0.98 a
105 cm	245 a	8.4 b	96.4 a	6.92 a	0.93 a
155 cm	247 a	9.9 a	98.2 a	6.60 a	0.85 a
Intra-row spacing					
15 cm	344 a	7.3 c	97.0 a	6.75 a	0.97 a
30 cm	237 b	8.2 b	96.5 a	6.47 a	0.93 a
45 cm	177 c	9.1 a	95.8 a	6.76 a	0.85 a

Means in the same column of pair or triplet followed by the same letter are not significantly different at the 5% level (Bayes LSD).

55, 105, and 155 cm height at cutting were 6.4, 8.4, and 9.9 mm, respectively. Similarly, wider plant spacing resulted in bigger stem diameter. Stem diameters at 15, 30, and 45 cm intra-row spacings were 7.3, 8.2, and 9.1 mm, respectively. There was no difference in stem diameter between varieties (average stem diameter = 8.2 mm).

K341 flowered earlier while K8 tended to remain vegetative. Under the system of intensive management, K8 did not produce flowers. Flowering of K341 was greatly influenced by plant spacing, with the most flowering occurring at the wider spacings.

There was no significant difference between the mimosine levels in the forage or stem fractions of K341 and K8. Height at cutting and intra-row spacing also appeared to have no influence on percent mimosine. Mimosine in the forage fraction was approximately seven times the level found in the stems. On the average, the crude protein (% N x 6.25) in the forage fraction consisted of about 24% mimosine whereas stem crude protein was comprised of only 10% mimosine.

Correlations among the parameters observed (Table 6). The yields of forage fraction (both dry matter and nitrogen) increased proportionally with increased yield of stem fraction (r = 0.71). As pointed out earlier, N yields were a function of DM yields (r = 0.96). There was no relationship between nitrogen contents of the forage fraction and stem. As expected, percentage forage fraction was negatively correlated with stem yield (r = 0.95) and stem diameter (r = 0.72).

Stem counts were not related to stem yields, but there was a negative relationship between the stem count and stem diameter (r = -0.46).

Table 6. Correlation matrix among parameters observed in K341 and K8.

	Variables								
	Forage fraction					Stem fraction			
Variables	1	2	3	4	5	6	7	9	10
Forage fraction									
1. Annual yield									
2. % forage fraction	-.54**								
3. % nitrogen	-.03	-.08							
4. % mimosine	-.17	-.11	.48**						
5. Annual N yield	.96**	-.51**	.20	--					
Stem fraction									
6. Annual yield	.71**	-.95**	-.04	--	.68**				
7. % nitrogen	.04	.21	-.01	.47**	.04	-.17			
8. % mimosine	.13	.12	-.14	.21	--	--	.47**		
9. Annual N yield	.76**	-.92**	-.09	--	.72**	.98**	-.11		
10. Stem diameter	.46**	-.72**	-.10	--	.46**	.68**	-.16	.65**	
11. Stem count	.38	--	-.04	--	.35**	.14	-.10	.20	-.46**

**Significant at 1% level of probability

Nitrogen and mimosine levels in the forage fraction were poorly correlated with levels of these constituents in the associated stems, but levels of nitrogen and mimosine were slightly correlated with each other (r = 0.47). Similarly, Gonzalez (1966) observed significant relationship between nitrogen and mimosine levels in the total dry matter (r = 0.89).

The lack of any relationship between mimosine contents and the yields of both the forage fraction and stems agreed with the findings and conclusion of Gonzalez (1966).

Seasonal effects on DM yield, growth duration and percent forage fraction. High yields of forage fraction were obtained during the period of high solar radiation and high night temperature (Figure 8). Variety K341 cut at 55 cm height yielded 40 kg/ha/day of forage fraction during July to October when solar radiation and night temperature were high (average night temperature of 22.2 C and average solar radiation of 550 ly/day). However, the average DM yield of forage fraction under the same cutting height was 27 kg/ha/day during November to June when the average night temperature was 19.6 C and average solar radiation was 461 ly/day. The trend was the same with other cutting regimes for both K8 and K341.

The regrowth periods were longer during the months of lower solar radiation and night temperature values, especially under less frequent cutting. For example, the regrowth of K8 required only 85 days to reach 155 cm height during August to October but needed 153 days to reach 155 cm height during October to March.

The correlation values between solar radiation and yields of

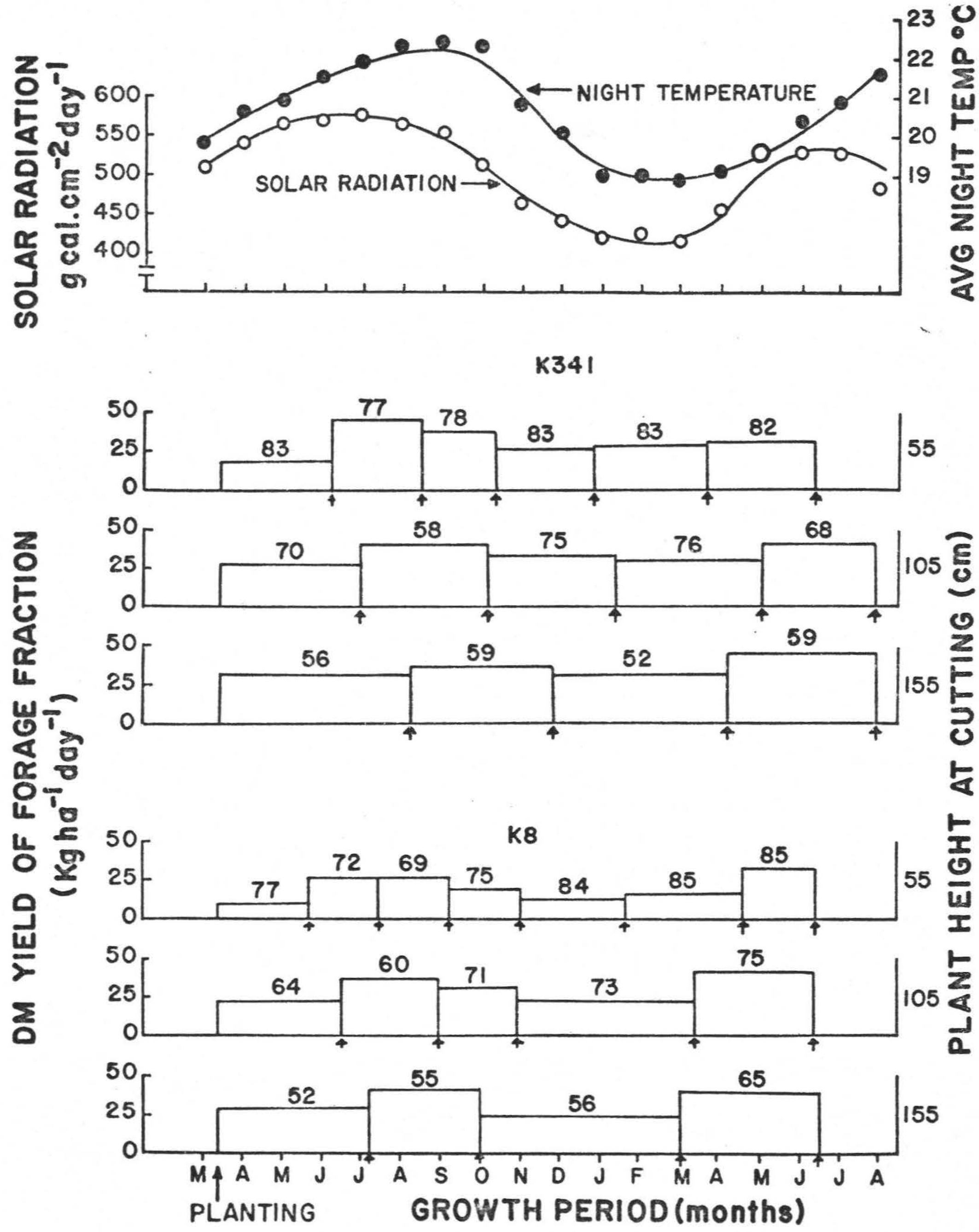

Figure 8. Relationship of dry matter yields of forage fraction with average solar radiation and night temperature. Values on the bars are percent forage fraction (avg of three intra-row spacings) K341: Upper three graphs, K8: Lower three graphs; ↑ indicates time of cutting.

forage fraction of K8 and K341 exceeded r = 0.90 (Figure 9). The correlation values between night temperatures and yields of forage fraction were lower with r = 0.68 (K8) and r = 0.81 (K341). This information seemed to show that yield of forage fraction is more closely related to solar radiation levels than to night temperatures. However, night temperature was reasonably well correlated with K341 forage fraction yields (r = 0.81).

Solar radiation and night temperature values appeared to have insignificant influences on the percentage of forage fraction. Levels of solar radiation and temperature also appeared to have no consistent effect on the percentage of nitrogen in the forage fraction (Figure 10). Nitrogen yields thus primarily reflected the DM yields shown in Figure 8.

Comparative performance of leucaena and alfalfa. Dry matter yield of alfalfa (Mesa-Sirsa and Hayden varieties) at the nearby experimental plots in Kohala averaged 83 kg/ha/day during the months of favorable weather (high solar radiation and temperature) and 68 kg/ha/day on the year round basis. During these periods, alfalfa was harvested every 28 days.[3] These yields of alfalfa were comparable to the yields obtained from the other Islands in the State of Hawaii (Goodell and Plucknett, 1972). In comparison, the average yield of forage fraction of leucaena was 28 - 38 kg/ha/day for K341 and 19 - 32 kg/ha/day for K8 on the year round cropping basis.

It should be noted that leucaena was harvested from 2 to 4 months interval while alfalfa was harvested every month. Alfalfa had to be

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[3] Personal communication from Dr. John R. Thompson, University of Hawaii, College of Tropical Agriculture, April 7, 1976.

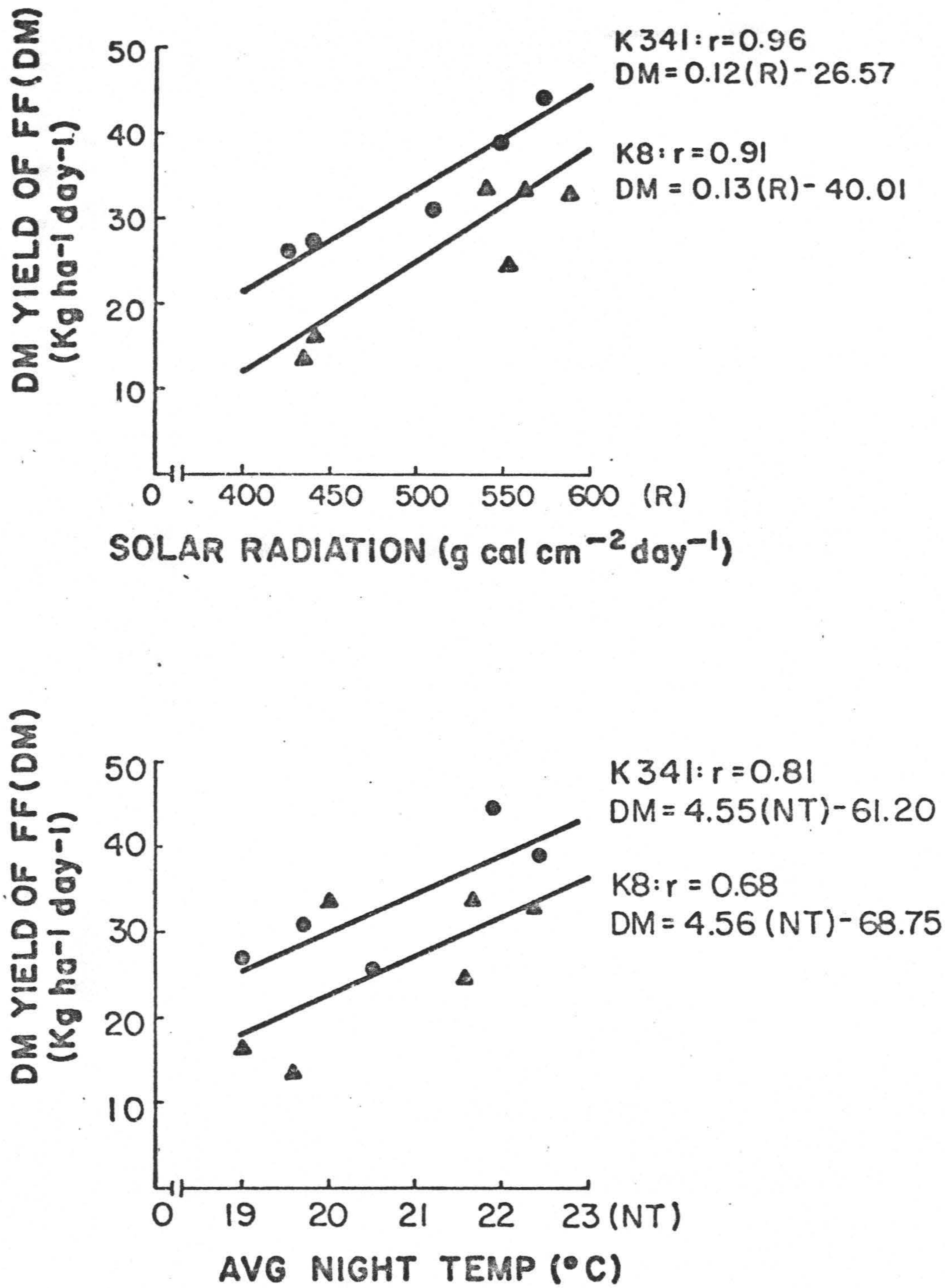


Figure 9. Correlation of DM yield of forage fraction with the average night temperature and solar radiation at 55 cm height at cutting (● K341, ▲ K8).

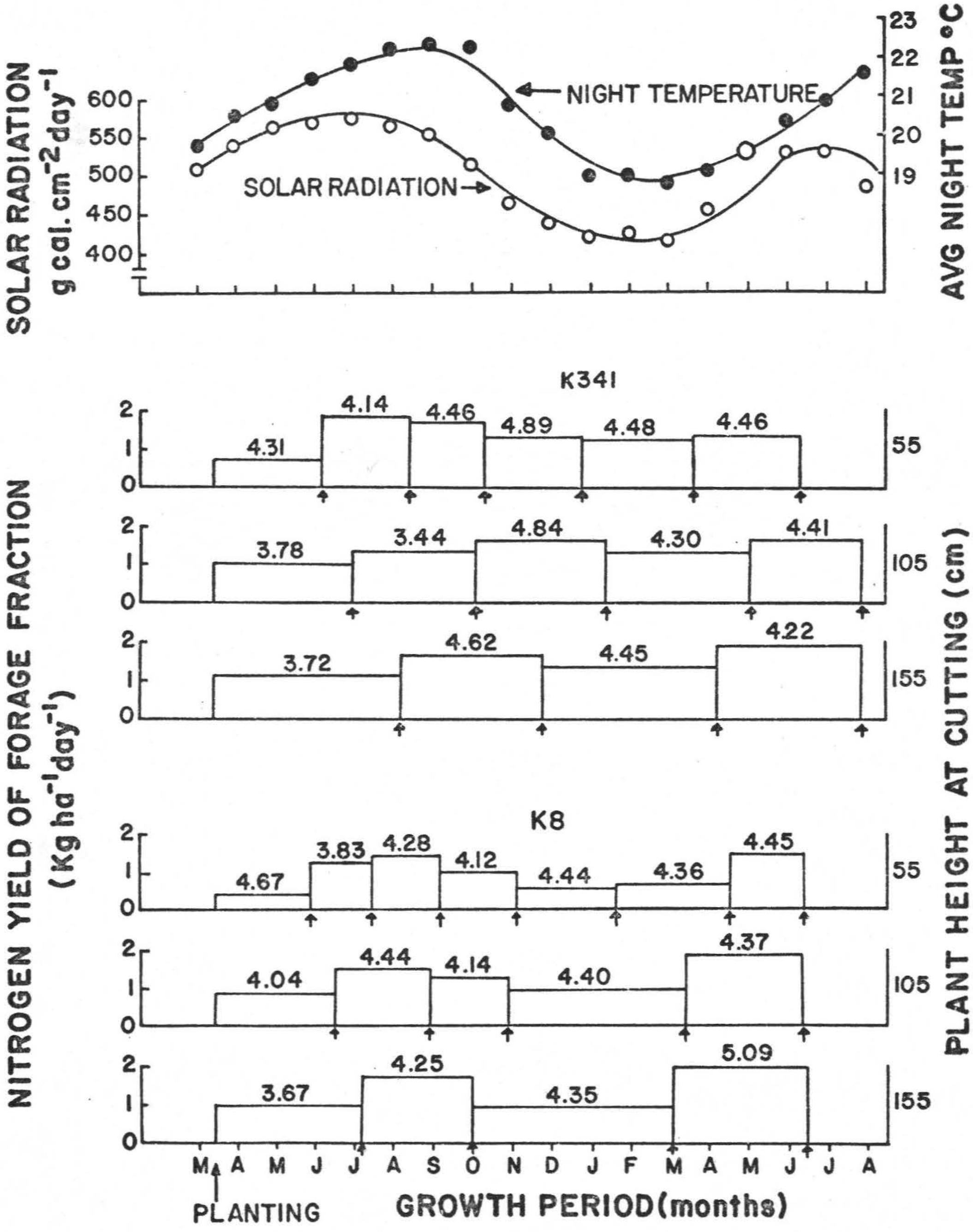


Figure 10. Relationship of nitrogen yields of forage fraction with the average solar radiation and night temperature. Values on the bars are percent nitrogen (avg of three intra-row spacings) K341: Upper three graphs, K8: Lower three graphs; ↑ indicates time of cutting.

cut before the basal growth buds became too tall to avoid damage during the cutting operation. The necessity of cutting alfalfa frequently and at a critical growth period each time added to increased costs and lack of flexibility in alfalfa management. Although, the absence of early basal growth in leucaena prior to cutting resulted in its slower growth recovery, it allowed less frequent and more flexible harvesting.

Present and previous results of experiments on leucaena. Results presented in this paper indicated that K341, a Hawaiian type, yielded higher than K8, a Salvador type. However, earlier studies showed that the Salvador types yielded higher than the Hawaiian types. Apparently, K8 in this study did not reach its yield potential since yields were significantly lower than in the earlier studies under different management (Oakes and Skov, 1967; Brewbaker, Plucknett and Gonzalez, 1972). However, the yield of K341 in this study was higher than the yields of the Hawaiian types in studies by Hutton and Bonner (1960), and Oakes and Skov (1967). The yield of K341 was comparable to that of K63 in the study of Brewbaker, Plucknett and Gonzalez (1972).

The difference in yield findings may have been influenced by the management factors done in this study. Therefore, explicit yield comparison of the leucaena cultivars should include the definition of the agronomic practices used. Some of the following agronomic management practices, when applied in various combinations to the Salvador and Hawaiian types will result in varied yield responses: (1) planting density, (2) row arrangement of the varietal types, (3) intensity of cutting, (4) weed control, (5) irrigation, and (6) fertilization. In addition, climatic factors affect the response of the varietal types to the management employed. Strains within varietal types differ also in yield response (Brewbaker, Plucknett and Gonzalez, 1972).

In this study, the seeds of the Hawaiian type (K341) used were collected from the Parker Ranch at North Kohala, Hawaii. K341 may have been selected under grazing pressure on deep soils. Whereas, the Hawaiian type (K63) used by Brewbaker, Plucknett and Gonzalez (1972) were selected from dry hillsides where selection pressure would have been survival under droughty conditions.

Summary and Conclusions

The growth behavior, yield and other agronomic characters of K341 and K8 varieties of leucaena were studied under three plant spacings (15, 30, and 45 cm) and three heights of plant at cutting (55, 105, and 155 cm).

The plant crops of both leucaena varieties showed three phases of growth: (1) the seedling establishment phase, (2) the lag vegetative phase, and (3) the active vegetative phase for K8 or active-vegetative-reproductive phase for K341. The ratoon crops followed the same growth phases except that the seedling establishment phase was absent. The seedling establishment and the lag vegetative phases of growth were critical periods for weed control. The early flowering habits of K341 particularly at wider spacings, coupled with more lateral branching apparently contributed to its slower rate of increase in height compared to the apically dominant K8. As a result of this, K341 was harvested about 10 days later than K8.

K8 intercepted sunlight more rapidly than K341 as both approached the cutting stages. By the time leucaena reached 55 cm height, light interception was approximately 95% in both cultivars, with very little increase thereafter. The amount of sunlight intercepted under various plant spacings were similar. The average light interception increased with increased plant height at cutting. At harvest, the light interception for the two varieties was about the same at 96 percent.

The rate of increase in the amount of sunlight intercepted at the vegetative growth stage is related to the rate of production of the photosynthetic surface area (lateral and upright growth). In addition to the efficient utilization of sunlight, a variety that grows rapidly competes with weeds and helps reduce soil evaporation and soil erosion more effectively than the slow growing variety.

Based on average of all treatments, the total dry matter yield of K341 (17.8 t/ha/yr) was higher than K8 (15.2 t/ha/yr). These yields consisted of 12.0 tons of forage fraction for K341 and 9.9 tons forage fraction for K8. The rest of the yield was stem fraction. The yields under more frequent cutting were lower but contained higher percentages of forage fraction than under less frequent cutting. As planting density increased, total yields also increased but percent forage fraction decreased. Planting at 15 cm x 50 cm spacing (133,000 plants per hectare) and cutting at plant height of about 1 m resulted in yields nearly as great as when the plant was cut at a later stage, and provided a forage much lower in stem fraction. Therefore, dense planting and cutting at approximately 1 m height at harvest were desirable management practices considering the forage yield, the percentage forage fraction and the average cutting frequency (3-month interval).

High yields of forage fraction and faster growth rate were obtained during the periods of high solar radiation and night temperature. Correlation values showed that the yield of forage fraction was primarily a function of solar radiation while growth rate was more influenced by night temperature. Night temperature and solar radiation had no clear cut relationship with the percentage of forage fraction or nitrogen and mimosine contents of dry matter yields.

Overall nitrogen and mimosine percentages were not influenced by any of the experimental variables except that stems declined in N content as cutting interval increased. Forage fraction consisted of 4.3 percent nitrogen and 6.7 percent mimosine, while the stem contained 1.5 percent nitrogen and 0.92 percent mimosine. Crude protein in the forage fraction and stem consisted of about 24% and 10% mimosine, respectively. Since nitrogen and mimosine contents of the forage fraction were not influenced by the climatic factors and the experimental variables tested, it seemed that leucaena adopted to a wide range of growth conditions without a significant change in the nutrient values of the forage.

Based on the forage fraction, K341 produced nearly 600 kg N/ha/yr while K8 produced about 500 kg N/ha/yr. The forage fraction contributed an average of 85 percent of the total nitrogen yield. Nitrogen yield increased with height at cutting and decreased with increasing width of intra-row spacing. The differences in the N yields among treatments were due to differences in dry matter yields.

Variety and height at cutting did not influence the number of stems per hectare, but increased with close plant spacing. Unlike tillering grasses, leucaena was not able to compensate for wider spacing by producing more stems. Therefore, optimum density at planting was critical in leucaena for maximum yield production.

There was no difference in stem diameter at harvest between varieties (8.2 mm). Less frequent cutting and low plant populations however, did result in larger stems.

Forage production of leucaena was about 1/2 - 2/3 that of alfalfa grown in small plots at the same location. Also weed control was more of a problem with leucaena than alfalfa due to restricted competition during the relatively long lag vegetative phase of growth. However, this was offset somewhat by the easier agronomic management of leucaena because of less frequent harvests, greater harvest flexibility, freedom from disease infestations and longevity of stand.

CHAPTER V. YIELD OF LEUCAENA AND ITS NITROGEN CONTRIBUTION TO INTERCROPPED CORN

Grasses in association with legumes may benefit from the nitrogen fixed by the legume through root excretion, sloughing of root nodules, and decomposition of legume roots and leaves. The quantity of nitrogen fixed by legumes varies widely from only a few kilograms to 700 kg/ha/yr (Allison, 1965; Date, 1973). The amount of N fixed is determined by many factors, such as plant species, density of plant stand, weed competition, climatic conditions, effectiveness of the bacterial strain, soil pH and nutrient status, and the amount of nitrogen available in the soil (Allison, 1965).

In New Zealand, the amount of nitrogen fixed by red and white clovers/rye pasture under very good growth conditions was 600 - 700 kg N/ha/yr (Melville and Sears, 1953). In Hawaii *Desmodium spp.* and *Centrosema pubescens* grown alone or together with grasses fixed 47 - 407 kg N/ha/yr depending on legume species and grass combination (Whitney, Kanehiro and Sherman, 1967; Whitney and Green, 1969). Previous experiments in this series (Chapter IV) showed that K341 and K8 cultivars of leucaena produced up to 581 and 507 kg N/ha/yr respectively in the forage fraction - which would be expected to decompose readily in soil.

It has been suggested in extensive literature reviews (Henzell and Norris, 1962; Allison, 1965; Whitehead, 1970) that the average N fixation by legumes was about 100 - 200 kg N/ha/yr.

Although forage legumes have been thoroughly studied as high-nitrogen animal feeds, very little work has been done on tropical forage legumes as sources of nitrogen for food crop production.

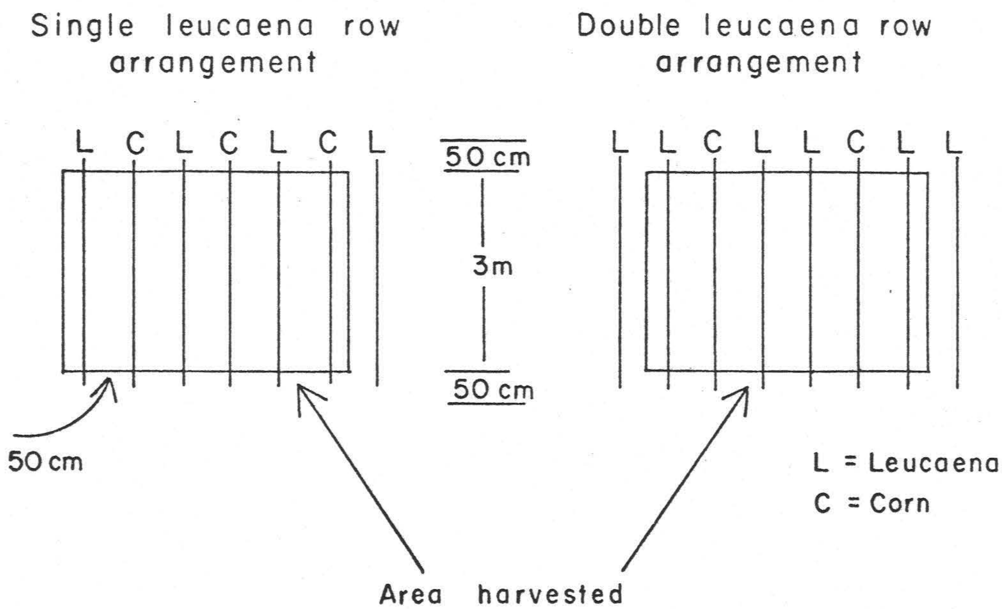
An experiment was therefore conducted to study the yield and nitrogen response of corn to fertilization with leucaena compared to fertilization with urea-nitrogen, and to better define the effects of various agronomic variables on the yields of corn and leucaena grown as intercrops.

Materials and Methods

An experiment was conducted from April 26, 1974 to June 5, 1975 at the Kohala site previously described (Chapter IV). K8 variety of leucaena was used because of its faster and more upright growth habit; and H610 single cross field corn hybrid was used because of its uniform growth and outstanding grain yields in Hawaii (Brewbaker and Ayres, 1973).

Leucaena and corn were arranged in superimposed split-split plot design in order to accommodate the effects of the intercrop management systems. Corn was planted between one single row or two paired rows of leucaena. Plots were replicated four times (Appendix Figure IX). Main plots were the times of cutting leucaena: (1) cutting at 1½-2 months old corn, (2) cutting at early flowering stage of corn, and (3) cutting at the late dough stage of corn. Sub-plots consisted of the number of rows of leucaena per row of corn: one row or two rows per row of corn. Sub-sub plots were corn hill spacings within corn rows: 30, 50, and 70 cm per hill, equivalent to 33,333; 20,000, and 14,285 plants/ha (field area basis), respectively in the single-leucaena-row plots. The corresponding populations of corn planted between double rows of leucaena were 22,222; 13,333, and 9,523 plants/ha.

Sub-plots were 12 m long and consisted of single leucaena rows alternating with single corn rows with 50 cm spacing between corn and leucaena rows or two leucaena rows alternating with one corn row (all at 50 cm spacing between rows). Within each sub-plot, sub-sub-plots were corn rows (and associated leucaena rows) 4 m long. Yields of leucaena and corn were based on the middle 3 m of row in each sub-sub-plot, e.g.:



Plots of unfertilized corn and corn fertilized with urea served as checks and positive controls and were randomly located in each replication. Main plots were fertilizer treatments (0, 75, and 150 kg N/ha) and sub-plots were corn hill spacings (30, 50, and 70 cm). Each main plot consisted of 3 rows, 12 m long and 1 m apart. Planting and harvesting of corn and cutting of leucaena were staggered by replication to distribute the labor requirement of the experiments.

Leucaena was planted on April 26, 1974 well before planting the intercropped corn so as to prevent excessive competition during the seedling establishment phase of the leucaena. After three months of growth, the leucaena was harvested, chopped and the forage applied to the area of the adjoining corn row. Fertilizer was applied to provide (in kg/ha) P-60, K-100, B-10, Mn-20, Cu-10, and the area was limes with $CaCO_3$ at 2000 kg/ha. The leucaena forage and fertilizer were tilled into the soil to 7 cm depth with a rotary tiller (Appendix Figure X). Corn was planted at the rate of 2 seeds per hill on the same day leucaena was incorporated. One corn plant per hill was later sampled at 1½ to 2 months of age for N analysis. Also at 1½ to 2 months after planting the corn, the leucaena in one sub-treatment was again cut and the forage applied to the base of the corn plants in the adjoining row without tillering (Appendix Figures XI and XII). A second sub-treatment consisted of leucaena forage cut and applied to adjoining corn plants when the corn plants reached the tasseling stage, and a third sub-treatment consisted of leucaena cut and applied onto the corn row when the corn was at the late dough stage (Appendix Figure XIII).

Urea was applied to the nitrogen-fertilized corn treatments to provide one-half the required amount at planting time and the remainder at 1½ to 2 months after planting.

Atrazine (on an active basis) was applied at 1.68 kg/ha before weeds and corn emerged and before the leucaena growth buds sprouted. In addition, paraquat was applied as directed spray at the rate of 1.5 kg/ha of active chemical.

The first crop of corn was planted from July 25 to August 6, 1974 and was harvested from November 12 to December 11, 1974. Six weeks after the corn was harvested all of the leucaena treatments were cut and the forage applied to the adjoining corn rows. Corn was again planted (December 23, 1974 to January 21, 1975) and a second cycle of corn-leucaena intercropping and side-dressing was carried out exactly as before. Harvesting of the second crop of corn was done from April 29, 1975 to June 2, 1975. One month after harvesting the corn, the plot was prepared as explained earlier for the third cycle of corn-leucaena intercropping. Corn hills were arranged 10 cm away from leucaena rows to allow early root contacts between the two crops. Unfortunately, corn growth was very uneven. This may be partly attributed to the early growth competition betwen the two crops. In addition, shredding of the leaves of corn seedlings was observed following windy days due to severe physical contact between the corn leaves and leucaena stems. Data from the third planting of corn were thus not included in this paper.

Results and Discussion

The leucaena intercropped with corn made excellent growth; comparable to that obtained in the monocropping experiment (Chapter IV). A high level of residual nitrogen from a previous experiment was present in the soil as indicated by the vigorous growth of the check treatment during the first crop of corn. However this effect was minimal during the second corn crop. As mentioned earlier, a third corn planting was made, but abandoned due to extreme variability associated with a different planting arrangement.

Growth of corn: cutting sequence and yield of leucaena. Figure 11 shows dry matter yield and cutting sequence of leucaena in relation to the

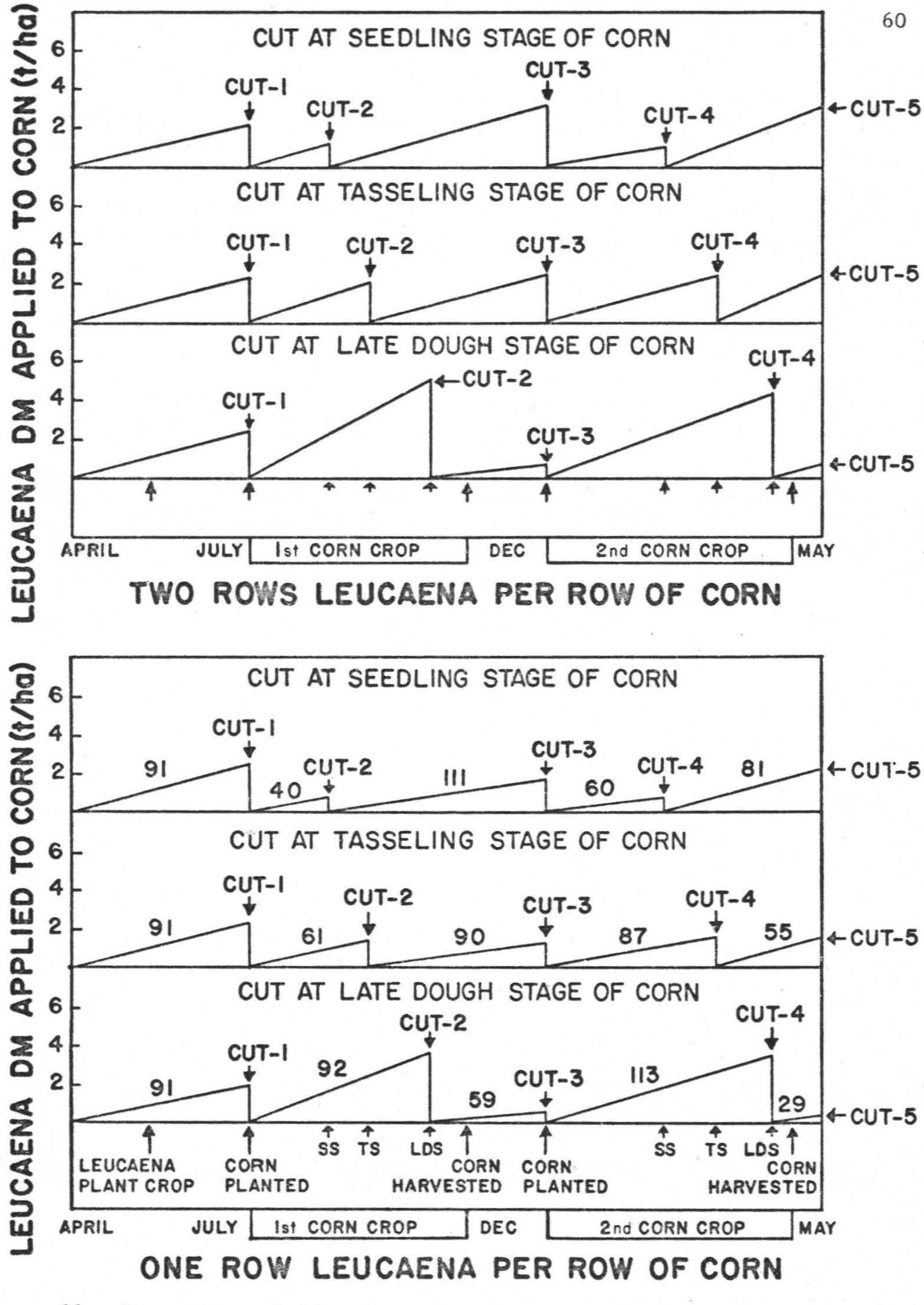


Figure 11. Dry matter yield and cutting sequence of leucaena in relation to the growth stages of intercropped corn. Values on the triangles are days of the growth periods for both the two rows and one row plantings of leucaena. SS = seedling stage; TS = tasseling stage; LDC = late dough stage.

growth stages of intercropped corn. The growth period of corn was shorter in the July planting (110 days) than the December planting (130 days). The seedling stage of corn was about 20 days longer in the second corn crop than in the first corn crop. The length of the growth periods following the seedling stage seemed to be similar in the two crops. The difference in the growth period between the first and second crop of corn was mainly due to the seedling stage.

Duration of regrowth and sequence of cutting leucaena followed the growth periods of various vegetative and reproductive stages of corn. In the first crop of corn, the second cutting of leucaena at the seedling, tasseling and late dough stages of corn were done at 40, 61 and 92 days following the first cut (time of planting corn). The corresponding regrowth periods of leucaena during the second corn crop at various stages of corn was about 20 days longer than cut-1 to cut-2.

There was no significant difference between the amount of forage topdressed to the first and second corn crops at comparable stages of growth (e.g. 0.79 and 0.74 t/ha for cut-2 and cut-4 at the seedling stage of corn).

The rate of growth of corn and leucaena in the intercrop was slow during the season of low temperature and solar radiation just as it was when leucaena was grown as a monocrop (Chapter IV).

<u>Dry matter production of leucaena with intercropped corn</u>. The first crop of corn was fertilized by applying forage from the 1st and 2nd leucaena cuttings and the second crop of corn received the leucaena forage from the 3rd and 4th cuttings (Table 7). The amount of leucaena

Table 7. Dry matter yields of leucaena harvested and applied to corn in relation to rows of leucaena per row of corn and stage of cutting leucaena. Avg of four replications.

Leucaena treatments	Leucaena DM applied to corn: First corn crop cut-1†	First corn crop cut-2‡	Second corn crop cut-3†	Second corn crop cut-4‡
	t/ha			
Cut at seedling stage of corn				
Single row of leucaena	1.93	0.79	1.72	0.74
Double row of leucaena	2.10	1.21	3.19	1.09
Cut at tasseling stage				
Single row	2.23	1.46	1.28	1.54
Double row	2.24	2.12	2.43	2.38
Cut at late dough stage*				
Single row	1.93	3.54	0.55	3.43
Double row	2.35	5.14	0.69	4.37

*Leucaena from 2nd cut or 4th cut applied at late dough stage of corn did not benefit the concurrent corn crop

†Incorporated into corn row at planting

‡Topdressed over corn row

forage produced and added to the corn increased with delayed cutting, with the double rows of leucaena and, to a limited extent, with decreased corn plant density.

The total dry matter (DM) production of the 1st cut of leucaena (plant crop) averaged 2.03 and 2.23 t/ha at single and double rows of leucaena, respectively. These yields were equivalent to an average total dry matter production of 23 kg/ha/day. The total DM production from subsequent cuttings varied mainly with the growth period of leucaena. For example, leucaena cut at the late dough stage of the corn crop (92 days) yielded 4 times as much as leucaena cut at the 1.5-month stage (40 days). When the leucaena was cut at the 1.5-month stage or at the tasseling stage, the subsequent regrowth of leucaena was retarded partly due to increased competition by the corn. Shading of young leucaena regrowth may have resulted in lower rates of photosynthesis, depletion of reserve substrate from the roots and basal stems, and reduced N fixation by the root nodules.

The total DM yields per unit field area of leucaena regrowth were about 50 percent higher in the double rows than in the single row planting of leucaena. Generally, DM yields of leucaena increased as the corn plant densities decreased. However, the magnitude of the corn density effect on the yield of leucaena was small compared to the effects of number of rows of leucaena and leucaena regrowth period.

Nitrogen content and nitrogen production of leucaena. Percent N of the total leucaena DM (stem plus forage fraction) decreased with delayed harvest (Table 8). Decreased percent N was mainly the result of an increase in the proportion of the stem fraction over the forage fraction

Table 8. Percent nitrogen of leucaena dry matter applied to corn as influenced by rows of leucaena per row of corn and stage of cutting leucaena.

Leucaena treatments	Percent nitrogen of leucaena			
	First corn crop		Second corn crop	
	cut-1	cut-2	cut-3	cut-4
	%			
Cut at seedling stage of corn				
Single row of leucaena	3.49	4.05	3.68	4.37
Double row of leucaena	3.40	3.97	3.07	4.48
Cut at tasseling stage				
Single row	3.41	4.09	3.68	3.93
Double row	3.39	3.87	3.38	4.18
Cut at late dough stage				
Single row	3.40	2.92	4.06	4.29
Double row	3.45	2.80	4.09	4.33

(Chapter IV). Forage harvested early contained up to 4.48 percent N (DM basis) while the later harvests contained as little as 2.80 percent nitrogen. Corn spacing and number of rows of leucaena did not significantly influence percentage N in the forage.

The amount of nitrogen in the leucaena forage applied to the first and second crops of corn varied from 92 to 261 kg/ha and from 82 to 247 kg/ha, respectively (Tables 10 and 14). However, the leucaena forage applied to the corn at the late dough stage would not be effective for that crop. Excluding this, the leucaena N applied to the first corn crop varied from 55 - 170 kg/ha and 63 - 183 kg/ha for the second corn crop. The larger amounts of nitrogen were associated with leucaena cut at the later stages. Double rows produced significantly higher amounts of N than single rows. The differences in N yields primarily reflected differences in the amount of DM produced rather than in the percent N in the dry matter.

First Corn Crop

Corn yields: grain and stover. Grain yield was computed on the field area, the corn area, and per plant bases. Yield on a field area was based on corn planted on rows 1 or 1½-meter apart intercropped between single or double rows of leucaena. The yield of corn on a corn area basis excluded the land area occupied by leucaena. Yields on the corn area and per plant bases were computed to compare more accurately the effects of various levels of leucaena forage application on the yields of corn (e.g. single *vs* double rows of leucaena).

There was no response in yield of corn grain and stover from the application of either urea or leucaena forage (Tables 9, 10 and 11).

Table 9. The effects of urea-N and plant spacings on the grain and stover yields of corn (H610). First crop of corn.

Nitrogen levels	Corn spacing	Dry matter yield* Grain	Stover
kg/ha	cm	t/ha	
0	30	4.17	3.72
	50	3.58	3.11
	70	2.60	2.28
75	30	5.28	4.65
	50	4.56	3.67
	70	2.98	2.10
150	30	4.61	4.01
	50	4.22	3.04
	70	2.83	2.46
N-fertilizer effects†			
Nitrogen levels			
0		3.45 a	3.03 a
75		4.27 a	3.47 a
150		3.88 a	3.17 a
Spacing effects†			
Plant spacing			
30		4.69 a	4.13 a
50		4.12 b	3.27 b
70		2.80 c	2.28 c

*Grain yields avg of four replications; stover yields avg of two replications.

†Means in the same column followed by the same letter are not significantly different at 5% level (Bayes LSD).

Table 10. The effects of intercropped leucaena on the grain and stover yields of corn (H610) planted at three spacings. First crop of corn.

Leucaena treatments	Corn spacing	Leucaena-N applied†	Dry matter yield: Field area basis Grain	Field area basis Stover	Corn area basis Grain	Per plant Grain
	cm	kg/ha	t/ha	t/ha	t/ha	g/plant
Applied planting time and seedling stage						
1 row	30	92	4.44	3.64	8.88	133
	50	100	3.64	3.18	7.28	182
	70	112	2.38	2.50	4.76	178
	Mean	101	3.48	3.11	6.97	164
2 rows	30	116	3.11	2.99	9.33	140
	50	116	2.29	2.15	6.87	172
	70	122	1.75	1.82	5.25	197
	Mean	118	2.38	2.32	7.15	170
Applied planting time and tasseling stage						
1 row	30	123	4.39	4.50	8.78	132
	50	146	3.76	3.67	7.52	188
	70	135	2.52	2.17	5.04	189
	Mean	135	3.56	3.45	7.11	170
2 rows	30	170	2.80	2.62	8.40	127
	50	147	2.63	2.25	7.89	198
	70	151	1.53	1.58	4.59	172
	Mean	156	2.32	2.15	6.96	166

Table 10. (Continued) The effects of intercropped leucaena on the grain and stover yields of corn (H610) planted at three spacings. First crop of corn.

			Dry matter yield			
Leucaena treatments	Corn spacing	Leucaena-N applied†	Field area basis		Corn area basis	Per plant
			Grain	Stover	Grain	Grain
	cm	kg/ha	t/ha			g/plant
Applied planting time (and late dough stage)						
1 row	30	76	3.98	3.02	7.96	120
	50	55	2.33	2.84	4.66	117
	70	73	2.35	2.21	4.70	176
	Mean	68	2.89	2.69	5.77	138
2 rows	30	74	2.77	2.38	8.31	125
	50	77	2.11	1.97	6.33	158
	70	96	1.51	1.38	4.53	170
	Mean	82	2.13	1.91	6.39	170

†N contained in leucaena incorporated at planting time (cut-1) plus leucaena topdressed at the seedling or tasseling stage (cut-2). Leucaena topdressed at late dough stage is excluded (no contribution to concurrent corn).

Table 11. Analysis of treatment effects (time of cutting, number of rows of leucaena, and corn spacing) on the grain and stover yields of corn (H610). First crop of corn.

Treatments	Dry matter yield-field area basis[†]	
	Grain	Stover
	t/ha	
__Main effects__		
Time of cutting leucaena		
Seedling stage	2.93 a	2.71 a
Tasseling stage	2.94 a	2.80 a
Late dough stage	2.51 a	2.30 a
Leucaena rows		
Single row	3.20 a	3.08 a
Double row	2.28 b	2.13 b
Corn spacing		
30 cm	3.47 a	3.19 a
50 cm	2.79 b	2.68 a
70 cm	2.01 c	1.94 b
__Within leucaena cutting treatments__		
Seedling stage		
30 cm	3.42 a	3.31 a
50 cm	2.96 a	2.67 b
70 cm	2.06 a	2.16 c
Tasseling stage		
30 cm	3.60 a	3.56 a
50 cm	3.20 a	2.96 b
70 cm	2.02 a	1.88 c
Late dough stage		
30 cm	3.38 a	2.70 a
50 cm	2.22 a	2.41 b
70 cm	1.93 a	1.80 c
__Within leucaena row treatments__		
Single row		
30 cm	4.04 a	3.72 a
50 cm	3.24 a	3.23 b
70 cm	2.41 a	2.30 c
Double row		
30 cm	2.89 a	2.66 a
50 cm	2.34 a	2.12 b
70 cm	1.60 a	1.59 c

[†]Means in the same column pair or triplet followed by the same letter are not significantly different at the 5% level (Bayes LSD).

It seemed that there was a sufficient amount of residual N from a previous sorghum experiment to mask the effects of the various N treatments. In addition, the short history of leucaena cropping did not permit the application of large quantities of leucaena forage. There was a significant effect of corn spacing on corn yields with close spacing resulting in higher yields. The average grain yields of corn over all urea-N-levels were 4.69, 4.12, and 2.80 t/ha for 30, 50, and 70 cm spacing, respectively. A similar trend was observed on the yields of corn stover.

The grain yields of corn intercropped with single row of leucaena per corn row cut at seedling (3.48 t/ha) or tasseling (3.56 t/ha) stage were comparable to the grain yields of the check plots (3.45 t/ha). The yield of corn under double rows of leucaena per corn row and under late cutting of leucaena was lower than the check. This can be attributed to the effects of computing the yield on a field area basis. When yields of corn grain intercropped with two rows of leucaena was computed on a corn-area and per plant bases however, they were nearly identical to the corn intercropped with single row of leucaena (Table 10). The lack of corn yield depression (on a corn-area basis) even by double rows of intercropped leucaena indicated that the competition between the two crops was minimal under conditions of adequate nitrogen.

Nitrogen analyses of the corn plant. Fertilization of the first crop of corn with urea did not result in higher levels of N in the leaf or whole plant samples at the late dough stage (green forage chop) (Table 12). This was undoubtedly due to the large amounts of residual fertilizer N available to the plants. Corn intercropped with leucaena

Table 12. The effects of urea-N and plant spacings on the percentage nitrogen of leaf samples at tasseling and whole plants at the late dough stage. First crop of corn.

Nitrogen levels	Corn spacing	Percent nitrogen: Leaf samples*	Percent nitrogen: Whole plants**
kg/ha	cm	%	%
0	30	2.43	1.44
	50	2.88	1.42
	70	2.89	1.47
75	30	2.88	1.49
	50	3.17	1.36
	70	3.16	1.52
150	30	2.88	1.49
	50	3.06	1.49
	70	3.14	1.52
N-fertilizer effects†			
Nitrogen levels			
0		2.73 a	1.44 a
75		3.07 a	1.46 a
150		3.03 a	1.50 a
Spacing effects†			
Plant spacing			
30		2.73 b	1.47 a
50		3.03 a	1.42 a
70		3.06 a	1.50 a

*Avg of four replications

**Avg of two replications

†Means in the same column followed by the same letter are not significantly different at the 5% level (Bayes LSD).

had lower average levels of N in the leaves (2.48%) and green forage (1.32%) than corn in the check plot (2.73% of leaf N and 1.44% forage N). The ear leaf samples of corn in leucaena were all in the range of 2.3 - 2.7% N with no difference due to treatment. This was slightly lower than the critical N level (2.7 to 2.9%) for corn ear leaf at tasseling that will result in 95% yield (Viets, et al., 1954; Dumenil, 1961; Daiger and Fox, 1971). However, the leaf N values were all higher than 2.28% defined by Viets, et al. (1954) as the critical N in the second leaf below the main ear before visual symptoms of N deficiency were observed. Percent N in whole plants at late dough stage also was not influenced by leucaena treatments and ranged from 1.2 to 1.5% nitrogen.

In the check and leucaena-N fertilized plots, close plant spacing resulted in lower percent N in the leaves but did not affect N in the green forage. Removal of corn samples for forage analysis from the margins of the yield plots may have minimized any effect of corn spacing on the percentage of N in the green forage.

Second Crop of Corn

Corn yields: seedling, grain and stover. In the second crop of corn, there was a significant response to N fertilization. Yield response of seedlings and grain to N fertilization were greater than the stover response. Yields of seedlings and grain from plots fertilized with 150 kg N were 2.5 and 2.1 times the yield of the controls, respectively, while the stover yields increased to only 1.6 times the yields of the control (Table 13). Apparently, photosynthates and reserve carbohydrates in the stover were translocated into the grain at the later stage of

Table 13. The effects of urea-N and plant spacings on the grain, stover and seedling yields of corn (H610). Second crop of corn.

Nitrogen levels	Corn spacing	Dry matter yield		
		Seedling*	Grain*	Stover**
kg/ha	cm	g/plant	t/ha	
0	30	1.58	2.12	2.26
	50	1.48	2.12	1.95
	70	1.86	1.54	1.59
75	30	3.62	5.35	3.46
	50	3.44	3.66	2.55
	70	3.12	2.40	2.09
150	30	4.12	5.72	4.26
	50	4.20	3.67	2.61
	70	4.16	2.90	2.50
N-fertilizer effects†				
Nitrogen levels				
0		1.64 c	1.93 b	1.94 c
75		3.40 b	3.80 a	2.70 b
150		4.16 a	4.09 a	3.12 a
Spacing effects†				
Plant spacing				
30		3.10 a	4.39 a	3.33 a
50		3.04 a	3.15 b	2.37 b
70		3.04 a	2.28 c	2.06 b

*Avg of four replications

**Avg of two replications

†Means in the same column within treatments followed by the same letter are not significantly different at the 5% level (Bayes LSD).

plant growth. At the seedling stage, yields per plant were not significantly different under various spacings. Grain yield per hectare was significantly higher at closer plant spacing, but yield per plant was higher at wider spacing. Similarly, stover yield per hectare increased with closer plant spacing.

Yields of corn seedlings, grain and stover in the second corn-leucaena intercrop were generally higher than in the check (Tables 13, 14, and 15). The yield of corn seedlings ranged from 2.70 - 4.36 g/plant, compared to 1.48 - 1.86 g/plant in the check treatment. Corn seedlings thus benefited from the nitrogen supplied by leucaena forage applied earlier. Seedlings from plots supplied with urea ranged from 3.12 g/plant (at 40 kg N/ha, basal) to 4.20 g/plant (at 75 kg N/ha basal).

The grain yields of corn intercropped with leucaena averaged 2.39 t/ha - 23 percent higher than the check. Grain yields were higher when leucaena was cut at the early stage of corn. The average yield of corn was 2.58, 2.45 and 2.15 t/ha when leucaena was cut at seedling stage, tasseling stage and late dough stage, respectively. The amounts of leucaena-N produced and applied to corn were higher for leucaena cut at the late dough stage, but, leucaena forage N applied at this stage was too late for the corn to utilize effectively. In addition, competition between leucaena and corn for light and perhaps other factors, seemed to limit the response of corn to added leucaena-N. It should be noted that there was a significant interaction between the time of cutting leucaena and corn spacing (Table 15). At the optimum corn spacing (30 cm) corn yields were significantly higher when

Table 14. The effects of intercropped leucaena on the grain, stover and seedling yields of corn (H610) planted at three spacings. Second crop of corn.

			Dry matter yield				
			Field area basis			Corn area basis	Per plant
Leucaena treatments	Corn spacing	Leucaena-N applied†	Seedling*	Grain*	Stover**	Grain	Grain
	cm	kg/ha					g/plant
Applied planting time and seedling stage							
1 row	30	100	2.70	3.74	3.30	7.48	112
	50	82	2.68	2.84	2.07	5.68	142
	70	105	3.18	2.33	1.66	4.66	175
	Mean	95	2.86	2.97	2.34	6.61	143
2 rows	30	140	3.58	3.13	2.51	9.40	141
	50	146	3.96	1.98	1.78	5.94	149
	70	150	4.28	1.49	1.45	4.48	168
	Mean	146	3.94	2.20	1.91	6.61	153
Applied planting time and tasseling stage							
1 row	30	99	2.72	3.63	2.97	7.26	109
	50	110	3.82	2.49	2.04	4.98	124
	70	111	4.12	2.08	1.93	4.16	156
	Mean	107	3.55	2.73	2.32	5.47	130
2 rows	30	174	4.04	2.85	2.84	8.56	128
	50	183	3.50	2.19	1.90	6.58	164
	70	180	4.36	1.45	1.30	4.36	164
	Mean	179	3.96	2.16	2.02	6.50	152

Table 14. (Continued) The effects of intercropped leucaena on the grain, stover and seedling yields of corn (H610) planted at three spacings. Second crop of corn.

Leucaena treatments	Corn spacing	Leucaena-N applied†	Dry matter yield: Field area basis: Seedling*	Field area basis: Grain*	Field area basis: Stover**	Corn area basis: grain	Per plant: grain
	cm	kg/ha					g/plant
Applied planting time (and late dough stage)‡							
1 row	30	63	3.14	2.97	2.23	5.94	88
	50	81	3.52	2.12	2.01	4.24	106
	70	80	3.06	2.03	1.66	4.06	153
	Mean	75	3.24	2.37	1.97	4.75	116
2 rows	30	95	3.34	2.44	1.75	7.32	110
	50	90	4.20	1.89	1.56	5.68	142
	70	116	3.84	1.48	1.08	4.44	167
	Mean	100	3.79	1.94	1.46	5.81	140

*Avg of four replications

**Avg of two replications

†N contained in leucaena incorporated at planting time (cut-3) plus leucaena topdressed at seedling or tasseling stage (cut-4). Leucaena applied at late dough stage is excluded (no contribution to concurrent corn).

‡Leucaena-N computed based on ½ of cut-2 plus cut-3

Table 15. Dry matter yields of seedlings, grain and stover from second corn crop as influenced by leucaena cutting treatment, number of rows of leucaena and corn spacing.

Treatments	Dry matter yield-field area basis†		
	Seedlings*	Grain*	Stover**
	g/plant	t/ha	
Main effects			
Time of cutting leucaena			
Seedling stage	3.40 a	2.58 a	2.13 a
Tasseling stage	3.76 a	2.45 a	2.17 a
Late dough stage	3.54 a	2.15 a	1.71 a
Leucaena rows			
Single row	3.22 b	2.69 a	2.21 a
Double row	3.92 a	2.10 b	1.80 a
Corn spacing (cm)			
30	3.26 b	3.12 a	2.60 a
50	3.62 a	2.25 b	1.89 b
70	3.84 a	1.81 c	1.52 c
Within leucaena cutting treatment			
Seedling stage			
30 cm	3.14 a	3.43 a	2.90 a
50 cm	3.32 a	2.41 b	1.93 a
70 cm	3.74 a	1.91 c	1.56 a
Tasseling stage			
30 cm	3.38 a	3.24 a	2.91 a
50 cm	3.66 a	2.34 b	1.97 a
70 cm	4.24 a	1.77 c	1.62 a
Late dough stage			
30 cm	3.24 a	2.70 a	1.99 a
50 cm	3.86 a	2.00 b	1.78 a
70 cm	3.52 a	1.76 b	1.37 a

*Avg of four replications

**Avg of two replications

†Means in the same column within treatments followed by the same letter are not significantly different at 5% level (Bayes LSD).

leucaena was cut at the seedling stage (3.43 t/ha) than when leucaena was cut at the late dough stage (2.70 t/ha). At the wider corn spacings, however, time of cutting leucaena had little influence on corn yield.

As in the previous crop, the average yield of corn per unit of field area intercropped with one row of leucaena was higher than with two rows of leucaena per row of corn. However, on a linear row or per plant basis, corn intercropped with two rows of leucaena yielded 12 percent more than corn intercropped with a single row of leucaena. Closer corn spacing also gave higher yield than did wider spacing on a field area or corn area basis. However, wider plant spacings resulted to higher grain yield per plant.

The yield of corn stover in corn intercropped with leucaena followed the same trend as the grain yield under the same crop management, except that there was no significant effect of the number of rows of leucaena on the yield of stover. Also, the effects of time of cutting leucaena on the stover yield was independent of corn spacing effects. However the tests of significance for stover yields were not very sensitive because of the limited number of replications.

Nitrogen analysis of corn plants. Nitrogen content of the seedlings and leaf samples increased significantly with increased urea-N application (Table 16). The significant effects of urea-N and spacing treatments on the nitrogen contents of the whole plant samples were not detected because of the limited number of replications, and samples were obtained from the border plants. Nevertheless, the increase in their N content followed the same trend as in the seedlings and leaf

Table 16. The effects of urea-N and plant spacing on the percentage nitrogen of seedlings, leaf samples at tasseling, and whole plants at the late dough stage. Second crop of corn.

Nitrogen levels	Corn spacing	Percent nitrogen Seedlings*	Leaf samples*	Whole plants**
kg/ha	cm	%		
0	30	3.04	2.01	1.50
	50	3.37	2.28	1.59
	70	3.19	2.39	1.62
75	30	3.76	3.04	1.72
	50	3.72	3.32	1.96
	70	3.74	3.36	1.93
150	30	3.93	3.16	1.71
	50	4.05	3.44	1.85
	70	4.04	3.66	1.88
N-fertilizer effects†				
Nitrogen levels				
0		3.20 b	2.23 b	1.57 a
75		3.74 a	3.24 a	1.87 a
150		4.01 a	3.42 a	1.81 a
Spacing effects†				
Plant spacing				
30		3.57 a	2.73 b	1.64 a
50		3.71 a	3.01 a	1.80 a
70		3.65 a	3.13 a	1.81 a

*Avg of four replications

**Avg of two replications

†Means in the same column within treatments followed by the same letter are not significantly different at 5% level (Bayes LSD).

samples. At the seedling stage, when N supply in the soil was not limiting, planting density had limited influence on the N content of the seedlings. The nitrogen content of the seedlings at 30 cm spacing differed from that at 70 cm spacing by only 0.08 percent. However, with increased plant growth and increased N uptake, planting density seemed to have a greater influence on the N level in the plant tissues (e.g. 30 cm spacing, 2.73% N; 70 cm spacing, 3.13% N on the leaf samples).

In the leucaena-N plots (Table 17 and 18), plant spacing affected significantly the N content of the seedlings, leaf and whole plant samples. Nitrogen content of the plant tissues increased significantly with decreased plant density. Corn seedlings contained 3.45 percent N in single leucaena row and 3.77 percent N in double leucaena row. The amount of leucaena-N added to corn at planting averaged 55 kg N/ha from single row and 88 kg N/ha from double leucaena rows (excluding the amount applied in the late dough stage treatment plot). The total amount of leucaena-N added to the corn plot averaged 100 kg N/ha and 162 kg N/ha for the single and double rows of leucaena, respectively. A higher level of leucaena-N application in corn intercropped with double rows of leucaenea was indicated by the higher percentage of N in the leaf (2.89% N) and plant samples (1.69%) compared to the same type of plant samples (2.53% N and 1.57% N) of corn intercropped with single row of leucaena.

In plots where topdressed leucaena was cut at the late dough stage of corn, the amount of leucaena-N applied to corn at planting averaged 25 kg N/ha. Corn seedlings under this treatment contained a higher

Table 17. The effects of intercropped leucaena on the percentage nitrogen of corn seedlings, leaf samples at tasseling, and whole plant at the late dough stage planted at three spacings. Second crop of corn.

Leucaena treatment	Corn spacing	Percent nitrogen Seedlings*	Leaf samples*	Whole plant**
	cm	%		
Cut at seedling stage of corn				
1 row	30	3.30	2.37	1.67
	50	3.58	2.68	1.42
	70	3.59	2.91	1.72
	Mean	3.49	2.65	1.60
2 rows	30	3.64	2.75	1.76
	50	3.72	3.22	1.68
	70	3.96	3.44	1.79
	Mean	3.77	3.14	1.74
Cut at tasseling stage				
1 row	30	3.49	2.13	1.70
	50	3.40	2.22	1.58
	70	3.79	2.61	1.66
	Mean	3.56	2.32	1.65
2 rows	30	3.90	2.50	1.64
	50	4.02	2.72	1.89
	70	3.94	3.00	1.80
	Mean	3.95	2.74	1.78
Cut at late dough stage				
1 row	30	3.16	1.96	1.47
	50	3.43	2.39	1.45
	70	3.36	2.54	1.48
	Mean	3.32	2.63	1.47
2 rows	30	3.52	2.27	1.38
	50	3.53	2.66	1.56
	70	3.72	2.84	1.76
	Mean	3.59	2.59	1.57

*Avg of four replications

**Avg of two replications

Table 18. Analysis of treatment effects (time of cutting and number of rows of leucaena and corn spacing) on the percentage nitrogen of corn (H610). Second crop of corn.

Treatments	Percent nitrogen†		
	Seedlings*	Leaf samples*	Whole plant**
	%		
Main effects			
Time of cutting leucaena			
Seedling stage	3.63 a	2.89 a	1.67 a
Tasseling stage	3.75 a	2.53 b	1.71 a
Late dough stage	3.45 b	2.61 b	1.52 a
Leucaena rows			
Singe row	3.45 a	2.53 b	1.57 a
Double row	3.77 a	2.82 a	1.69 a
Corn spacing (cm)			
30	3.50 b	2.33 c	1.60 b
50	3.61 ab	2.64 b	1.59 b
70	3.72 a	2.89 a	1.70 a

*Avg of four replications

**Avg of two replications

†Means in the same column within treatments followed by the same letter are not significantly different at the 5% level (Bayes LSD).

percentage nitrogen (3.45%) compared to control (3.20% N). The nitrogen contents of the leaf samples (2.61%) and plant sample (1.52%) where leucaena was cut at the late dough stage were lower than the same plant samples (2.89% N and 1.67% N) of corn plants where leucaena was cut at seedling stage. Cutting leucaena and topdressing at the late dough stage of corn apparently was too late for the corn plant to effectively use the nitrogen released by leucaena.

It should be noted that percentage nitrogen in corn decreased with the age of the corn tissues sampled. The overall percentage N of the seedlings, leaves (tasseling stage) and whole plant samples (late dough stage) were 3.61, 2.67, and 1.63 percent, respectively.

Nitrogen nutrition of intercropped corn in relation to urea-fertilized corn. When the percentage of nitrogen in sampled corn seedlings, leaves and whole plants from the corn-leucaena intercrop were plotted against the nitrogen response curves of the same tissues sampled from the urea-N treatments, the equivalent amounts of fertilizer N required to equal the leucaena contribution could be estimated (Figure 12). The average values of spacing effects under various levels of N were used because their contribution to the N content of the samples were less than the effects of urea-N treatment.

The level of N nutrition in corn seedlings, leaf samples and whole plants (avg overall spacings) in the corn-leucaena intercrop was equivalent to similar corn fertilized with urea at rates of 28 kg N/ha (seedlings), 16 kg N/ha (leaves) and 9.0 kg N/ha (whole plants).

The weight of corn seedlings from the corn-leucaena intercrop grown at 30, 50, and 70 cm corn spacings was about 3.3, 3.6, and 3.8

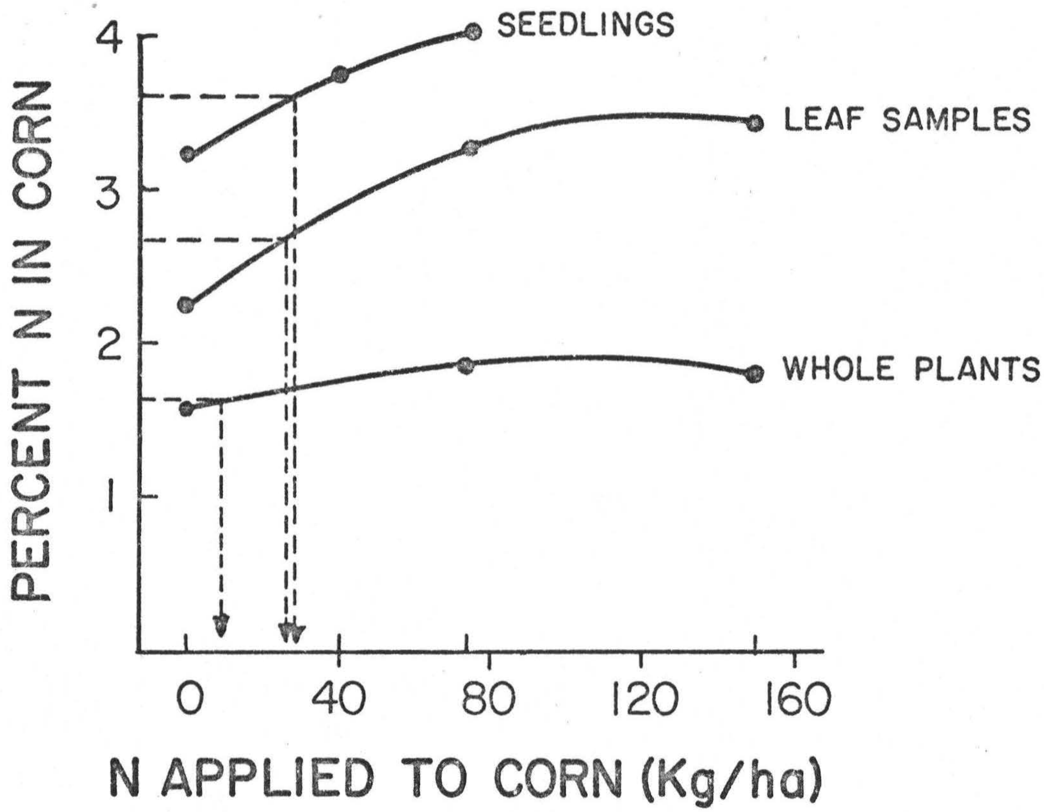


Figure 12. Nitrogen content of corn tissues from corn-leucaena intercrop plotted against the nitrogen tissue response curve of corn under various levels of urea-N. Avg of three corn spacings, two rows and three harvesting treatments of leucaena. Second crop of corn.

g/plant. When plotted against the urea-N response curve of corn seedlings (Figure 13), the seedling weights were equivalent to similar seedlings fertilized with urea at rates of 32, 48, and 58 kg N/ha for seedlings spaced at 30, 50, and 70 cm, respectively.

Grain yield of corn under three spacings within one or two rows of leucaena was plotted against the grain yield response curve of corn in similar spacings under various levels of urea-N (Figure 14). In terms of grain yield (field area basis), leucaena supplied approximately the equivalent of 0 to 12 kg N/ha of urea-N; with the exception of 70 cm spacing of corn intercropped with one row of leucaena (50 kg N/ha). The yields of corn intercropped with two rows of leucaena were lower than in one row of leucaena due to lower corn population per unit of field area.

In terms of nitrogen efficiency, urea-N at 75 kg N/ha resulted in corn grain yield of 5.35 t/ha under 30 cm spacing (Table 13) or a yield increase of 3.23 t/ha over the control (2.12 t/ha) under similar spacing. This is equivalent to the grain yield production of 43.1 kg/kg N applied. Under similar spacing, corn intercropped with single row of leucaena supplied with leucaena forage containing 100 kg N/ha yielded 3.74 t/ha of grain or grain yield increased 1.62 t/ha over the control. Grain yield production of corn in leucaena was 16.2 kg/ha/kg of leucaena-N. Under this system of management, the efficiency of leucaena in supplying nitrogen to corn was about 38 percent of that of urea. This result was similar to the results of the experiments of Fribourg and Bartholomew (1956) where alfalfa supplied nitrogen to corn at the efficiency rate of 35 percent of that of ammonium nitrogen.

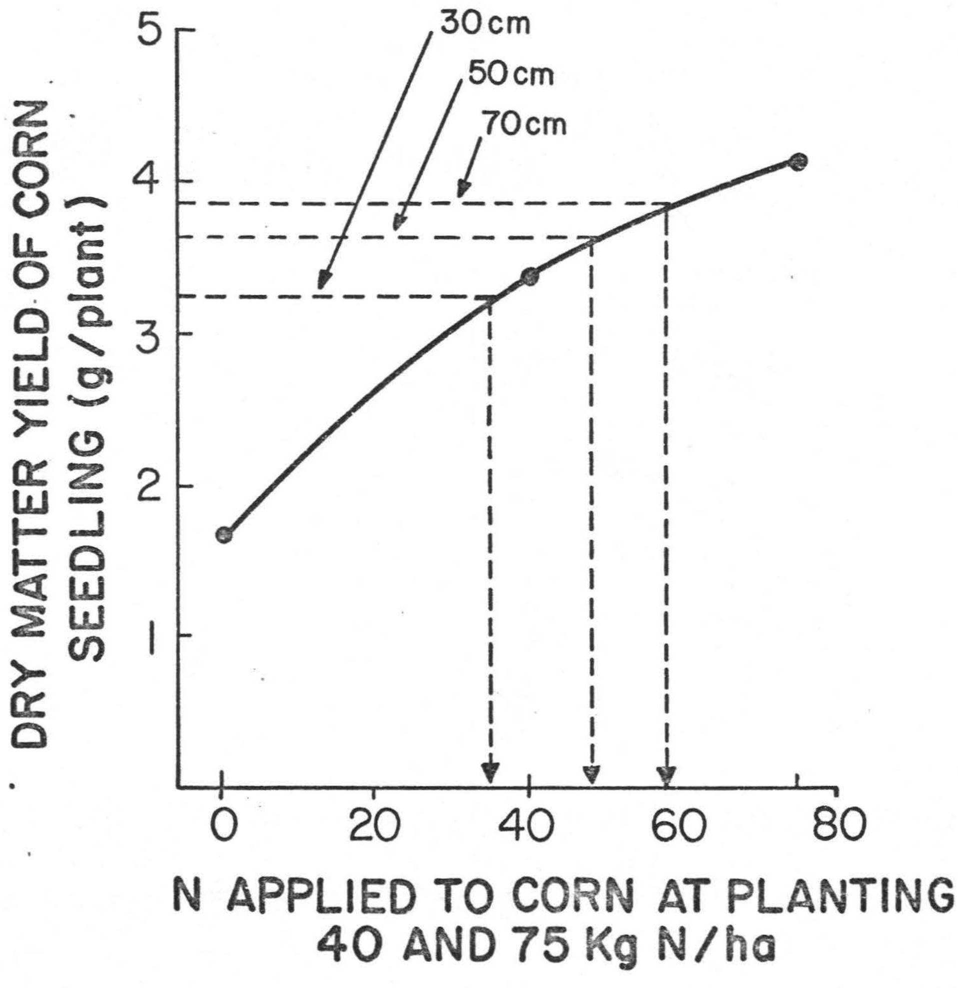


Figure 13. Dry matter yield of corn seedlings at three spacings intercropped with leucaena, plotted against the overall seedling yield response curve of corn under various levels of urea-N. Second crop of corn.

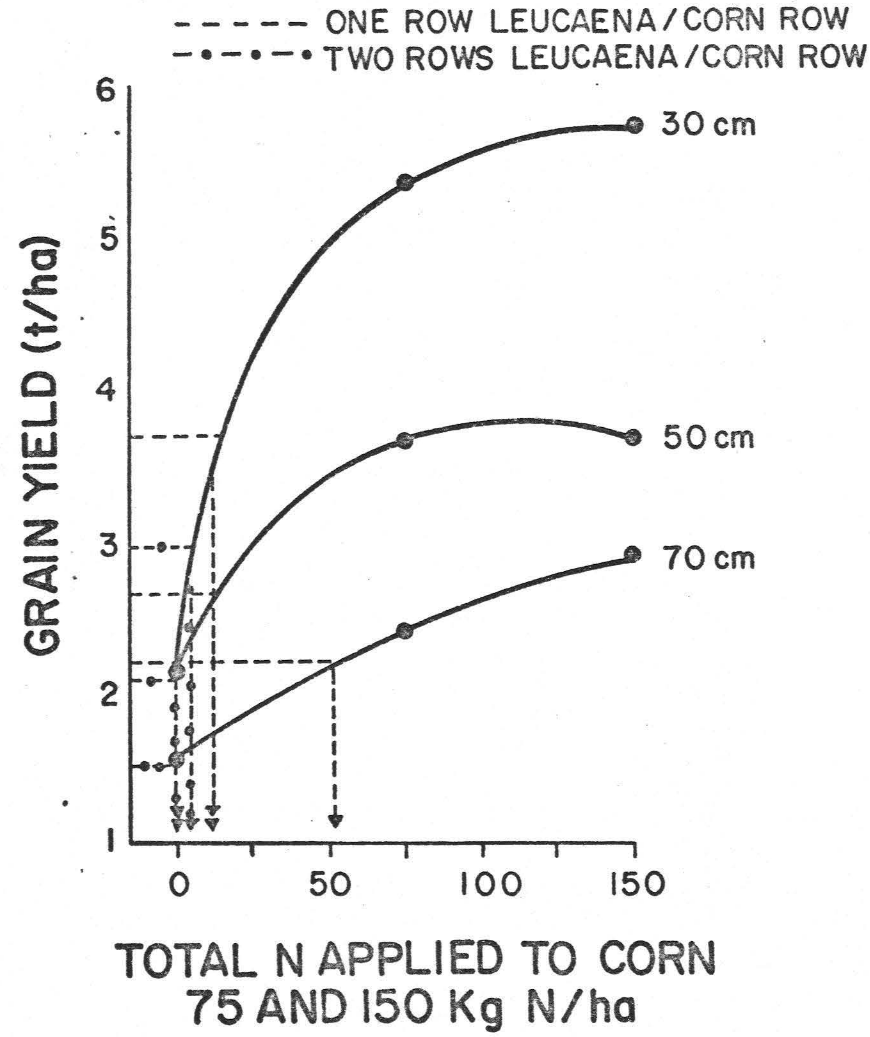


Figure 14, Grain yield of corn under three spacings within one and two rows of leucaena plotted against the grain yield response curve of corn under various levels of urea-N. Avg of yield of corn in leucaena cut at seedling and tasseling stages, and under three spacings. Second crop of corn.

<u>The relationship of corn spacing and application of leucaena-N to corn grain yield.</u> Step-wise regression analyses were done to determine the relationship of grain yield (Y) (corn area basis) with plant spacing (S) and amount of leucaena-N applied (N). In the first crop of corn the multiple correlation coefficient was highly significant for spacing and grain yield at $r_s = 0.904$. The correlation coefficient for leucaena-N and grain yield was only 0.174. However, when leucaena-N data were added to the spacing data, the coefficient of determination increased from 82% to 88%. Although most of the variation in the yield of corn could be attributed to spacing, the addition of leucaena-N may have had a minor influence also. The regression equation was:

$$Y = 5.02 + 0.0064\ (N) - 0.0465\ (S)$$

The simple correlation coefficient for the relationship between spacing and grain yield for the second crop was highly significant at $r_s = 0.865$. The correlation between leucaena-N and yield was again poor with $r_n = 0.166$. The coefficient of determination associated with spacing was 75% and when the leucaena-N data were included, coefficient of determination increased to 84% for an increase of 9 percentage units. The regression equation was:

$$Y = 4.32 + 0.0063\ (N) - 0.0431\ (S)$$

<u>Forage production of corn-leucaena intercrop.</u> Table 19 shows the forage and crude protein yields in corn-leucaena intercrop compared with corn alone during the second crop of corn and 4th cutting of leucaena. Fresh forage yield of corn was estimated from the total dry matter

Table 19. Dry matter, fresh forage, and crude protein yields of leucaena and corn harvested at the late dough stage. Second crop of corn, cut-4 of leucaena.

Treatments	Corn spacing	Fresh weight yield*			Dry matter yield†			Crude protein (CP) yield‡			Percent CP of dry matter
		Leucaena	Corn	Total	Leucaena	Corn	Total	Leucaena	Corn	Total	
	cm	t/ha									%
Leucaena row											
1	30	7.51	19.30	26.81	3.22	5.20	8.42	0.87	0.47	1.34	15.91
	50	6.53	13.78	20.31	2.86	4.13	6.99	0.76	0.40	1.16	16.59
	70	9.80	13.20	23.00	4.21	3.69	7.90	1.14	0.37	1.51	19.11
	Mean	7.94	15.42	23.37	3.43	4.34	7.77	0.92	0.41	1.33	17.20
2	30	10.10	15.86	25.96	4.33	4.19	8.52	1.17	0.40	1.57	18.45
	50	9.31	12.28	21.59	3.98	3.45	7.43	1.12	0.34	1.46	19.65
	70	11.20	9.62	20.82	4.81	2.56	7.37	1.34	0.28	1.62	21.98
	Mean	10.20	12.58	22.79	4.37	3.40	7.77	1.21	0.34	1.55	20.02
N level (kg/ha)											
0	30		13.78	13.78		4.38	4.38		0.41	0.41	9.36
	50		13.78	13.78		4.07	4.07		0.40	0.40	9.82
	70		10.01	10.01		3.13	3.13		0.31	0.31	9.90
	Mean		12.52	12.52		3.86	3.86		0.37	0.37	9.69
75	30		34.77	34.77		8.81	8.81		0.94	0.94	10.66
	50		23.79	23.79		6.21	6.21		0.75	0.75	12.07
	70		15.60	15.60		4.49	4.49		0.54	0.54	12.02
	Mean		24.72	24.72		6.50	6.50		0.74	0.74	11.58

*Leucaena: based on 70% moisture; corn: based on 60% moisture, whole plant green forage calculated as dry grain yield x 6.5.

†Leucaena: based on DM yield at cut-4, corn: based on total DM yield at maturity.

‡Leucaena crude protein yield calculated as DM yield x 6.25 x % N: corn crude protein yield calculated as green forage at 15% moisture x 6.25 x % N.

yield. Corn for green forage was considered ready for harvest at the late dough stage when the moisture content was about 60 percent. The moisture content of the newly harvested leucaena fresh forage was about 70 percent.

At 70 cm corn spacing, leucaena yielded an average of 4.51 t/ha of dry matter, which was significantly higher than the yield of leucaena intercropped with corn planted at higher densities. The yield of leucaena at 30 cm corn spacing (avg 3.77 t DM/ha) was significantly higher than the yield at 50 cm corn spacing (avg 3.42 t DM/ha). The lack of a consistent trend in the yield of leucaena in relation to the corn planting densities cannot be clearly explained from the information obtained.

Leucaena yielded (fresh or dry forage per hectare) 28 percent higher under double-row than single-row planting. Intercropped corn yield was 27 percent (dry weight basis) and 22 percent (fresh weight basis) higher in single leucaena row than in double rows of leucaena. The total yields of corn and leucaena, however, were similar in both leucaena row treatments, 23 t/ha and 7.8 t/ha on fresh and dry weight bases, respectively. These yields were about twice the yield in the monocrop corn where urea-N was not applied, and about equal to the yield of corn when 75 kg N/ha was applied (25 t/ha fresh weight basis). On a dry weight basis, monocrop corn fertilized with 75 kg N/ha yielded lower (6.5 t/ha) than the total yield of corn-leucaena intercrop.

Crude protein yield of leucaena in single-row planting (0.92 t/ha) was lower than with double-row planting (1.21 t/ha). The difference in the crude protein yield was mainly due to the difference in the total dry matter yields. Crude protein yields of corn in the corn-leucaena intercrop and monocrop corn without urea-N were about equal (average 0.37 t/ha). These yields were 45 percent lower than the protein yields of monocrop corn fertilized with urea at 75 kg N/ha.

The combined crude protein yields of corn leucaena intercrop averaged four times higher (1.44 t/ha) than in the monocrop corn without urea-N (0.37 t/ha) and two times higher than corn fertilized with 75 kg N/ha.

The total dry matter yields in corn-leucaena intercrop and monocrop corn consisted of an average of 19 percent and 11 percent crude protein, respectively.

Summary and Conclusions

Leucaena and corn were intercropped to compare the yield and nitrogen response of corn to N supplied from leucaena and from urea. The effects of intercropping, including several agronomic variables, on the yield and nitrogen content of corn and leucaena were also studied.

The leucaena (variety K8) intercropped with corn (single cross hybrid H610) made excellent growth which was comparable to that obtained in the monocropping experiment. A high level of residual soil N from a previous sorghum experiment minimized the effects of urea and leucaena forage application to the first crop of corn. This effect was negligible during the second corn crop. A third corn planting was made but abandoned due to extreme variability associated with a different planting arrangement which caused heavy wind damage to the corn.

The regrowth duration and the cutting sequence of leucaena followed the vegetative and reproductive stages of corn. The rate of growth of corn and leucaena was slow during the season of low temperature and solar radiation. The effects of climatic factors were most pronounced during the seedling stage. The seedling stage of corn was about 20 days longer during the second corn crop than during the first corn crop.

The amount of leucaena forage produced and added to the corn increased with delayed cutting, was greater with double rows than with single rows of leucaena, and was slightly enhanced at low corn plant densities.

Percent nitrogen of the total leucaena DM decreased with delayed harvest due to the increase in the proportion of stem fraction to the forage fraction. Corn spacing and number of rows of leucaena did not significantly influence percentage N in the forage.

The contribution of leucaena N to each corn crop varied from about 60 to 180 kg/ha.

First Corn Crop

During the first corn crop, the application of either urea or leucaena forage did not affect the yield of corn grain and stover because of the presence of residual N from a previous sorghum experiment. In addition, the short history of leucaena cropping did not permit the application of large quantities of leucaena forage. Higher grain and stover yields were obtained with close spacing of the corn than with wider spacing. The grain yields of corn intercropped with single row of leucaena per corn row cut at seedling stage (3.48 t/ha) or tasseling (3.56 t/ha) stage were comparable to the grain yields of the check plots (3.45 t/ha). Yields of corn grain and stover from corn intercropped with double rows of leucaena were lower than in single rows on a field area basis but higher on a corn area basis and per plant basis.

Fertilization with urea did not affect the levels of N in the leaf samples and whole plant samples at the late dough stage. The nitrogen content of the ear leaf samples of intercropped corn ranged from 2.3 - 2.7% with no differences due to treatments. Without N, nitrogen percent in ear leaf samples ranged from 2.4 - 2.9. Symptoms of nitrogen deficiency were not observed in any of the corn plants.

Second Corn Crop

Corn responded significantly to urea fertilizer. The yield response of both seedlings and grain to nitrogen was greater than the stover yield. Apparently, photosynthates and reserve carbohydrates in the stover were translocated into the grain at the later stage of plant growth. Corn seedlings yielded from 2.70 - 4.36 g/plant with leucaena-N; in the check treatment, they yielded from 1.48 - 1.86 g/plant. The grain yields of corn intercropped with leucaena averaged 2.39 t/ha which was 23 percent higher than the check. Grain yields were higher when leucaena was applied at the early stage of corn growth.

The amounts of leucaena-N produced and applied to corn were higher when leucaena was cut at the late dough stage, but this was too late to be effectively utilized by the corn. At wider corn spacing, the time when the leucaena was cut had little influence on corn yield.

The average yield of corn per unit of field area intercropped with one row of leucaena was higher than with two rows of leucaena per row of corn. On a corn area basis, however, corn intercropped with two rows of leucaena yielded more than corn intercropped with a single row of leucaena. The effects of various treatments on the N contents of the plant samples were similar to their effects on grain yields.

Nitrogen content of the seedlings, leaf and whole plant samples increased as amounts of urea and leucaena forage applied increased. Under urea-N treatments, where nitrogen was not limiting at the seedling stage of corn, plant spacing had a limited influence on the N content of the seedlings. However, with increased growth of corn and N uptake, plant spacing or planting density greatly influenced the N content of the corn plants. With intercropping of corn and leucaena, the nitrogen content of the corn plant tissue increased consistently with increased plant spacing.

The equivalent amounts of urea-N required to equal the nitrogen contribution of leucaena forage were estimated based on: (1) the concentration of N in the corn plant tissue samples, (2) the weight of corn seedlings, and (3) grain yields. The equivalent urea-N in the intercropped corn were as follows: corn plant tissue samples, 9 - 28 kg N/ha; weight of seedlings, 32 - 58 kg N/ha; and grain yield, 0 - 12 kg N/ha. The efficiency of leucaena in supplying nitrogen to corn was about 38 percent of that of urea. This estimate was obtained by comparing the grain yield increase over the control (0 nitrogen) of the following treatments; 75 kg N/ha from urea against 100 kg N/ha from leucaena with the corn spaced 30 cm between plants (33,333 plants/ha).

The correlation between corn spacing and grain yield ($r = -0.87$) was greater than that of leucaena-N and grain yield ($r = 0.17$). The coefficient of determination associated with spacing was 75 percent and when leucaena-N data were added to the spacing data, the coefficient of determination increased to 84 percent.

Therefore, based on these findings, leucaena contributed significantly to the nitrogen requirements of the intercropped corn. Release of other nutrients from the leucaena forage to corn was not determined but its importance was not overlooked.

The total fresh forage production in the second corn-leucaena intercrop (23 t/ha) was considerably higher than in corn alone without added urea-nitrogen (12 t/ha). The yield of fresh forage in the corn-leucaena intercrop was comparable to the yield of corn alone (25 t/ha) fertilized with 75 kg N/ha from urea.

Crude protein yields were considerably higher in the corn-leucaena intercrop (1.44 t/ha) compared to corn alone (0.75 t/ha) fertilized with 75 kg N/ha of urea or without nitrogen (0.37 t/ha).

Percent crude protein of the corn-leucaena forage ranged from 15.91 to 21.98 percent. Percent crude protein of corn without N was 9.36 to 9.90 percent and at 75 kg N/ha, 10.66 to 12.07 percent.

Therefore, the value of intercropping leucaena and corn for forage production was associated with the ability of the corn to utilize some of the nitrogen fixed by leucaena. In addition, forage yield, crude protein yield and percentage crude protein increased significantly in the corn-leucaena mixture compared to the monocropping of corn.

Appendix Table I. General description of the soil profile of Hawi, latitude 20°14'07" N, longitude 155°52'48" W and elevation of 130 meters (Gardiner, 1967).

Soil depth (cm)	General description of the soil
0-15	Dark brown (7.5 YR 3/3, moist), dark brown (10 YR 3/4, dry); clay; strong fine granular structure; soft (dry), friable (moist), sticky and plastic (wet); smooth clear boundary; abundant roots; fine and very fine pores; few rock fragments and a few black specks.
15-38	Dark brown (7.5 YR 3/3, moist), dark brown (10 YR 3/4, dry); clay; moderate, coarse blocky structure and moderate, fine subangular blocky structure; soft but ped hard (dry), friable (moist), sticky and plastic (wet); wavy clear boundary; abundant roots; fine to very fine pores; few black specks.
38-66	Dark brown (7.5 YR 3/3, moist), dark brown (10 YR 3/4, dry); clay loam; weak, coarse prismatic structure; hard (dry), very firm (moist), sticky and plastic (wet), wavy gradual boundary; few roots confined to vertical abundant fine cracks; few rock fragments.
66-83	Dark brown (7.5 YR 3/4, moist), dark brown (10 YR 3/4, dry); silty clay loam; weak, medium subangular blocky structure; hard (dry), firm (moist), sticky and plastic (wet); wavy gradual boundary; few roots, abundant fine to very fine pores; common rock fragments.
83-122	Dark brown (7.5 YR 3/4, moist), dark brown (10 YR 3/4, dry); silty clay loam; structureless; soft (dry), friable to firm (moist), slightly sticky and plastic (wet); wavy gradual boundary; very few roots; abundant fine to very fine pores; many rock fragments.
122 +	Dark brown (7.5 YR 3/4, moist), dark brown (10 YR 3/4, dry); silt loam; weak, medium subangular blocky structure; soft (dry), friable (moist), slightly sticky and slightly plastic (wet); wavy gradual boundary; very few roots; abundant fine to very fine pores.

Appendix Table II. Exchangeable cations, free salt, pH and percent secondary minerals of Hawi soil (Gardiner, 1967).

Soil Properties	Soil depth (cm)					
	0-15	15-38	38-66	66-84	84-122	122+
CEC (pH = 7)	30.4	25.0	25.9	34.9	45.4	39.5
Ca^{++}m.e./100g	16.3	9.6	11.2	17.4	25.1	19.1
Mg^{++}m.e./100g	9.5	8.2	9.1	10.3	13.2	13.9
Na^{+}m.e./100g	0.73	0.91	1.2	3.7	6.1	7.9
K^{+}m.e./100g	3.8	2.8	1.7	1.7	0.39	0.14
Total bases m.e./100g	30.3	21.5	23.2	33.1	44.8	41.1
% Base saturation	100	86	89	95	99	104
Free salt	0.60	0.39	0.55	0.65	0.71	1.1
pH	6.8	6.6	6.8	7.3	7.7	7.5
Kaolin (%)	54	58	59	58	46	50
Quartz (%)	5.3	4.9	4.9	2.1	1.3	0.5
Illite (%)	13.4	13.0	13.0	4.6	0.3	0.5
Gibbsite (%)	2.6	2.2	2.2	1.4	0.5	0.3

Appendix Table III. The effects of plant height at cutting, intra-row spacing on dry matter yields of K341 over a 16-month period.

			DM yield per cutting					
			Intra-row spacing					
Avg height	Date of		15 cm		30 cm		45 cm	
at cutting	cutting		FF†	Stem	FF†	Stem	FF†	Stem
cm			t/ha					
55	22 Jun 74		2.00	0.50	1.42	0.31	1.17	0.20
	29 Aug 74		3.44	1.15	2.98	0.92	2.57	0.68
	25 Oct 74		2.45	0.76	2.20	0.61	1.95	0.50
	9 Jan 75		2.15	0.40	1.91	0.40	1.76	0.39
	4 Apr 75		2.42	0.45	2.30	0.48	2.07	0.43
	25 Jun 75		2.70	0.57	2.69	0.73	2.33	0.51
		Mean	2.53	0.64	2.25	0.58	1.97	0.45
105	15 Jul 74		3.62	1.95	2.97	1.19	2.80	1.00
	18 Oct 74		3.77	3.10	3.74	2.64	3.77	2.47
	27 Jan 75		3.62	1.34	3.29	1.10	3.23	0.92
	16 May 75		3.51	1.17	3.19	1.05	2.93	0.99
	11 Aug 75		3.25	1.67	3.71	1.58	3.72	1.67
		Mean	3.55	1.85	3.38	1.51	3.29	1.41
155	22 Aug 74		4.94	4.67	5.21	4.06	3.50	2.47
	9 Dec 74		4.08	2.47	4.37	3.70	3.51	2.36
	22 Apr 75		3.91	2.14	4.46	2.31	3.88	1.92
	11 Aug 75		5.01	3.40	5.14	3.76	4.86	3.22
		Mean	4.49	3.17	4.80	3.46	3.94	2.49

†FF: Forage fraction

Appendix Table IV. The effects of plant height at cutting on dry matter yields and percent forage fraction of K341 over a 16-month period. Avg of three intra-row spacings.

Avg height at cutting	Date of cutting		DM yield per cutting FF†	DM yield per cutting Stem	Percent forage fraction
cm			t/ha	t/ha	%
55	22 June 74		1.53	0.34	82
	29 Aug 74		3.00	0.92	77
	25 Oct 74		2.20	0.62	78
	9 Jan 75		1.94	0.40	83
	4 Apr 75		2.26	0.45	83
	25 Jun 75		2.57	0.60	81
		Mean	2.25	0.56	81
105	15 Jul 74		3.13	1.38	69
	18 Oct 74		3.76	2.74	58
	27 Jan 75		3.38	1.12	75
	16 May 75		3.21	1.07	75
	11 Aug 75		3.56	1.64	68
		Mean	3.41	1.59	68
155	22 Aug 74		4.55	3.73	55
	9 Dec 74		4.02	2.84	59
	22 Apr 75		4.08	2.12	66
	11 Aug 75		5.00	3.46	59
		Mean	4.41	3.04	60

†FF: Forage fraction

Appendix Table V. The effects of plant height at cutting and intra-row spacing on dry matter yields of K8 over a 16-month period.

Avg height at cutting	Date of cutting		DM yield per cutting — Intra-row spacing — 15 cm FF†	15 cm Stem	30 cm FF†	30 cm Stem	45 cm FF†	45 cm Stem
cm			t/ha					
55	6 Jun 74		0.99	0.35	0.62	0.16	0.46	0.12
	29 Jul 74		2.29	1.03	1.67	0.64	1.39	0.52
	20 Sep 74		2.00	1.00	1.72	0.71	1.51	0.66
	14 Nov 74		1.51	0.51	1.41	0.45	1.09	0.41
	4 Feb 75		1.29	0.19	1.08	0.19	0.95	0.23
	2 May 75		1.63	0.32	1.37	0.24	1.33	0.26
	27 Jun 75		1.88	0.30	1.81	0.32	1.80	0.35
		Mean	1.65	0.53	1.38	0.39	1.22	0.36
105	1 Jul 74		2.75	1.64	2.05	1.14	1.82	0.96
	13 Sep 74		2.78	1.90	2.49	1.67	2.51	1.61
	13 Nov 74		2.04	0.71	1.87	0.84	1.86	0.81
	27 Mar 75		3.19	1.17	2.75	1.08	2.86	1.08
	25 Jun 75		3.64	1.25	3.64	1.20	3.60	1.17
		Mean	2.88	1.33	2.56	1.19	2.53	1.13
155	22 Jul 74		3.42	3.45	3.53	2.97	3.04	2.83
	15 Oct 74		3.61	3.10	3.33	2.64	3.39	2.74
	17 Mar 75		3.55	3.17	3.32	2.55	3.39	2.37
	30 Jun 75		4.16	2.37	4.16	2.10	3.84	2.32
		Mean	3.68	3.02	3.59	2.56	3.41	2.56

†FF: Forage fraction

Appendix Table VI. The effects of plant height at cutting and dry matter yields of K8 over a 16-month period. Avg of three spacings.

Avg height at cutting	Date of cutting		DM yield per cutting FF†	Stem	Percent forage fraction
cm			t/ha		%
55	6 Jun 74		0.69	0.21	77
	29 Jul 74		1.78	0.73	71
	20 Sep 74		1.74	0.79	69
	14 Nov 74		1.34	0.46	74
	4 Feb 75		1.11	0.20	85
	2 May 75		1.44	0.27	84
	27 Jun 75		1.83	0.32	85
		Mean	1.42	0.43	77
105	1 Jul 74		2.21	1.25	64
	13 Sep 74		2.59	1.72	60
	13 Nov 74		1.92	0.79	71
	27 Mar 75		2.93	1.11	72
	25 Jun 75		3.63	1.21	75
		Mean	2.66	1.22	68
155	22 Jul 74		3.33	3.08	52
	15 Oct 74		3.44	2.83	55
	17 Mar 75		3.42	2.70	56
	30 Jun 75		4.05	2.26	64
		Mean	3.56	2.72	57

†FF: Forage fraction

Appendix Table VII. Analysis of variance of the annual dry matter and nitrogen yields (kg/ha), and percentage forage fraction of leucaena (variety x cutting x spacing, leucaena).

Source of variation	df	Annual dry matter yield: Forage fraction	Annual dry matter yield: Stem fraction	Percent forage fraction	Annual nitrogen yield: Forage fraction	Annual nitrogen yield: Stem fraction
		Mean squares				
Reps(R)	3	10774865*	11954392**	59.2*	25250*	1521*
Variety(V)	1	76797355**	3941496**	66.1*	128609**	2775*
Error(a)	3	486760	60442	2.5	2465	95
Cutting(C)	2	48220184**	229296987**	2522.2*	77083**	32709**
V x C	2	3336066*	598721	15.8	17626**	351
Error(b)	12	815539	1170150	5.8	1600	170
Spacing(S)	2	16533144**	10379420**	32.8**	28041**	2384**
V x S	2	1244976	2186222**	8.3	1441	421**
C x S	4	2480404*	876534*	1.8	4469	163
V x C x S	4	498299	1336837**	6.2	1619	153
Error(c)	36	626510	254942	3.2	1744	63
Total	71					

*Significant at 5% level

**Significant at 1% level

Appendix Table VIII. Analysis of variance of the percentage nitrogen and mimosine, stem diameter (mm) and stem count (thousand/ha) of leucaena (variety x cutting x spacing, leucaena).

Source of variation	df	Percent nitrogen: Forage fraction	Percent nitrogen: Stem fraction	Percent mimosine: Forage fraction	Percent mimosine: Stem fraction	Stem diameter	Stem count
		Mean squares					
Reps(R)	3	0.04	0.15	1.00	0.04	0.94	1723
Variety(V)	1	0.04	0.14	5.21	0.30	2.80	17547
Error(a)	3	0.10	0.50	2.79	0.15	0.40	2803
Cutting(C)	2	0.20**	1.01	1.50	0.10	69.38**	2709
V x C	2	0.18**	0.03	2.60*	0.47**	2.81**	4407*
Error(b)	12	0.03	0.28	0.60	0.04	0.23	1012
Spacing(S)	2	0.05	0.23	0.99	0.08*	18.95**	171168**
V x S	2	0.02	0.38	1.10	0.01	0.92	3289*
C x S	4	0.01	0.16	0.93	0.04	1.05*	1223
V x C x S	4	0.07	0.44	1.42*	0.01	0.28	380
Error(C)	36	0.03	0.25	0.39	0.02	0.34	728
Total	71						

*Significant at 5% level

**Significant at 1% level

Appendix Table IX. Analysis of variance of total dry matter yields (kg/ha) of leucaena at various cuttings, intercropped with the first and second crops of corn.

Source of variation	df	Total dry matter yields at indicated cutting				Dry matter yields from the combined harvest of leucaena	
		Cut-1	Cut-2	Cut-3	Cut-4	(Cut-1 + Cut-2)†	+ (Cut-3 + Cut-4)‡
		Mean squares					
Rep(R)	3	2087097	736943	2626792**	5516360	4391952	9574907
Harvest(H)	2	300019	72984719**	20957053**	55183312**	76166860**	8005480
Error(a)	6	2143648	824171	233946	7991752	1749970	7999209
Rows(Rn)	1	733260	14315709**	15245322**	9146365**	21528828**	47646695**
H x Rn	2	253066	2296277	2912469**	589339*	3826835	1497169
Error(b)	9	1113666	910997	278829	108528	1701739	439652
Spacing(C)	2	244685	1131824**	239520	812890**	1947733	1455544**
H x C	4	156415	1040308**	41965	848294**	1604616	962834**
Rn x C	2	24536	209818	10480	160461	272832	182437**
H x Rn x C	4	341849	246172	128132	35986	834240	146360**
Error(c)	36	481538	161090	90245	151076	943030	29210
Total	71						

*Significant at 5% level

**Significant at 1% level

†Leucaena forage applied to the 1st crop of corn

‡Leucaena forage applied to the 2nd crop of corn

Appendix Table X. Analysis of variance of percent nitrogen and nitrogen yields (kg/ha) of total dry matter of leucaena at various cuttings intercropped with the first and second crops of corn.

Source of variation	df	Percent N at indicated cutting				N yield at indicated cutting				N applied to corn crop from combined harvests of leucaena	
		Cut-1	Cut-2	Cut-3	Cut-4	Cut-1	Cut-2	Cut-3	Cut-4	(Cut-1+Cut-2)†	+(Cut-3+Cut-4)‡
		Mean squares									
Rep(R)	3	1.27**	0.23	3.18	0.83	2807	1046	2026	14244	5673	23893
Harvest(H)	2	0.01	10.23**	3.21	0.87	300	40793**	19315**	107554*	46588**	35653
Error(a)	6	0.07	0.46	1.23	1.07	2755	1079	1297	21202	2527	16957
Rows(Rn)	1	0.01	0.34	1.55	0.33	399	12795**	10695**	20200**	17829**	60436**
H x Rn	2	0.03	0.03	0.63	0.07	427	1118	1514**	1460**	2895	885
Error(b)	9	0.12	0.22	0.34	0.16	1482	475	297	113	1441	462
Spacing(C)	2	0.07	0.06	0.32**	0.06	436	689**	258	1832**	1927	3305**
H x C	4	0.01	0.10	0.09**	0.12	241	622**	99	1534**	1222	1631*
Rn x C	2	0.00	0.07	0.26**	0.02	43	342*	23	192	591	1285
H x Rn x C	4	0.01	0.17	0.19**	0.03	466	303*	77	63	597	105
Error(c)	36	0.06	0.04	0.02	0.13	783	93	114	319	1068	538
Total	71										

*Significant at 5% level

**Significant at 1% level

†Leucaena forage yields applied to the 1st crop of corn

‡Leucaena forage yields applied to the 2nd crop of corn

Appendix Table XI. Analysis of variance of grain yields (kg/ha), seedling weights (g/plant) and percentage nitrogen of the first and second crops of corn intercropped with leucaena and fertilized with leucaena-N.

		First crop of corn				Second crop of corn					
		Dry matter yield		Percent N		Dry matter yield			Percent N		
Source of variation	df	Grain	Stover	Leaf samples	Whole plant†	Grain	Stover†	Seedling	Seedlings	Leaf samples	Whole plant†
		Mean squares									
Rep(R)	3	1703572	6016660*	1.24*	0.00	1275716	1078136	859**	11.23**	1.36*	0.09
Harvest(H)	2	1469319	1698001	0.12	0.03	1159170	753538	20	0.56*	1.37*	0.13
Error(a)	6	569504	740770	0.20	0.03	356306	746842	26	0.07	0.16	0.02
Rows(Rn)	1	19125051**	16433645**	0.06	0.03	6295335**	1526872	219*	1.79	2.88**	0.14
H x Rn	2	362649	527366	0.06	0.00	165079	31618	18	0.03	0.05	0.00
Error(b)	9	345349	866977	0.08	0.01	397067	177330	29	0.08	0.03	0.08
Spacing(C)	2	14921579**	9448140**	0.41*	0.07	10724016**	3644069**	50**	0.31*	1.88**	0.04*
H x C	4	488773	385375**	0.04	0.01	211990*	231888	13	0.02	0.04	0.03
Rn x C	2	544908	290628**	0.00	0.01	75246	30332	3	0.01	0.01	0.05
H x Rn x C	4	246354	341334	0.05	0.03	73619	76405	20	0.08	0.01	0.02
Error(c)	36	284623	20649	0.09	0.02	77958	78453	9	0.06	0.02	0.01
Total	71										

*Significant at 5% level

**Significant at 1% level

† Two replications

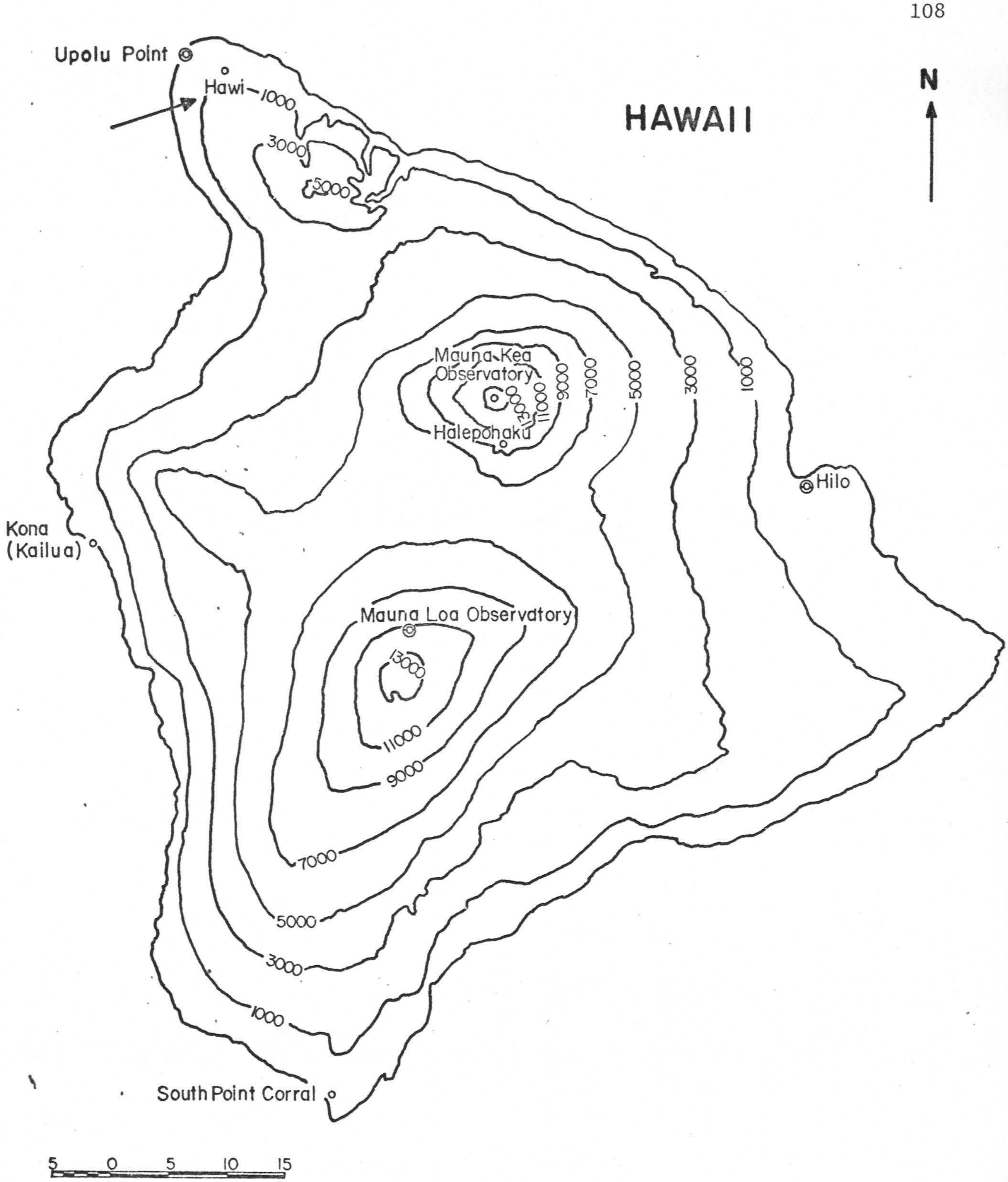
Appendix Table XII. Analysis of variance of grain yields (kg/ha), seedling weights (g/plant) and percentage nitrogen of the first and second crops of corn under various levels of urea-N.

		First crop of corn				Second crop of corn					
		Dry matter yield		Percent N		Dry matter yield			Percent N		
Analysis of variance	df	Grain	Stover	Leaf samples	Whole plant†	Grain	Stover†	Seedling	Seedlings	Leaf samples	Whole plant†
		Mean squares									
Rep(R)	3	1267747	3873891	1.02**	0.02	743879	1508584	573*	3.85**	0.42	0.05
N level(N)	2	2032724	609993	0.40	0.01	16607796*	2166367*	501	2.03**	4.96**	0.15
Error(a)	6	2069980	1726539	0.09	0.00	1595397	283510	109	0.16	0.14	0.03
Spacing(C)	2	11244037**	10222429**	0.41*	0.01	13573747**	2624942**	0.41	0.06	0.50**	0.05
N x C	4	171663	456555	0.02	0.00	2072010**	260333	5	0.03	0.01	0.00
Error(b)	18	321911	667864	0.03	0.01	139467	196997	3	0.05	0.04	0.03
Total	35										

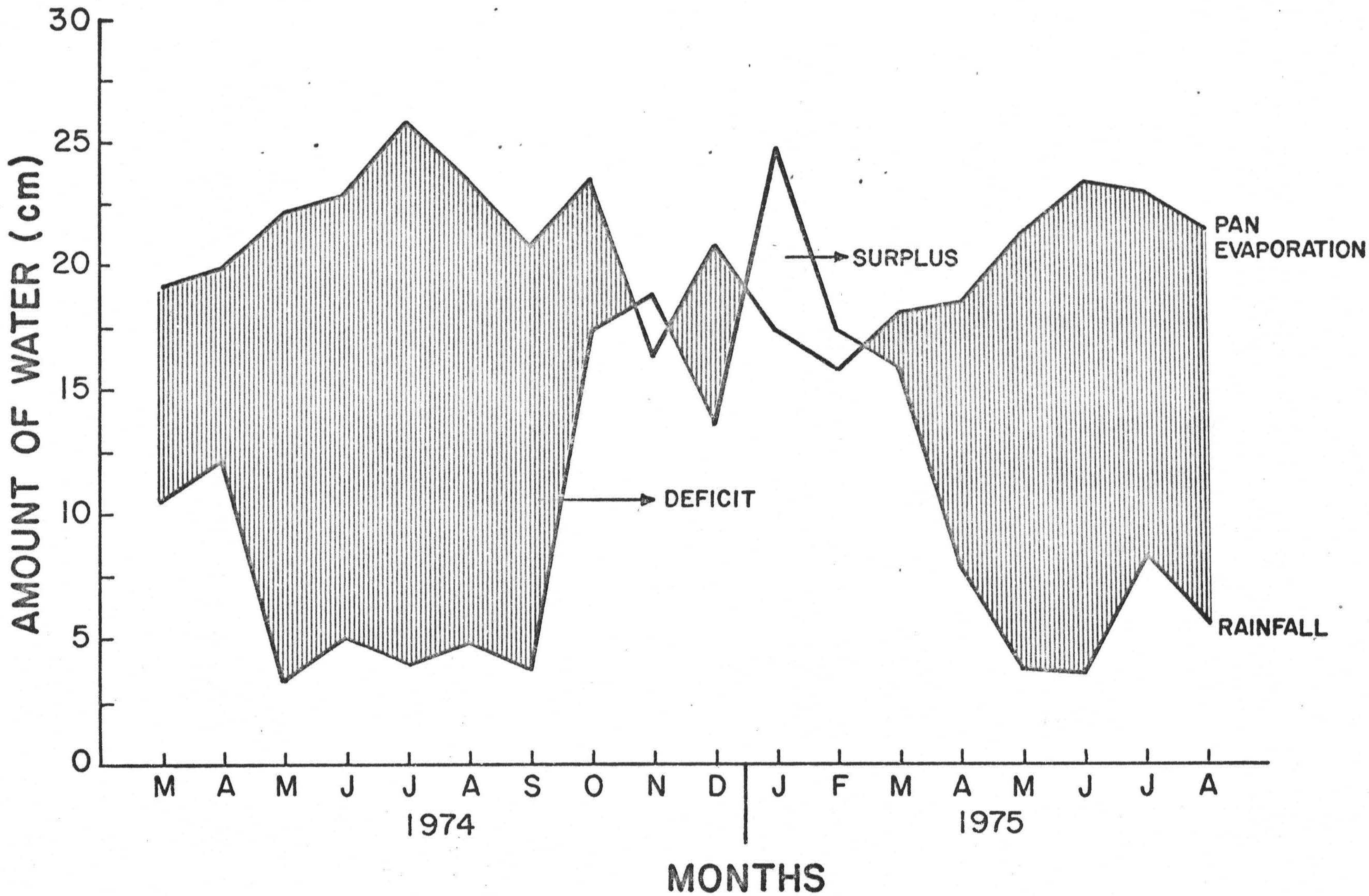
*Significant at 5% level

**Significant at 1% level

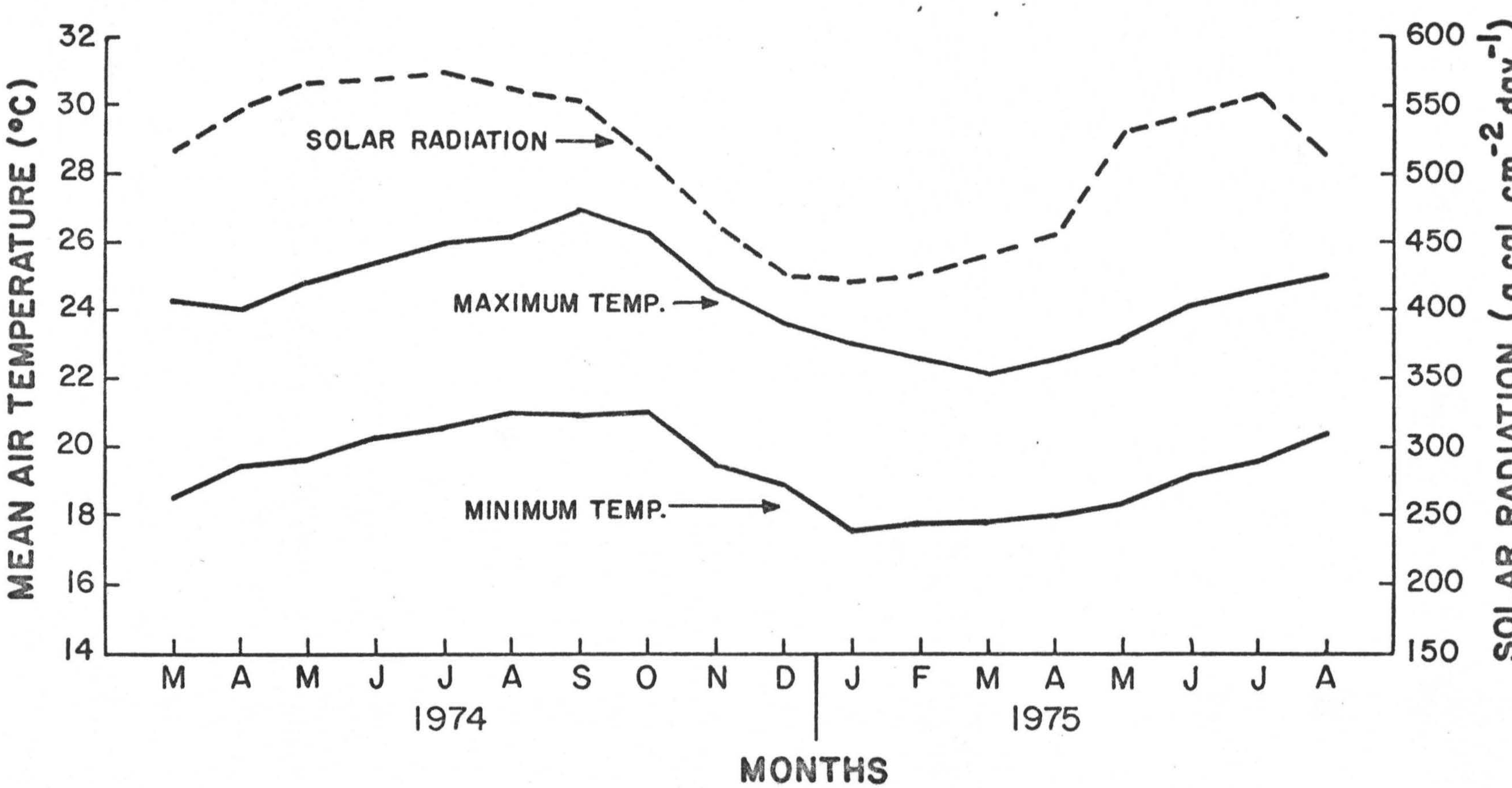
†Two replications



Appendix Figure I. Map of Hawaii, location of the experiment was at Hawi (↑), on the northern side of the island (Climatological Data, Hawaii and Pacific. U.S. Dept. of Commerce, Monthly Report).

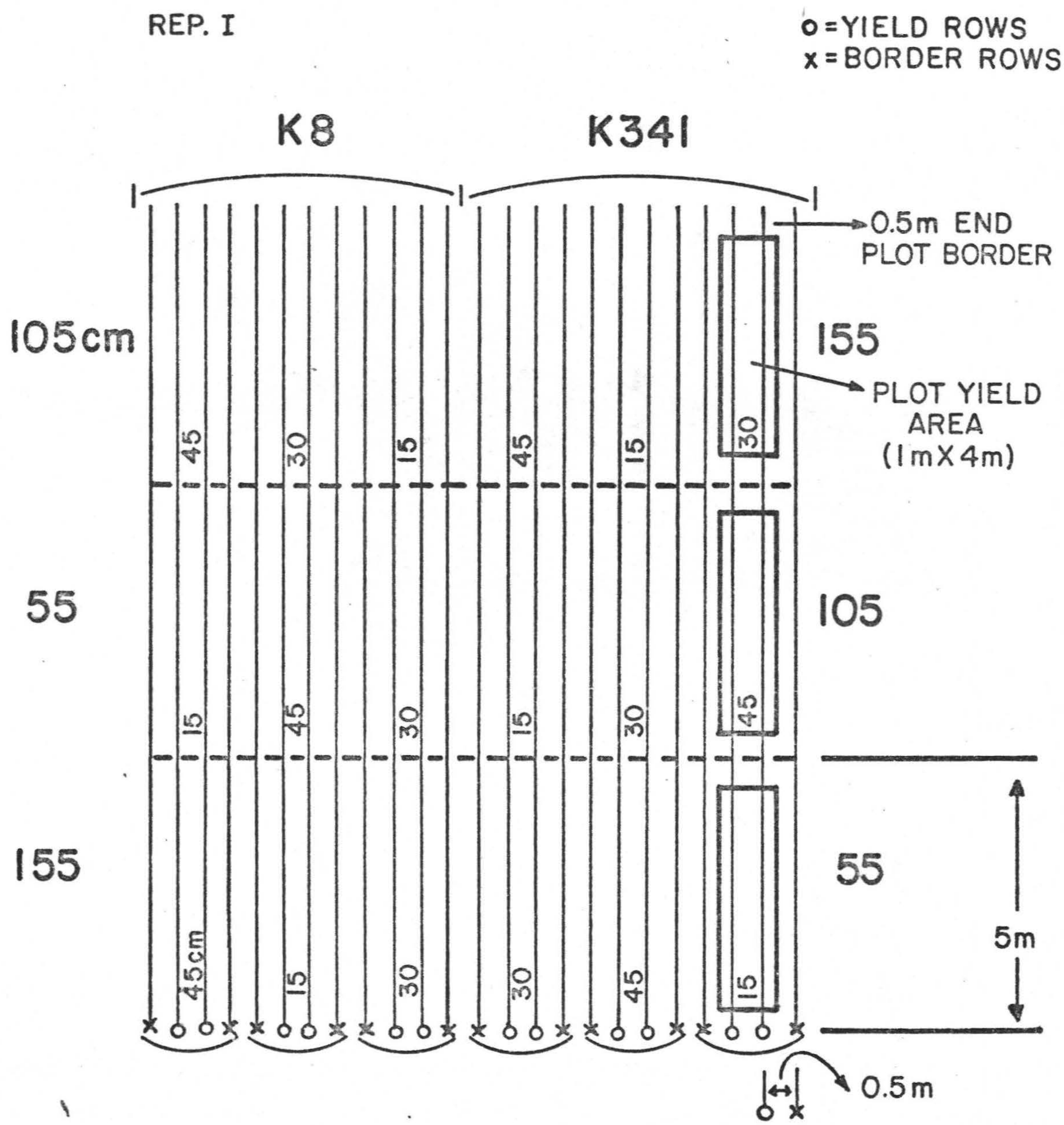


Appendix Figure II. Monthly rainfall and pan evaporation in Hawi during the conduct of the experiments.



Appendix Figure III. Monthly mean air temperature and solar radiation during the conduct of the experiments.

Appendix Figure IV. General view of leucaena at various stages of growth in the variety, cutting intervals and intra-row spacing experiment.



Appendix Figure V. Plot field layout showing the arrangement of treatments, plot dimensions and plot yield area (variety x cutting x spacing; leucaena).

Appendix Figure VI. K8 at three heights of cutting.

Appendix Figure VII. Stumps of leucaena after being cut four times at attained height of 155 cm during 15 months of growth.

Appendix Figure VIII. Forage and stem fractions in K8 and K341. Flower bud in K341 indicated by an arrow.

Appendix Figure IX. Partial view of corn-leucaena intercrop. A: 1 row of leucaena per row of corn; B: 2 rows of leucaena per row of corn; C: corn urea-N plot (75 kg N/ha).

Appendix Figure X. Chopped leucaena and fertilizers (no N) tilled into the soil before planting corn; note stumps of recently-harvested leucaena.

Appendix Figure XI. Corn-leucaena intercrop after 1.5 months of growth, just before leucaena was cut and topdressed to corn.

Appendix Figure XII. Leucaena forage cut and topdressed to corn. Note leucaena stumps in foreground.

Appendix Figure XIII. Corn growth and leucaena regrowth. The leucaena had been previously cut and sidedressed to the corn at the 1.5 months stage of growth.

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To Elsa, Mayette and Agnes