CULTURAL PRACTICES FOR PIGEON PEA (*Cajanus cajan* (L.) Millsp.) AS FORAGE, GREEN MANURE, AND GRAIN CROPS

BY

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Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

CULTURAL PRACTICES FOR PIGEON PEA (Cajanus cajan (L.) Millsp.) AS FORAGE, GREEN MANURE, AND GRAIN CROPS

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Pigeon pea (Cajanus cajan (L.) Millsp.) is a promising new crop plant for Florida and Southern USA. Pigeon peas were evaluated as forage, green manure, and grain crops under different cultural practices during two seasons.

Ten cultivars or lines of pigeon pea grown for forage from 15 May to 2 November 1979, and from 22 April to 7 November 1980, were cut at heights of 25 and 50 cm. All plants were harvested three times, except for the 50 cm cutting height in 1980 which was harvested four times. Two-year average annual dry matter yields varied among cultivar-lines from 3.46 to 6.08 t/ha. In vitro organic matter digestibility (IVOMD) of forage ranged from 41.4 to 68.8%, and crude protein ranged from 17.3 to 31.9%.

Ten cultivars or lines were planted in rows 41 cm apart on 22 April and harvested on 24 September 1980. The highest dry matter yield was 9.0 t/ha by ICP 6344. Nitrogen concentration of cultivar-line entries ranged from 2.0 to 2.8% and N yield from 25 to 190 kg/ha.

Field experiments conducted in 1979 and 1980 to study pigeon pea as a grain crop included a cultivar and several lines, three dates of planting, three row widths, and three plant populations. Several Florida lines gave highest grain yields--2,520 kg/ha for FL 81d in 1979 and 2,120 kg/ha for FL 24c in 1980. Optimum planting time for grain was 15 June to 5 July when Florida lines should give high grain yields with little risk of freeze damage. Row widths of 41, 61, and 91 cm, and plant populations ranging from 3.3 to 13.2/m^2 had little effect on grain yield, plant height, days to 50% flowering, pod maturity, and number of seeds per pod.

Early plantings produced lower grain yield per hectare, taller plants, higher percentage of pod maturity, higher leaf area index, and lower harvest index than did late plantings.

INTRODUCTION

Pigeon pea (Cajanus cajan (L.) Millsp.) has the potential to become a forage, green manure, and grain crop in Florida and the Southern USA. Pigeon pea has the ability to grow well in marginal land and in a wide range of soil types. It is a legume and is capable of fixing its own N. High yields are obtainable from pigeon pea, both as grain and/or vegetable seed pods or as forage.

This crop has been widely used as human food and, to a lesser extent, for livestock nutrition in many parts of the world, including India, South America, Southeast Asia, and many African countries. Pigeon pea seeds contain 19 to 30% protein, and are high in carbohydrates, Ca, P, and Fe. They are also a good source of vitamins A and B.

The podded green top of pigeon pea fed to milking cows not only resulted in higher milk production than with alfalfa (Medicago sativa L.), but also provided sufficient protein to substitute for soybean meal. Cattle fed on pigeon pea pastures increased their live weight rapidly (Gooding, 1962; Krauss, 1932; and Schaaffhausen, 1965).

The root system of pigeon peas is extensive and penetrates the soil deeply, allowing for optimum moisture and nutrient utilization. This allows plants to thrive on light, sandy soil with low moisture-holding capacity. The extensive ground cover of pigeon pea plants minimizes

erosion by wind and water. Because of relatively rapid coverage of the soil surface by the canopy, weed control is needed only during early growth.

Since pigeon pea is capable of growing on marginal lands, the area of arable land can be expanded. When pigeon pea is grown in rotation with other crops its N-fixing ability, especially when it is plowed in, will benefit subsequent crops.

Problems with a longer growing period, photoperiodicity, harvesting, nematodes, etc., are becoming less important as progress in pigeon pea plant breeding widens the area suitable for this crop.

However, as with other crop, proper cultural practices for improved cultivars are important factors that contribute to maximize net economic return by pigeon pea.

The objective of studies on this crop was to identify yield potential of pigeon pea lines and cultivars for grain, green manure, and forage from different cultural practices and planting dates in North Florida.

LITERATURE REVIEW

Botany

Pigeon pea is known also as Congo pea, Angola pea, Puerto Rico pea, red gram, and no eye pea. Because it has broad geographical range, it has many different local names, such as gandul or gandur in Cuba and Puerto Rico, guandul or chicharo de paloma in Colombia, timbolillo or quimbolillo in Costa Rica, guandu in Panama, pusoporoto in Peru, kadios in the Philippines, and kacang goode in Indonesia (Morton, 1976).

The suggested botanical name for pigeon pea is Cajanus cajan (L.) Millsp., in Subfamily Papilionaceae, of the Family Leguminosae (Hutchinson, 1967; Tutin, 1958). In many previous publications, it may be known as Cytisus cajan (L.), Cajanus indicus Spreng, and Cajanus cajan (L.) Druce (Purseglove, 1968).

Pigeon pea can be grown annually or perennially. It is a bushy shrub that may reach a height of 3.5 m; the stem is woody at the base. It has a deep vertical tap root and numerous rootlets, some bearing nodules inhabited by N-fixing bacteria (Morton, 1976). The leaves are pinnate, three-foliate, dark green and silky on the upper surface,

densely silvery-downy, and dotted with glands on the upper surface (El Baradi, 1978). Yellow or yellow-red flowers are borne in racemes in leaf axils. The dorsal side of the flower is either red, purple, or deep orange; another variation includes the standard yellow flower with either red or purple veining on the dorsal side (Rachie and Roberts, 1974). The majority of flowers open between 11 a.m. and 3 p.m. and remain open for about 6 hours. Rain at flowering will reduce fertilization (Purseglove, 1968). Flowering extends for several months and flower dropping may reach up to 68% (Rangasamy, 1975). The flowers are about 2.5 cm in length.

The pods are somewhat flattened, indehiscent, and obliquely constricted between the seeds; there are about two to eight seeds per pod, with the average being four seeds. The pods are 4 to 10 cm in length and 0.6 to 1.5 cm in width. Unripe pods may be solid green, purple, maroon, or green-blotched with purple or maroon coloring. Seeds vary in size, are usually globular in shape, and weigh 7 to 15 g/100. The immature seeds are green, and when mature, they may be white, grayish, red, brown, dark-purplish, or speckled in color and have a small white hilum (Rachie and Roberts, 1974). The seeds are very hard when mature and dry, but become soft and enlarged when soaked in water (Morton, 1976).

Although pigeon peas are normally self-fertilized (Krauss, 1932; Wilsie and Takahashi, 1934) with filament

elongation and pollen shedding occurring prior to flower opening, natural crossing is common. The more plants that are grown, the greater the chance that natural crossing will occur. Natural crossing also depends upon the efficiency of the pollination agents. It has been reported that natural crossing ranges from 0.15 to 65% (Ariyanayagan, 1976; Howard et al., 1919; Krauss, 1932; Purseglove, 1968; and Veerswamy and Rathnaswamy, 1972). Bees (in particular Magachile spp.), as well as other insects such as Apis dorsata, are probably responsible for cross pollination (Williams, 1977).

Origin and Distribution

The exact origin of pigeon pea is unknown. It is probably a native wild species of Africa in the sub-Saharan region. Seeds were found in the Egyptian tombs of the 12th Dynasty, which indicates that the crop was known in Egypt between 2200 and 2400 B.C. (El Baradi, 1978). It was introduced from Africa to Brazil and India (Krauss, 1932), and from India to Australia, Ceylon, Gambia and Jamaica (FAO, 1959). The crop was introduced to the New World in early post-Colombian days, but it did not reach the Pacific until introduced to Guam in 1772 (Purseglove, 1968). It was probably first brought to Florida by fishermen and spongers from the Bahamas who settled on the Florida Keys and in Coconut Grove. It is speculated that the bushes were grown in their dooryards (Morton, 1976).

Pigeon peas are now widely grown in many countries of the tropics and subtropics. The main producing countries are Uganda, Tanzania and Malawi in Africa; Dominican Republic, Haiti, Panama, Puerto Rico, Trinidad and Venezuela in Latin America; and India, Bangladesh, Pakistan and Burma in Asia (FAO, 1974).

Climatic and Soil Requirements

Pigeon pea can grow under widely different climatic and soil conditions from 30 N to 30 S latitudes (Akinola et al., 1975). It can grow well under semi-arid conditions with an average annual rainfall of about 625 mm; it is drought resistant, but it is intolerant of water-logged conditions and very sensitive to frost (El Baradi, 1978; Krauss, 1932; Morton, 1976). The fact that it is a deep-rooted plant may be related of its tolerance to both drought and heat (Gooding, 1962; May and Milthorpe, 1962).

The crop thrives on a wide range of soils, provided the soils are not deficient in lime and are well-drained. On extremely acid soils, nodulation may be adversely affected, and on slightly alkaline soils (about pH 7.5) regrowth after the first bearing of fruits may become extremely cholorotic and the plants may suffer die-back (El Baradi, 1978). Salinity tolerance of pigeon pea varies with varieties, but ranges from 6 to 12 mmhos/cm^3. Generally, pigeon pea is more salt tolerant than cowpea (Purseglove, 1968).

According to several reports, pigeon pea can grow at elevations up to 3,000 m (Morton, 1976), but best growth is achieved in Hawaii between 30 and 460 m. Plants tested at elevations between 1,070 and 1,520 m failed to produce fruit (Krauss, 1932).

Importance and Potential

Pigeon pea, as a food item, can be marketed in a variety of ways. It is sold as dry seed, immature seeds, ripe peas, or as young pods. The popularity of these varieties depends upon the culture in which they are sold. In India, it is the dried seed that is most important, although the cooking time is very long--4 to 5 hours. In Puerto Rico, the fresh immature seeds are most popular even though they sell for twice the price of the mature, dried peas. The Puerto Ricans feel that the immature seeds are tastier and more tender, not to mention the reduced cooking time.

Dhal (split pea) is produced in India by milling dried pigeon peas. Milling consists of two main steps; loosening the outer husk by a wet or a dry method and removal of the husk, and then splitting the pea into two cotyledons (El Baradi, 1978). Byproducts of milling including husk, powder, and small broken seeds are usually sold as cattle feed.

The green stage peas are usually canned, but good preparation, high quality, and proper maturity are required to obtain a uniform product (Sanchez, 1963).

Pigeon pea seeds are high in protein (varying from 19 to 30%), and rich in vitamin B. The seeds are also a good source of all minerals; such minerals are generally low in traditional staple food crops (Gooding, 1962; Oliveira, 1976).

The green pea has about 66.7% of water, 20% carbohydrates, 7.0% protein, 3.5% fiber and 1.3% ash. Dried ripe seeds contain about 10% water, 23% protein, 56% carbohydrates, 8.1% fiber and 3.8% ash (Rachie and Roberts, 1974). As in most other grain legumes, pigeon peas are somewhat deficient in S-containing amino acids and tryptophan. Leaves contain about 9% protein; young pods contain 7 to 10% protein, and pod husks contain about 7.04% protein (Morton, 1976.)

Reports on pigeon peas as feed mostly deal with the vegetative parts of the plant, although the seed and its byproducts can also be used as feed. The upper third of the plant contains 70% moisture, 7.11% crude protein, 1.6% fat, 7.88% N-free extract, 10.72% crude fiber and 2.64% ash (Krauss, 1932). Immature hay (cut before flowering stage) contained 11.12% crude protein, 2.71% fat, 25.2% crude fiber, 47.09% N-free extract and digestibility coefficient of 71.44, 67.57, 52.87 and 64.67%, respectively (Prine and Werner, 1977).

The straw of pigeon pea, consisting of stems, leaves, and pods after the removal of the seeds contained about 11% crude protein, 2% ether extract, 29% crude fiber, 47% N-free

extract, 75.6% carbohydrates, 11.5% ash, and 0.15% P. The digestibilities of crude protein, ether extract, crude fiber and N-free extract were 37.8, 21.3, 44.3, and 65.7%, respectively (Jayal et al., 1970). The digestibility coefficient for the crude protein of pigeon pea dried at 100 C was 71.5% (Gooding, 1962).

Pigeon peas grown in Hawaii are used as feed for domestic animals primarily as hay, or as meal for horses, mules, cattle, and goats. The flowers and buds of the plants are used as feed for ducks, chickens, turkeys, pigeons, and rabbits (Krauss, 1932); and it has been incorporated into pellet rations for fowl (Draper, 1944). The protein value of pigeon pea forage in Hawaii is about equal to that of alfalfa and the yield of forage per hectare may be 10 times that of alfalfa (Barrett, 1928).

It has been reported that cattle fed exclusively on this plant gain approximately 0.68 to 1.25 kg/ head/day. In a feeding period of 100 to 200 days, 2-year-old steers gained 22 to 45 kg/head more on pigeon pea than on grass pastures (Krauss, 1932). Zebu bulls, grazing on pigeon pea pastures, gained an average of 35 kg during 93 days of severe drought, while the control animals, grazing on pangolagrass (Digitaria decumbens stent) lost 6 kg (Schaaffhausen, 1965).

The major drawback in pigeon pea utilization as a grazing crop has been its poor survival and severe breakage which reduces the effective grazing duration to about 3

years (Anon., 1948). Consequently, silage would probably be better than direct grazing, particularly where an all-year-round feed supply is needed (Akinola et al., 1975).

In addition to food and feedstuff, pigeon pea is also used as a windbreak; it should be planted 3 m or more from the nearest crop row to avoid root competition (Winters and Miskimen, 1967). In Central and South America, it is used as a shade plant for coffee, cacao, tea, and citrus seedlings (Killinger, 1968). It is also used as bee forage (Krauss, 1932) and for rearing silkworms (Broceras cajani) (Morton, 1976). In India, the dried stems are used for fuel directly or made into charcoal.

In Argentina, India, Java (Indonesia), West Africa, Cuba, and Colombia, the leaves, flowers, and immature pods are used as folk medicine to cure certain ailments (El Baradi, 1978; Morton 1976).

The seeds have slightly narcotic properties, since too much consumption of raw seeds seems to induce sleepiness, but without any serious consequences (Johnson and Raymond, 1964).

Yields of pigeon peas vary widely according to cultural practices, pest infestation, disease infection, prevailing climatic conditions at flowering, and variety (El Baradi, 1978). In Florida, field grown pigeon peas, sown in May and harvested at ground level when the plants were 154 days old, produced 7,970 kg of oven-dry matter/ha (Killinger, 1968).

Green matter production, between 10,050 and 20,000 kg/ha, was obtained when the upper one-third to one-half of mature stands spaced for grain was harvested (Krauss, 1932). Parbery (1967) recorded a dry matter yield of 30,250 kg/ha from mature 220-day-old stands sown in January. In three harvests cut 5 cm above ground level within 1 year, dry matter production of 15,820 kg/ha was obtained (Oakes and Skov, 1962).

In Colombia, a number of studies conducted by Herrera et al. (1966) demonstrated that cutting at ground level caused no regrowth compared to cutting at 30 cm.

As reported earlier, very high forage yields can be expected from a well-managed pure stand of pigeon pea. To insure stand longevity and continuous regrowth, pigeon pea harvests require a suitable combine harvester adapted for high-level cutting with minimum bruising. Although varieties could be expected to differ in resistance to severity of defoliation, practical consideration should favor higher cutting levels for plants growing in drier environments, unless irrigation facilities are available.

According to Prine and Werner (1977), pigeon peas offer promise as a forage crop under tropical and subtropical conditions. Research needed includes (1) breeding and selection of cultivars which will persist under grazing and cutting pressure, and (2) management studies to determine grazing pressure, rest periods, cutting frequencies, and heights that will increase longevity of plants.

As mentioned earlier, pigeon pea is consumed either as dry grain or as green pod (or unripe pod and seed). The latter is to meet the demand for a green vegetable and for canning. At a population of 47,900 plants/ha, yield of nearly 8,000 kg/ha of green pods was obtained (Hammerton, 1971). A trial in Trinidad indicated that "Grenada Long Podded" selection reached a potential yield of 8,970 kg/ha. The highest green pod yield recorded in Marie-Galante Island, Trinidad was 8,970 to 14,570 kg /ha (Salette and Courbois, 1968).

Dry seed production under favorable growing conditions can result in yields of 1,600 to 2,500 kg/ha (Rachie and Roberts, 1974). However, the highest yield of dry seed was 7,500 kg/ha from a small plot of variety UQ50 in Australia (Akinola et al., 1975).

Pests, Diseases, and Their Control

Insect pests

Insect pests are considered a serious problem for pigeon peas, both in the field and in storage. There are more than 200 insect species that have been reported to damage pigeon peas in India (ICRISAT, 1978). Among them, leafhoppers and pod borers are the most serious pests (El Baradi, 1978).

Some insect pests that cause damage to pod and developing seeds in the field from different places are Heliothis obsoleta (gram caterpillar), H. armigerra

(American bollworm), H. virescens Fabr. (tobacco bud worm) H. zea Boddie (corn earworm), Agromiza obtusa M. (gram pod fly), Ancylostomia stercorea (Zell.) (pod borer), Etiella zinckenella Tretschke (pea pod borer), Exelastis atomosa W. (red gram plume moth), Elasmopalpus rubedinellus (Zell.) (pyramid moth), Anticanisca gemmatilis Hub (velvet bean caterpillar), Clavigralla gibbosa Spin (coreid bug), Coccus elongatus (flat scale insect) (Bindra and Jakhmola, 1967; Egwuata and Taylor, 1976; Gangrade, 1963; Killinger, 1968; Pramanik and Basur, 1967; Purseglove, 1968; Rachie and Roberts, 1974; Rachie and Wurster, 1971; Vaishampayan and Singh, 1969).

Nematodes attacking pigeon pea are Helicotylenchus dihystera, Meliodogyne arenaria, M. javanica (eelworm), M. incognita, M. hapla, Pratylenchus spp. and Rotylenchulus reniformis. Growing a resistant cultivar seems to be the best way to solve the nematode problem.

Insect pests attacking pigeon pea in storage are Bruchus spp., Trogoderma granarium, Cadra cantella, Sitophilus oryzae, Tribolium castaneum and Lantheticus spp. To control these insect pests, fumigation with ethylene dibromide, phosphine or methylbromide is used, or malathion is added to storage sack.

A number of insecticides have been developed which help control pigeon pea field and storage attacks, such as DDT, Malathion, Dieldrin, Endrin, Dimethoate, Endosulfan, Disulfoton, Mephospholan, Furadan, Thiodan, and BHC.

Diseases

Pigeon pea is infested with fungal, bacterial, and virus diseases (Spence, 1975). Diseases attacking root and stem bases are Fusarium udum, Macrophomina phaseoli, Phaseolus manihotis, Phyllosphora cajanae, Phoma cajani and Diplodia cajani. Among those diseases attacking the stem and leaf are Colletotrichum cajani, Uromyces spp., Uredo cajani, Cercospora spp. and Phytophthora cajani. Sterility mosaic has been reported as the main attacking virus.

The most practical methods of disease control (ICRISAT, 1978; Rachie and Roberts, 1974): (1) growing resistant varieties (this is ideally the most practical control mechanism), (2) practicing good farming techniques, such as crop rotation, sanitation, planting dates and control of disease vectors (insects and nematodes), and (3) using seed treatments, such as fungicides Benlate, Demosan and Phorate,and insecticides Lannate and Furadan.

Weeds

As with any other legume crop, many kinds of weeds can infest pigeon pea fields. Weeds can be controlled manually, mechanically, chemically, or by using a combination of these methods.

It has been reported that pigeon pea can suppress the growth of weeds, but this is true only when the plants have reached a height of about 1 m. Therefore, effective weed control at early growth stages of the crop is important for high yield production.

Prometryne, a pre-emergence treatment, provided good weed control in pigeon pea (Kasasian, 1964). Post-emergence application of Gramoxone (or Paraquat), as directed spray, also gave good weed control. Other herbicides that have been used successfully are Ametryne, Chloramben, Diphenamid and Diquat (Akinola et al., 1975). It has been reported that mechanical weeding at 20 to 45 days after planting is effective in creating a weed-free condition (Saxena and Yadav, 1975).

Cultural Management

Cultivation

If soil is free from weeds, land preparation may not be necessary. Satisfactory germination has often been obtained with little cultivation. However, for best germination, pigeon pea requires a seed-bed with good tilth.

For clay soils, pre-sowing tillage and cultivation are recommended (Krauss, 1932). It has been reported that deep plowing (25 cm) of light loam soil does not increase pigeon pea yield grown under irrigated conditions as compared with shallow plowing (10 to 12.5 cm) using a traditional country plow (Khan and Mathur, 1962). El Baradi (1978) suggested that under rainfed conditions, it is advisable to use an appropriate soil moisture conservation method to store the highest possible moisture quantity in the soil before planting. In soil subjected to water-logging, yields were increased by 30% when the seeds were sown on ridges rather than on the flat (Choudhury and Bhatia, 1971).

Pigeon pea can be grown as an annual or perennial crop; it can be grown in pure stands or mixed with other crops such as maize, sorghum, peanut, finger millet, or with cotton (El Baradi, 1978; Gooding, 1962; Tiwari, 1977). In addition, pigeon pea can be planted in rows or sown broadcast. The broadcast method is usually used when pigeon pea is planted as green manure, as a cover crop, or as a fodder crop. There is evidence that the row-planting method increases seed yield and reduces seeding rate when compared with the broadcast method (Mukherjee, 1960).

Fertilization

Because pigeon pea plants have a deep and extensive root system that allows them to utilize available nutrients present deep in the soil, many investigators have reported that pigeon pea does not respond to fertilizers (Morton, 1976). However, some responses to fertilizers have been obtained. Killinger (1968), experimenting on a dry sandy soil at the University of Florida, recommended 336 to 560 kg of 0-8-8 or 0-10-10 ($N-P_2O_5-K_2O$) fertilizer/ha at seeding time. Salette and Courbois (1968) reported that a strain local to Marie-Galante showed a 34 to 45% yield response to 112 kg of P_2O_5 and 134 kg of K_2O/ha, whereas an introduction from Puerto Rico gave no response to nutrients. This implies that there may be considerable differences among varieties in nutrient requirements or in their capacities to absorb nutrients from soils.

Since the crop is a legume, it does not generally require N fertilization, except in some cases where N is added in amounts of not more than 25 kg/ha to stimulate nodulation or to increase protein content (Manihi, 1973). Addition of a high rate of N depresses N fixation of the plants (Batawardekar et al., 1966; Dalal and Quilt, 1974).

Under tropical conditions, most studies indicate P to be the first limiting element, and it is recommended to apply 20 to 80 kg/ha of P_2O_5 (Batawadekar et al., 1966; Khan and Mathur, 1962). Moderate application of P and K can be expected to produce economic return on soils deficient in those elements (Rachie and Roberts, 1974).

On field trials of three pigeon pea varieties, application of 25, 44 and 21 kg/ha of N, P and K, respectively, increased grain yield from 1,600 (no fertilizer) to 2,300 kg/ha (Manihi et al., 1973). In another field experiment, increasing the superphosphate rate from 33 to 100 kg P_2O_5/ha increased grain yield from 2,030 to 2,760 kg/ha (El Baradi, 1978). Pot trials showed that application of sulphur, in combination with N, P and K significantly increased the nethionine content and grain yield, but had no significant effect on its N content (Oke, 1976).

The effect of 22.4 kh N/ha as ammonium sulphate on grain for yield was studied on pigeon pea, peanut, and sorghum (Singh and Sahasrabudhe, 1957). The N decreased pigeon pea yield, but increased production in the other two

crops. It was speculated that the cause of reduced yield in pigeon pea by N was due to the fact that pigeon pea grows relatively slowly in its early stages; in addition, the low C/N ratio did not favor nodulation by Rhizobium japonicum (Nichols, 1965).

In India, 200 kg of N/ha applied to a Vertisol did not increase grain, but increased total dry matter by about 43% over no N application. There was increased N uptake because of more dry matter in plant parts than in grain (ICRISAT, 1978).

Pigeon pea utilizes the same rhizobial complex as cowpea, acasia, albizzia, cassia, centrocema, desmodium and indigofera (Burton and Martinez, 1980). Research in Nigeria (Oke, 1976) pointed out that N fixation and transfer of N to other parts of the plant can be quite efficient. Maximum fixation per plant for pigeon pea was 14.5 mg/ day, while for Centrocema and Stylosanthes, maximum fixation was 10.3 and 4.6 mg/day per plant, respectively. Younger plants were more effective than older ones in the fixation process.

Planting Dates

There are two basic groups of pigeon pea -- early and late maturing (Krauss, 1932; Purseglove, 1968). Gooding (1960) reported that in Trinidad, the time for pod formation differed by up to 106 days in earlier maturing lines and up to 237 days in later maturing lines. In addition to those two groups, there is also a day neutral cultivar, Amarillo, which flowers at any season of the year in Florida (Killinger, 1968).

According to Knott and Deanon (1967), for the short type of pigeon pea, planting can be done at any time, but preferably between October and December in Puerto Rico, and between December and January in Trinidad. For the tall type, flowering occurs in the period of short day length; therefore, depending on planting time, flowering may take place as early as 125 days to as late as 430 days from seeding.

Most varieties of pigeon pea are sensitive to photoperiod and the sowing date has an important influence on the vegetative and reproductive processes (Akinola and Whiteman, 1975). Killinger (1968) reported that in Florida, 120 and 150 days are usually required for flowering. In Hawaii, the tall-growing plants produce seed within 60 to 80 days after sowing (Krauss, 1932). It has been reported that in Sudan, the first pod ripening requires 5 to 6 months and in Kenya, maturity takes about 6 months (Akinola et al., 1975).

Plant Population

Yield responses to sowing density are basically consequences of inter- and intra-plant competition for water, nutrients, and light. The responses are affected by sowing date, light duration and intensity, temperature, soil structure and nutrient status, moisture availability, species or genotype,and pest and disease control (Akinola and Whiteman, 1975).

Close spacing tends to increase plant height and reduce individual plant productivity. Hammerton (1971) reported that maximum yield per plant is obtained at spacing of 122 x 122 cm, and highest yield per hectare is obtained at a spacing of 61 x 61 cm.

In East Bengal (India), pigeon pea for seed production (either as a monocrop or mixed with cereals) was usually sown in rows of 92 cm with plants 122 cm apart in the row. Plants were thinned to 33 to 46 cm within rows, or broadcast sown at 18.0 to 22.4 kg of seed/ha (FAO, 1959). Killinger (1968) suggested a row width of 75 to 95 cm at 6.7 kg of seed/ha for cultivar Norman as a grain crop, and as a cover crop, a row width of 30 to 45 cm at 6.8 to 22.4 kg of seed/ha.

Rachie and Roberts (1974) reported that late maturing crops generally responded best to a low population of 7,000 to 10,000 plants/ha. A seeding rate of 160 kg/ha has been reported by growers of pigeon pea for forage (FAO, 1959).

MATERIALS AND METHODS

Field experiments were divided into two groups:

a. Pigeon peas for forage and green manure.

b. Pigeon peas for grain.

All field experiments were conducted on the main Agronomy Research Farm at the University of Florida, Gainesville, during the 1979 and 1980. The soil was Arredondo fine sand, a member of the loamy, siliceous, hyperthermic family of Grossarenic Paleudalfs (Carlisle and NeSmith, 1972), with pH between 6.2 and 6.4.

The land was prepared before each planting by disk harrowing twice and dragging to level. A 0-10-20 ($N-P_2O_5-K_2O$) fertilizer was applied at a rate of 560 kg/ha just before the second disking. Herbicide mixture of benefin (N-butyl-N-ethyl-,-trifluoro-2,6-dinitro-p-tuluidine) and vernolate (S-propyl dipropyithiocarbamate) at the rates of 1.36 liters a.i./ha and 3.11 liters a.i./ha, respectively, were incorporated into the soil 10 to 14 days before planting.

To control weeds after crop establishment, the herbicide bentazon (3-isopropyl-1H-2,1,3-benzothiadizin-4(3H)-one,2,2 dioxide) was applied at the rate of 1.0 liters a.i./ha when plants were 9 to 10 weeks old. Lay-by cultivation was made 7 to 8 weeks after planting. Additional hand weedings controlled those weeds left behind by the previous weed control measures.

To obtain correct plant population in grain crop experiments, the seeds were planted in excess and then thinned later to proper population about 2 weeks after planting. The inter-row plant spacings at different populations and row widths are presented in Table 1. In case of poor seed germination, new seeds were applied in skips as soon as they could be recognized. Sprinkler irrigation was applied when needed for rapid seed germination.

The insecticide, Methomyl [(S-methyl N-[(methylcaroamoil)oxy] thiacetimidate, was applied at the rate of 0.56 kg a.i/ha as necessary to control insects attacking leaves and pods.

Grain was harvested after plants were killed by freezes on 14 November 1979 and 12 December 1980. Forage was harvested three to four times depending on the vigor and recovery growth of the plants. Plants for green manure were harvested when losses of bottom leaves became severe. Forage and green manure were harvested with hand sickles and seed pods were hand picked from plants for grain yields.

The distances between rows for the grain crop were 41, 61, and 91 cm. Plots consisted of 4, 3 and 2 plant rows for these row widths, respectively. Plants for forage and green manure studies were all seeded with row widths of 41 cm and with four plant rows per plot. For both experiments, plot size was 5.49 m long and 1.83 m wide.

Table 1. Inter-row plant spacings at different populations and row widths.

Row widths	Population	Inter-row plant spacing
----cm----	--plant/m^2--	--- cm ---
41	4	62
	8	31
	12	21
61	3.3	50
	6.6	25
	13.2	12.5
	4	41
	8	21
	12	14
91	4	27
	8	14
	12	9

The seed of cultivar-lines except Norman and Florida lines used in forage and green manure studies were obtained from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), India (Table 2).

Forage and Green Manure Experiments

Forage

Ten cultivars or lines of pigeon pea were planted at each season, and seven of them were common in both seasons (Table 2). The experimental design for both seasons was a split plot with each treatment replicated four times. Cultivars or lines of pigeon pea were main-plot treatment, and cutting height of 25 and 50 cm high were subplot treatments.

In 1979, plots were seeded on 15 May. The first forage harvest was made on 24 July 69 days after planting (DAP), the second harvest was on 10 September or 48 days after first harvest (DAFH) and the third harvest on 2 November. Plant harvested for both cutting heights was at the same time in this season.

In 1980, plots were seeded on 22 April. Plants with cutting height of 25 cm were harvested three times; on 9 July, 79 DAP; on 25 August, 47 DAFH; and on 7 November, 75 days after second harvest (DASH). At 50 cm cutting height, the plants were harvested four times: on 1 October, 49 DASH; and on 7 November, 37 days after third harvest (DATH).

Table 2. Cultivar and lines of pigeon pea in forage and green manure study.

Code No.	ICP No.	Pedigree	Season of study	Source
Norman	---	---	1,2	U.of F.
121	---	73081 (D_1 bulk)	2	
122	6344	T-7	1,2	Test 27, ICRISAT†
123	7221	Gwalior-3	1,2	Test 27, ICRISAT
124	7182	BDN-1	1,2	Test 43, ICRISAT
125	1	---	1,2	V.P., ICRISAT
126	7118	C-11	2	Test 40 ICRISAT
127	7065	M.P. Collection, India	1,2	V.P., ICRISAT
128	8530	Tamil Nadu Collection, India	1	Germplasm, ICRISAT
129	1641	T-17	1	Germplasm, ICRISAT
130	8518	LRG-30	1,2	V.P, ICRISAT
131	---	FL composite	1	U.of F.
132	---	FL 81d	2	U.of F.

† ICRISAT = International Crops Research Institute for the Semi-Arid Tropics, India.

Data recorded in both forage experiments were plant survival, plant height, days to harvest, forage dry matter production, forage protein content, in vitro organic matter digestibility of forage. In addition, protein content, and in vitro organic matter digestibility (IVOMD) of component parts of forage were determined in the 1980 crop.

Green manure

Ten cultivars or lines of pigeon peas (Table 9) were planted on 22 April and were harvested on 24 September 1980.

The experimental design was a randomized block with each treatment replicated four times. Days to harvest, dry matter production, plant height, N content, and plant survival were determined.

Grain Experiments

Row width

A similar experiment was conducted in each season. The row spacings were maintained at 41, 61, and 91 cm on both experiments. In the first season, three cultivar or lines of pigeon pea (Table 10) were planted on 19 July 1979. The distance between plants within the row was about 10 to 15 cm. Grain was harvested on 22 November 1979. Cultivars or lines were placed as main plot treatments, and row-widths as subplot treatments in a split plot design. Each treatment was replicated four times.

For the second season, three different pigeon pea lines (Table 11) were planted on three dates: 3 June, 24 June, and 15 July 1980. Plant population was maintained at eight/ m^2. All plants on each date of planting were harvested on 17 December 1980. In this second season, the experimental design was a split plot with each treatment replicated five times. Pigeon pea lines were main plot treatments, and row-widths were subplot treatments.

Grain yield, days to harvest, and plant height data for both seasons were collected. The number of seeds per pod, seed weight, and percentage of good seeds were also collected in the first season experiment. Maturity stage in November and at harvest, and days to reach 50% flowering stage were recorded for the second experiment.

Plant population

In this study, experiments were conducted in both 1979 and 1980 seasons. Row-width was maintained at 61 cm in each experiment. The experimental design was a split plot with each treatment replicated five times. Cultivars or lines of pigeon pea were main plot treatments and plant populations were subplot treatments.

In the first season, nine cultivar or lines of pigeon pea (Table 13) were planted at three plant populations: 3.3, 6.6, and 13.2 plants/m^2. Each set of these treatments was planted at three dates: on 24 May, 22 June, and 19 July 1979. All plants on each date of seeding were harvested on 20 November 1979.

For the second season, five cultivars or lines of pigeon pea (Table 13) were planted at three plant populations: 4, 8, and 12 plants/m^2. Each set of these treatments was planted on 3 June, 24 June, and 15 July 1980. All plants on each date of planting were harvested on 17 December 1980.

Data on days to harvest, days to 50% flowering, plant height, maturity stage before harvest, leaf area index (LAI) of FL 90c pigeon pea and grain yield production were collected. In addition, seed weight, number of seeds per pod, and percentage of good seed were determined.

Row width and plant population interaction

Line FL 81d pigeon pea was planted at three row-widths: 41, 61 and 91 cm apart, and at three plant populations: 4, 8 and 12 plants/m^2. Each set of these treatments was planted at three dates: 3 June, 24 June, and 15 July 1980. Plants from each date were harvested on 17 December 1980.

Row-widths were main plot treatments and plant poulations were subplot treatments in a split plot design. All treatments were replicated five times.

Days to harvest, days to 50% flowering, plant height, percentage of good seed, maturity stage before harvest, and grain yield were determined.

Method of Data Collection

Forage and green manure experiments

Forage dry matter production was based on the fresh weight of the two center rows of four-row plots, with an area of 2.97 m^2. A representative subsample was weighed and oven dried at 65 C to a constant moisture content; dry weight was recorded. Forage dry matter production then was calculated to t/ha. For forage, the plants were harvested either at 25 or 50 cm height, depending on the treatment. For dry matter production in green manure study, the plants were harvested about 5 cm above ground.

Nitrogen content and digestibility analyses were performed at Agronomy Research Support Laboratory, University of Florida. Plant samples were prepared by grinding them in a Wiley mill (Standard Model 3) with a 1-mm screen. Nitrogen was analyzed by using an aluminum block digester following the method by Gallaher et al. (1975), and crude protein content was calculated by multiplying percent N times 6.25 (Schneider and Flatt, 1975). In vitro organic matter digestibility of the samples was determined by the modified "Tilley and Terry" two-stage technique (Moore and Dunham, 1971).

Plant survival was expressed in percent, based on the number of plants surviving in the two-center rows prior to harvest. The height of the plant prior to each harvest recorded in cm was the average of three plants measured from ground level to the tallest part of the plant. Days to

harvest was the duration (in days) between planting and the first harvest, or between two consecutive harvests.

Grain experiments

Grain yield was based on constant grain dry-weight per plot adjusted to kg/ha. Harvested plot area was 3.35, 2.23 and 2.97 m^2 for 2, 3 and 4 plant rows per plot, respectively.

Days to 50% flowering and days to harvest were durations from planting to the time when approximately 50% of plants in each plot were flowering or were harvested, respectively.

Leaf area index (LAI) was the total leaf area of the plant divided by the land area which it occupied. Three plant samples were taken from each plot and leaf area was measured by an automatic portable area meter, a Lambda Instrument Corporation, Model LI-3000.

Pod maturity was the maturity stage of the pod prior to harvest, expressed in percent.

A 100-pod sample was taken at random from each plot to be used in measuring the number of seeds per pod, percent of good seed, and 100-seed weight. The number of seeds per pod was the total number of seeds from a 100-pod sample divided by 100. The percentage of good seed was obtained by dividing the weight of good seeds by the total weight of seeds from a 100-pod sample, and the 100-seed weight is the weight of 100 seeds in grams.

Harvest Index (HI) was the ratio between total grain production and the total dry matter of the plant shoot. Three plant samples were randomly selected from each plot by cutting them at ground level and drying at 65 C to constant moisture content. Both dry weight of grain and total dry matter (include grain weight) were recorded.

RESULTS AND DISCUSSION

Forage and Green Manure Experiments

Forage

Significant differences in total dry matter forage production was obtained among cultivar-line entries (Table 3). There were no significant differences in dry matter yield between 25 and 50 cm cutting height. The average forage yield was 5.83 t/ha for 1979 and 4.60 t/ha for 1980 (Table 3, and Appendix Tables 22 and 23).

Cultivar-lines which were planted in both years produced average annual dry matter yields ranging from 3.46 to 6.08 t/ha. The cultivar Norman gave the highest yield. Cultivar-line entries consistently produced lower yields in 1980 than in the 1979 season. Lack of rainfall in 1980 (Fig. 1B) may have been the main factor for lower dry matter yield in this year. Plants received 759 mm rainfall during the growing period in 1979, while the plants received only 622 mm rainfall in 1980. The 1979 rainfall was higher than the 70-year average, while 1980 rainfall was lower than 70-year average (Fig. 1A).

Dry matter yields over all cultivar-lines for each harvest at both cutting heights for the two crop seasons are shown in Fig. 2 and Table 3, and in Appendix Tables 22 and 23. For 1979, average forage yield from the cutting at 25 cm was higher in the first harvest, but the next two

Table 3. Total dry matter forage production of pigeon pea cut at two heights for two seasons at Gainesville, Florida.

Cultivar or line	Year						Two-year avg.
	1979			1980			
	Cutting height						
	25†	50†	Avg.	25†	50‡	Avg.	
	-------- Oven dry forage, t/ha ----------						
Norman	6.05	6.86	6.45ab*	5.78	5.66	5.72	6.08a
121	---	---	---	3.99	4.53	4.26bc	---
122	5.71	6.25	5.98ab	4.54	4.86	4.70ab	5.34a
123	5.54	6.03	5.78ab	5.45	4.56	5.01ab	5.39a
124	5.42	6.52	5.97ab	4.93	5.20	5.06ab	5.51a
125	5.89	5.47	5.68b	5.33	4.95	5.14ab	5.41a
126	---	---	---	4.00	2.73	3.37cd	---
127	3.35	5.27	4.31c	2.55	2.65	2.62d	3.46b
128	4.84	6.34	5.59	---	---	---	---
129	5.61	6.11	5.86ab	---	---	---	---
130	5.51	6.41	5.96ab	4.72	4.50	4.61ab	5.28a
131	6.07	7.33	6.70a	---	---	---	---
132	---	---	---	5.35	5.61	5.48ab	---
Avg.	5.40a	6.25a	5.83	4.66a	4.53a	4.60	5.21

* Means followed by the same letter within the same column or within the same line in the same year are not significantly different at 5% level according to Duncan Multiple Range Test (DMRT).

† Total yield of three harvests.

‡ Total yield of four harvests.

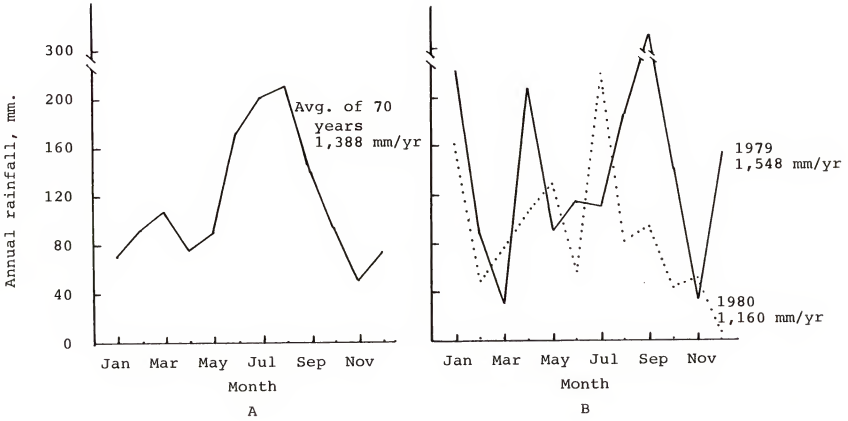

Fig. 1. Average annual rainfall (A) and rainfall in 1979 and 1980 (B) at Gainesville, Florida (data furnished by Dr. D.E. McCloud, unpublished data).

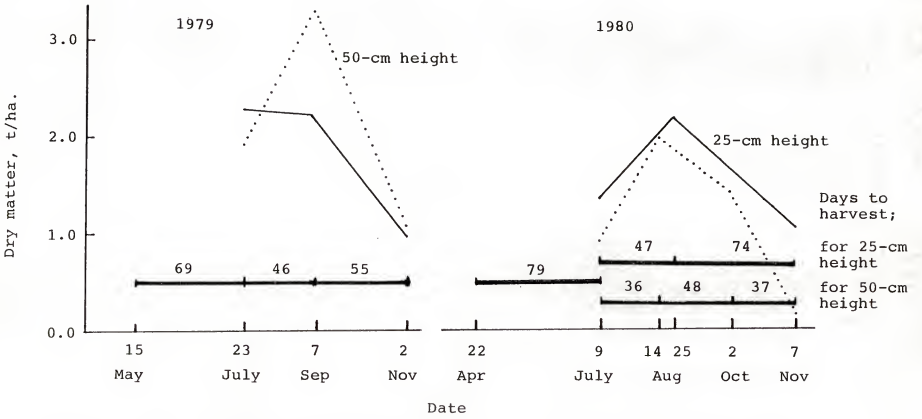

Fig. 2. Average dry matter forage production over 10 pigeon pea entries when cut at two heights for two crop seasons. Gainesville, Florida.

harvests were lower than those cut at 50-cm height. In the 1980 crop, cutting at 25 cm consistently produced higher dry matter yield than those cut at 50-cm height (Fig. 2). The harvest intervals for both cutting heights was equal in 1979, but in 1980, plants cut at 50-cm heights were harvested four times while plants cut at 25-cm height were harvested only three times. The result was lower yields for the 50-cm cutting height, but improved quality of forage.

Crop stand or plant survival data (either before the first harvest or as affected by cutting height) are presented in Table 4 and Appendix Table 24. The plant stand of 1980 entries before the first harvest was about 10% lower when compared to 1979. For the 1979 planting, cutting at 25-cm height reduced the number of plants surviving to 77 and 51%, respectively, after the first and second harvests. During the same year, cutting at 50-cm height resulted in a plant survival rate of 99 and 77%, respectively, after the first and second harvests. In both harvests, plants cut at 50 cm had significantly more plant survival than those cut at 25 cm (Appendix Table 24). In 1980, survival of plants cut at 25 cm was reduced to 71 and 31%, respectively, after the first and second harvests. When cut at 50 cm, plant survival was higher than those cut at 25 cm; survival rate was reduced to 80, 71, and 56% after the first, second, and third harvests, respectively. In 1980, an interaction occurred between cutting heights and cultivar-lines after the second harvest, suggesting that some cultivar-lines have

Table 4. Average growth duration, plant survival, harvested shoot length, and dry matter forage yield over all pigeon pea entries on each harvest at two cutting heights for two crop seasons. Gainesville, Florida.

Number of harvests	25-cm cutting height				50-cm cutting height			
	Growth duration	Plant survival	Harvested shoot length†	Dry matter forage yield	Growth duration	Plant survival	Harvested shoot length†	Dry matter forage yield
	--days--	---%---	---cm---	---t/ha---	--days--	---%---	---cm---	--t/ha---
				1979				
1	69	100	102	2.29	69	100	80	1.89
2	46	77	84	2.20	46	99	95	3.29
3	55	51	81	0.91	55	77	81	1.07
	170			5.40	170			6.25
				1980				
1	79	91	77	1.40	79	90	52	0.98
2	47	71	89	2.20	36	80	67	1.97
3	74	31	70	1.06	48	71	67	1.40
4	--	--	--	---	37	56	12	0.18
	200			4.66	200			4.53

† Plant height before harvest subtracted by cutting height.

differential capacities to withstand different cutting heights and cutting frequencies.

Pigeon pea entries had significant differences in plant height either before or after harvest (Appendix Tables 25 and 26). Shoot lengths, after the first harvests of both crop seasons, were similar (Table 4), but dry-forage yields showed large differences. The 1979 crop, cut at 25 cm after the first harvest, produced 165 cm (or 84 cm + 81 cm) of shoot; when it was cut at 50 cm, it produced 176 cm (or 95 + 81 cm) of shoot with corresponding dry matter yields of 3.11 t/ha (or 2.20 t/ha + 0.91 t/ha) and 4.36 t/ha (or 3.29 t/ha + 1.07 t/ha), respectively. The 1980 crop, cut at 25- and 50-cm heights after the first harvest, produced 159 and 146 cm of harvested shoot, and dry matter yields of 3.26 and 3.55 t/ha, respectively. These data point out that plant survival (shoot density) had more effect on the total dry matter production than the length of harvested shoot.

Increasing both length of growing period and the number of harvests for the 1980 crop did not increase dry matter yield. Increasing the length of the 1980 growing period by about 30 days over the 1979 growing season permitted four harvests at cutting height of 50 cm, while only three harvests were obtained at 25 cm cutting height. After the first 1980 harvest, total dry matter forage yield from the 25- cm cutting height was 3.26 t/ha in two harvests, and 3.55 t/ha in three harvests at the 50-cm cutting height, both in 121 growing days (Table 4). By including the yield

of the first harvest, cutting at 25-cm height produced slightly higher dry forage yields, but it was not significantly different over cutting at 50-cm height. Over the 2 years, cutting heights did not cause significant differences in total dry matter production. However, a cutting height of 50 cm seemed to be the best, because it permitted greater plant survival.

In vitro organic matter digestibility analyses of dry matter forage for both crop seasons on each harvest are presented in Appendix Table 27. The percentage of IVOMD ranged from 41.4 to 68.8% with an average of 51.7%. Cultivar-lines planted in both seasons indicated that the cutting height of 50 cm had a slightly higher percentage of IVOMD, 54.9 compared to 50.5% for the 25-cm cutting height. The difference in IVOMD among cultivar-lines was small.

In both crop seasons, plants cut at 50-cm height produced more digestible organic matter than those cut at 25 cm (Table 5). Digestible organic matter production ranged from 0.85 to 3.77 t/ha with an average of 2.58 t/ha. Of the seven cultivar-lines planted in both seasons, one line had significantly lower IVOMD yield than the other entries due to lower dry matter production.

Component parts of forage from the last harvest of both 1980 cutting heights are presented in Tables 6 and 7. Plants cut at 25-cm height, which had 74 growing days, consisted of 41% leaves, 40% stems, 12% flowers, and about 11% fruits. The IVOMD percentage of young fruits (pod +

Table 5. In vitro digestible organic matter production of pigeon pea forage when cut at two heights for two crop seasons. Gainesville, Florida.

Cultivar or line	Year						Two-year avg.
	1979			1980			
	Cutting height						
	25	50	Avg.	25	50	Avg.	
	----------			t/ha			----------
Norman	2.93	3.27	3.10a*	2.84	3.28	3.06a	3.08a
121	---	---	---	1.88	2.10	1.99bc	---
122	3.09	2.97	3.03a	2.74	2.54	2.64ab	2.83a
123	2.22	2.95	2.58a	2.66	2.91	2.78ab	2.68a
124	2.54	3.41	2.97a	2.64	2.79	2.71ab	2.84a
125	3.09	2.45	2.77a	2.11	2.46	2.28ab	2.53a
126	---	---	---	1.51	1.42	1.47cd	---
127	1.93	2.54	2.23a	0.85	1.19	1.02d	1.63b
128	2.16	3.10	2.63a	---	---	---	---
129	2.51	2.74	2.63a	---	---	---	---
130	3.07	3.35	3.21a	2.67	2.29	2.48ab	2.85a
131	2.26	3.77	3.01	---	---	---	---
132	---	---	---	2.60	3.55	3.08a	---
Avg.†	2.58a	3.05a	2.82	2.25a	2.45a	2.35	2.63

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† Average means followed by the same letter in the same line of the same year are not significantly different at 5% level according to DMRT.

seeds) was 58.1%, leaves 52.9%, flowers 46.7%, and stems 31.2% (Table 6). Plants of the last harvest of 50 cm cutting height, which had 37 growing days, consisted of 65% leaves and 35% stems. The IVOMD of leaves was 57.5% and stems was 38.6%.

For both cutting heights, IVOMD values of forage suggest that cultivar-lines which have a relatively high percentage of leaves will have more digestible organic matter.

The crude protein percentages for both crop seasons indicated that cutting at 50 cm height resulted in slightly more crude protein than cutting at 25 cm . The average crude protein ranged from 17.3 to 31.9%, with an average of about 22.3% (Appendix Table 28). This was slightly higher than the amount reported by Krauss (1932).

Total crude protein production in both crop years for each cutting height is presented in Table 8. The 50 cm cutting height produced more crude protein than the 25 cm height. Annual crude protein yield over both crop seasons ranged from 0.35 to 1.67 t/ha with an average of 1.11 t/ha.

Crude protein contents of different forage components of the last 1980 harvest for both cutting heights are presented in Tables 6 and 7. At the 25-cm cutting height, crude protein concentrations in leaves, flowers, fruits and stems were 28.6, 22.6, 17.7, and 8.7%, respectively. For those plants cut at the 50-cm height, leaves contained the highest crude protein, 29.5%, followed by stems with 11.9% of crude protein.

Table 6. Weight, IVOMD, and crude protein content of component parts of forage from the third harvest† for 25 cm cutting height at Gainesville, Florida, in 1980.

Cultivar	Leaves			Stems			Flowers			Fruits		
or line	Weight‡	IVOMD	Protein	Weight‡	IVOMD	Protein	Weight‡	IVOMD	Protein	Weight‡	IVOMD	Protein
	%											
Norman	34	52.1a*	28.8a	41	29.4a	8.3a	18	46.3a	22.6a	7	55.0a	17.8a
122	51	54.5a	29.4a	44	32.9a	8.4a	5	51.8a	23.9a	-	---	---
123	37	52.2a	27.6a	35	31.4a	9.4a	14	44.5a	22.0a	14	60.1a	17.6a
Avg.	41	52.9	28.6	40	31.2	8.7	12	46.7	22.6	11	58.3	17.7

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† The third harvest was 74 days after the second harvest.

‡ Weight of total forage.

Table 7. Weight, IVOMD, and crude protein content of component parts of forage from the fourth harvest† for 50-cm cutting height at Gainesville, Florida, in 1980.

Cultivar	Leaves			Stems		
or line	Weight‡	IVOMD	Protein	Weight‡	IVOMD	Protein
	%			%		
Norman	64	58.8a*	30.4a	36	39.1a	12.1a
122	66	60.5a	30.5a	34	38.9a	11.3a
132	64	56.2a	27.7a	36	37.8a	12.4a
Avg.	65	57.5	29.5	35	38.6	11.9

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† The fourth harvest was 37 days after the third harvest.

‡ Weight of total forage.

Table 8. Crude protein production of pigeon pea forage when cut at two heights for two crop seasons. Gainesville, Florida.

Cultivar or line	Year						Two-year avg.
	1979			1980			
	Cutting height						
	25	50	Avg.	25	50	Avg.	
	Crude protein, t/ha						
Norman	1.21	1.43	1.32a*	1.21	1.38	1.30a	1.31a
121	---	---	---	0.86	0.94	0.90bc	---
122	1.26	1.28	1.27ab	1.13	1.07	1.10ab	1.18a
123	0.87	1.29	1.08ab	1.05	1.22	1.13ab	1.11a
124	1.11	1.62	1.37a	1.18	1.27	1.23ab	1.30a
125	1.34	1.12	1.23ab	0.88	1.05	1.97abc	1.10a
126	---	---	---	0.65	0.67	0.66cd	---
127	0.78	1.14	0.96b	0.35	0.52	0.44b	0.70b
128	0.92	1.39	1.16ab	---	---	---	---
129	1.10	1.24	1.17ab	---	---	---	---
130	1.24	1.48	1.37a	1.14	1.00	1.07ab	1.22a
131	0.94	1.66	1.30ab	---	---	---	---
132	---	---	---	1.15	1.47	1.31a	---
Avg.†	1.08a	1.37a	1.22	0.96a	1.06a	1.01	1.13

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† Means followed by the same letter in the same line of the same year are not significantly different at 5% level according to DMRT.

Both IVOMD and crude protein content data showed stems or branches to have low values. Therefore, for quality one should select pigeon pea cultivar-lines that have higher percentage of leaves.

Green manure

In 1980, when 10 pigeon pea cultivar-lines were grown as green manure, dry-matter production ranged from 1.0 to 9.0 t/ha with an average of 5.2 t/ha (Table 9). The highest dry-matter production (9.0 t/ha) in 156 days of growth was produced by entry ICP 6344. This dry matter was higher than that obtained by Killinger (1968) in Florida during the same length of growing period.

As shown in Table 9, the number of missing plants was high and varied among cultivar-lines. Plant height also varied, ranging from 125 to 281 cm.

The N concentration of the dry matter for each cultivar-line as green manure ranged from 2.0 to 2.8%, and there were no significant difference those cultivar-lines (Table 9). Total N production, therefore, depended upon the total dry-matter production. In this study, N production ranged from 25 to 190 kg/ha.

Grain Experiments

Row width

The effect of row width on grain yields of three pigeon pea cultivar-lines is presented in Table 10. Pigeon pea

Table 9. Dry matter production and some agronomic characteristics of pigeon pea grown as a green manure crop at Gainesville, Florida, in 1980.

Cultivar or line	Dry matter production	Plant survival	Plant height	Nitrogen concentration	Nitrogen production
	--- t/ha -	-- % --	- cm -	-- % ----	-- kg/ha -
Norman	5.3bc*	51bc	281a	2.2a	130ab
121	2.8cd	35c	125f	2.8a	35cd
122	9.0a	94a	255bc	2.3a	175a
123	5.6bc	80ab	234d	2.2a	150ab
124	5.9bc	75ab	210e	2.3a	135ab
125	5.1bc	79ab	235d	2.5a	190a
126	5.0bc	30cd	199e	2.0a	80bcd
127	1.0d	4d	196e	2.3a	25d
129	6.7ab	69ab	263b	2.5a	160ab
130	5.9bc	78ab	244cd	2.1a	110abc
Avg.	5.2	60	205	2.3	119

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

Table 10. Grain yield and some agronomic characteristics of three cultivar-lines of pigeon pea and of three row widths at Gainesville, Florida, in 1979.

Treatment	Grain yield	Plant height	Number of seeds per pod	100-seed weight	Good seed
Cultivar or line	kg/ha	cm		-- g --	--- % ---
FL 68	960a*	138b	---	---	---
FL 10de	880a	127c	4a	9.5a	65a
Norman	220b	218a	3b	6.1b	30b
Row width					
41 cm	620b	161a	4a	7.7a	39b
61 cm	590b	160a	4a	7.8a	52a
91 cm	840a	163a	4a	7.8a	52a

* Means followed by the same letter within cultivar-line effect, or within row widths effect in the same column are not significantly different at 5% level according to DMRT.

lines FL 68 and FL 10de both produced significantly more grain than cultivar Norman. Plant height was significantly different among those three cultivar-lines; Norman was the tallest while FL 10de was the shortest.

When compared with Norman, line FL 10de had significantly more seed per pod. In addition, FL 10de seeds were heavier than Norman, and it had a greater percentage of good seeds (Table 10).

In the 1979 study, the widest row width (91 cm) produced significantly more grain than the two narrower widths. There were no significant differences in plant height, number of seeds per pod, or seed weight among the different row widths. However, 61- and 91-cm rows had significantly higher percentages of good seeds than the 41-cm rows.

Since this crop was seeded on 19 July 1979, the plants did not have enough time to produce mature seed; frost stopped their growth in the middle of November 1979. The growing period was only 127 days.

In the 1980 study, plant population was maintained at eight/m^2 (Tables 11 and 12, and Figs. 3 and 4). The average grain yield production indicated the optimum planting date is either 24 June or 15 July this season. Of the three lines of pigeon pea planted, FL 24c yielded the highest grain production when planted on 24 June 1980. The other two lines of pigeon pea (FL 90c and FL 81d) yielded highest when planted on 15 July 1980 (Fig. 3 and Table 11).

Table 11. Grain yield and some agronomic characteristics of three pigeon pea lines planted on three dates at Gainesville, Florida, in 1980.

Pigeon pea line	Planting date							
	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.
	Grain, kg/ha				Plant height, cm			
FL 24c	1,000†	1,980a*	1,590a	1,520‡	158c	143†	117†	139‡
FL 81d	1,140	1,620b	1,750a	1,500	188a	157	132	159
FL 90c	1,030	1,540b	1,660a	1,410	170b	155	127	151
Avg.	1,060	1,710	1,670		172	152	125	

Table 11 continued .....

Pigeon pea line	Planting date							
	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.
	Days to 50% flowering				% pod maturity at 9 Nov.			
FL 24c	68b	73†	64b	68‡	93†	86†	48†	76‡
FL 81d	69b	74	66a	69	92	80	29	67
FL 90c	71a	74	64b	70	92	83	63	79
Avg.	69	73	65		92	83	47	

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† There was an interaction effect between pigeon pea lines and row width.

‡ There was an interaction effect between pigeon pea lines and date of planting.

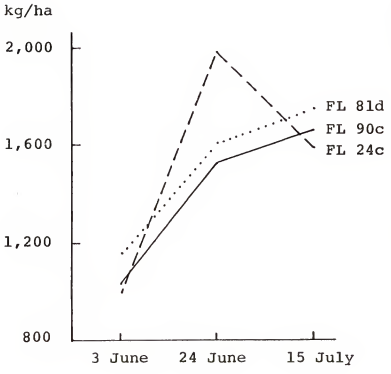

Fig. 3. Grain yield production of three pigeon pea lines in three dates of planting. Gainesville, Florida, 1980.

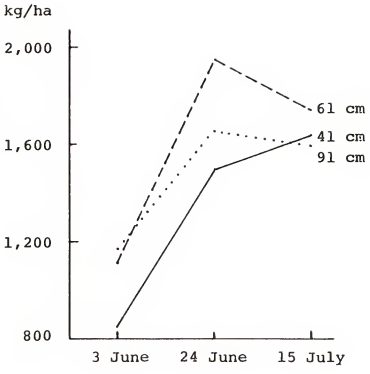

Fig. 4. Grain yield production of pigeon pea in three row widths and in three dates of planting. Florida, 1980.

Minimum air temperature data (Figs. 5 and 6) indicated that frost may often kill plants in early November. For that reason, the 24 June planting has less risk of low yields due to a freeze.

Additional evidence to support the preferred 24 June planting is indicated in pod maturity. From this planting, 80% of the pods reached maturity by 9 November 1980, as compared with only 47% for the 15 July planting. The 15 July plantings produced about the same grain yield as the 24 June planting, since a freeze did not occur until the middle of December (Fig. 7). This late freeze permitted plants of the last seeding to continue their filling process.

All pigeon pea lines reached the 50% flowering stage 65 to 73 days after planting. Regardless of planting time, the plant required about 2 to 2.5 months for vegetative growth.

As planting time was delayed, plant height was increasingly shortened. Plants from the 3 June seeding grew to an average height of 172 cm, while those seeded 15 July plants grew only to an average height of 125 cm.

The average grain yield for different row widths is presented in Table 12. The highest grain yield, 1,950 kg/ha, was obtained from rows 61 cm apart in 24 June planting (Fig. 4). There were no significant differences in yield due to row width in 15 July planting, while the 3 June planting had an interaction effect between cultivar-lines and row width.

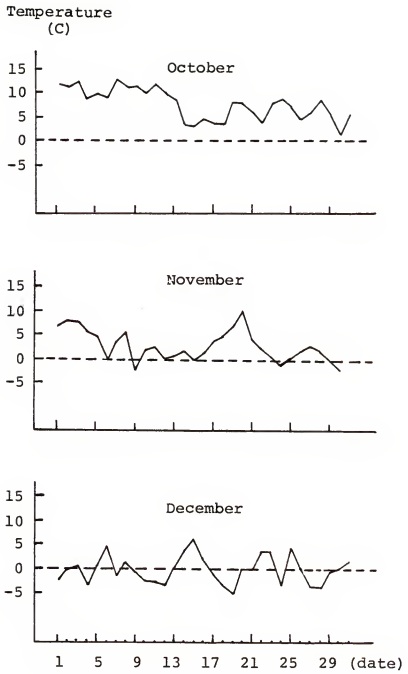

Fig. 5. Minimum air temperature for the months of October, November, December from 1972 and 1980, at 152.5 cm above ground, at Gainesville, Florida (data furnished by Dr. D.E. McCloud, unpublished data).

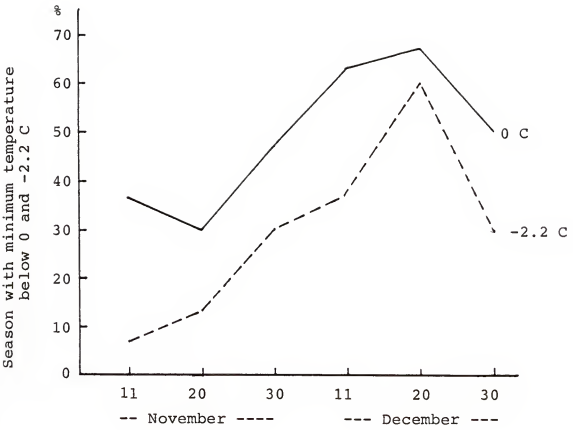

Fig. 6. Percent of seasons with minimum temperature at or below 0 and -2.2 C during 10 day period endings, 1937-1967, at Gainesville, Florida (adapted from Johnson, 1970).

Table 12. Grain yield and some agronomic characteristics of pigeon pea planted on three dates for three row widths at Gainesville, Florida, in 1980.

Row width	Planting date							
	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.
-- cm ---	----- Grain, kg/ha --------				------ Plant height, cm -----			
41	870†	1,520b*	1,640a	1,340‡	172a	150†	122†	148‡
61	1,130	1,950a	1,740a	1,610	170a	154	125	150
91	1,170	1,670b	1,620a	1,490	173a	151	129	151
Avg.	1,060	1,710	1,670		172	152	125	

Table 12 continued .....

Row width	Planting date							
	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.
-- cm ---	-- Days to 50% flowering --				-- % pod maturity at 9 Nov. --			
41	69a	74†	65a	69‡	94†	84†	46†	74‡
61	69a	73	65a	69	91	82	47	74
91	69a	73	64a	70	92	83	48	74
Avg.	69	73	65		92	83	47	

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† There was an interaction effect between pigeon pea lines and row width.

‡ There was an interaction effect between pigeon pea lines and date of planting

There were only slight differences in height due to variation in row width. Similar trends were also observed at the 50% flowering and pod maturity stage (Table 12). As row width became wider, grain production per plant increased, but a significant difference was obtained only for row widths of 61 and 91 cm over 41 cm for the 24 June planting.

Plant population

Grain yield data from the 1979 study indicated interaction effects either between date of planting, cultivar-line entries, and plant population, or between cultivar-line entries and plant population within the planting date. The average grain yield production on each planting date, however, suggested that 24 May and 22 June were the best planting dates (Table 13). Six of those nine cultivar-lines gave highest yield when planted on 22 June, and all of them produced lowest grain yield when planted on 19 July 1979.

In the 1980 study, grain yield data also indicated an interaction effect similar to that in 1979, but the average grain yield production on each date of planting suggested that 24 June and 15 July were the best planting dates. Four of five cultivar-lines gave highest grain yield when planted on 24 June, and all of them gave lowest yield when planted on 3 June (Table 11).

Table 13. Grain yield of pigeon pea cultivar or line entries as affected by dates of planting and plant population in two crop seasons at Gainesville, Florida.

Cultivar or line	Planting date							
	1979				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
	kg/ha							
FL 45c	1,560*	1,250*	1,070*	1,300†	---	---	---	---
FL 74205	1,150	1,280	730	1,050	---	---	---	---
FL 88ab	1,790	2,060	1,690	1,850	---	---	---	---
FL 67	1,970	1,940	1,550	1,820	---	---	---	---
FL 81a	1,870	1,930	1,370	1,720	---	---	---	---
FL 95a	1,430	1,610	1,320	1,460	---	---	---	---
FL 90c	1,830	2,130	1,690	1,880	960*	1,680*	1,740*	1,460†
FL 81d	2,520	2,310	2,090	2,310	1,250	1,770	1,570	1,530
Norman	1,140	1,230	540	970	1,090	1,320	1,130	1,180
FL 68	---	---	---	---	550	1,430	1,340	1,110
FL 24c	---	---	---	---	1,160	2,120	1,840	1,710
Avg.	1,700	1,750	1,340	1,600	1,000	1,660	1,520	1,390

Population	Planting date							
	1979				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
Plants/m^2	kg/ha							
3.3	1,690*	1,580*	1,170*	1,480†	---	---	---	---
6.6	1,690	1,860	1,350	1,640	---	---	---	---
13.2	1,710	1,810	1,500	1,670	---	---	---	---
4.0	---	---	---	---	960*	1,590*	1,510*	1,350†
8.0	---	---	---	---	1,070	1,690	1,480	1,410
12.0	---	---	---	---	990	1,740	1,440	1,390
Avg.	1,700	1,750	1,340	1,600	1,000	1,660	1,520	1,390

* There was an interaction effect between cultivar and plant population within the same date of planting.

† There was an interaction effect between date of planting, cultivar or lines, and plant populations within the same crop year.

Based on these 2 years of research, the best planting date was at the 22 June and 24 June planting dates. When planted 3 to 4 weeks earlier or later than these dates, a low grain production resulted in one or the other of the 2 years studied. In the first year, all plants were harvested on 20 November 1979 due to early frost which killed plants of the last planting before seeds were mature (Fig. 7A). In the second year, the plants were not killed by frost until the seeds were mature in the middle of December 1980 (Fig. 7B), which contributed to the greater grain yield of the last planting. A recommended time of planting ranging from about 15 June to 5 July with Florida lines, should give both high grain yields and little risk of freeze damage in North Florida.

Data for minimum air temperature (Figs. 5 and 6) indicated that the frost may damage the plants in November, which mandates that plants reach physiological maturity in early November. Therefore, 22 June or 24 June seemed to be the optimum planting dates.

As far as grain yield is concerned, FL 81d and FL 90c yielded consistently well (Table 13). Line FL 24c outyielded FL 81d in the second year of study (Fig. 8). The highest grain yield obtained was 2,800 kg/ha produced by FL 81d when planted in 61-cm rows at 13.2 plants/m^2 on 24 May 1979.

The effect of plant population on grain yields is presented in Table 13 and Fig. 9. Although there was an

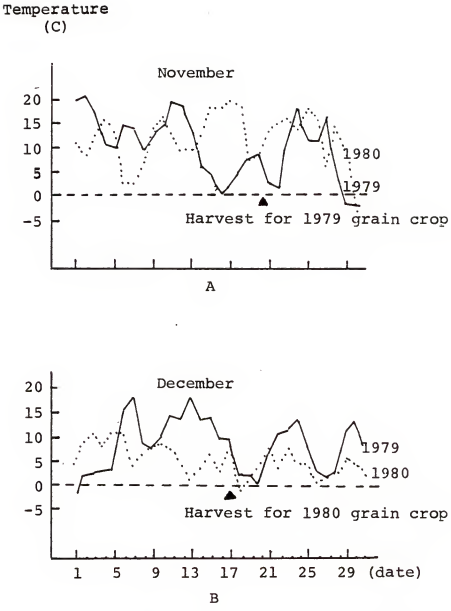

Fig. 7. Minimum air temperature for the months of November (A) and December (B) of 1979 and 1980, at 152.5 cm above ground, at Gainesville, Florida.

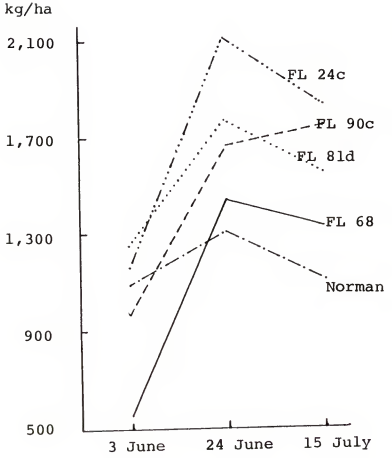

Fig. 8. Average grain yield of five cultivar-lines of pigeon pea in three dates of planting. Gainesville, Florida, 1980.

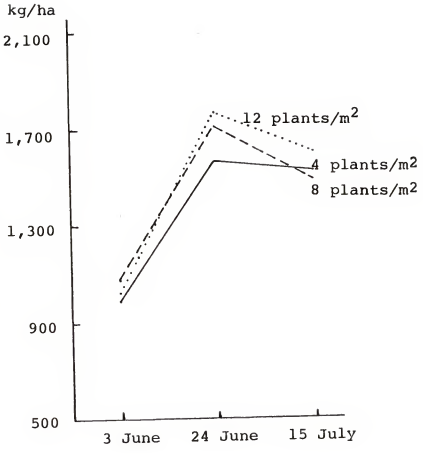

Fig. 9. Average grain yield of pigeon pea over five cultivar-lines at three plant populations and in three dates of planting. Gainesville, Florida, 1980.

interaction effect between planting date, cultivar-line entries and plant population, the average grain yield at populations of 6.6 and 13.2 plants/m^2 or 8 and 12 plants/m^2 were higher than yields from populaitons with to 3.3 and 4 plants/m^2, respectively. In the first year, the highest grain yield obtained was at 6.6 plants/m^2 when planted on 22 June. In the second year, the highest grain yield obtained was at 12 plants/m^2 when planted on 24 June.

Pod maturities recorded on 12 November 1979 and 9 November 1980 indicated that the cultivar-line entries had different pod maturities (Table 14). The average percentages of pod maturity of the 1979 plants were lower than the 1980 plants. It is speculated that more pods were produced in the 1979 plants due to higher rainfall received in that year,which contributed to a lower percentage of pod maturity. The 1979 plants received 782 mm of rainfall while the 1980 plants received only 552 mm of rainfall.

Pod maturity of the 1979 crop as affected by population is shown in Table 14. As indicated, only the 24 May plants (population of 3.3 plants/m^2) produced greater percentage of pod maturity than the other two populations. The 1980 crop indicated no significant differences in pod maturity due to population (Table 14).

The average number of days to reach the 50% flowering stage ranged from 67 to 75 days (Table 15). Except for cultivar Norman, most plants reached the 50% flowering stage

Table 14. Pod maturity of pigeon pea on 12 November 1979 and 9 November 1980 as affected by dates of planting and plant populations in two crop seasons at Gainesville, Florida.

Cultivar or line	Planting date							
	1979				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
	% mature pod							
FL 45c	19h*	11e	6de	12†	---	---	---	---
FL 74205	38g	7f	6de	17	---	---	---	---
FL 88ab	97a	50a	29a	59	---	---	---	---
FL 67	84c	30c	7de	40	---	---	---	---
FL 81a	65e	12e	8d	28	---	---	---	---
FL 95a	56f	11e	6de	24	---	---	---	---
FL 90c	93b	39b	20b	51	89b	80b	53b	74†
FL 81d	73d	16d	13c	34	93a	80b	28d	68
Norman	69e	17d	5e	30	75c	51c	5e	44
FL 68	---	---	---	---	94a	84a	32c	70
FL 24c	---	---	---	---	92a	86a	60a	79
Avg.	66	21	12		89	76	36	

Population	Planting date							
	1979				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
Plants/m^2	% mature pod							
3.3	68a	21a	11a	33†	---	---	---	---
6.6	65b	21a	12a	33	---	---	---	---
13.2	65b	22a	12a	33	---	---	---	---
4.0	---	---	---	---	89a	76a	43a	66a
8.0	---	---	---	---	89a	77a	37a	68c
12.0	---	---	---	---	88a	76a	36a	67b
Avg.	66	21	12		89	76	36	

* Means followed by the same letter within the same date are not significantly different at 5% level according to DMRT.

† There was an interaction effect between cultivar or lines and date of of planting, and or between population and date of planting.

in the same length of time when planted from 24 May to 24 June. Plants of the last planting (15 July and 19 July) flowered slightly earlier than the two earlier plantings. Pigeon pea plants at all planting dates had a vegetative period of more than 2 months (Table 15). Plants may continue to produce new flowers and pods, even though the earlier pods were already physiologically mature.

There was a negative relationship indicated between plant height and date of planting for both crop years. As planting date was delayed, plant height decreased (Table 16).

Leaf area indices of FL 90c for both crop years are shown in Table 17. The data indicated significant differences in LAI between 1 month and 2-month- old plants and/or at the 50% flowering stage. These data showed the slow rate of growth of pigeon pea plants in the early stages. There was a positive relationship between population and LAI. As population increased, so did LAI.

There was a slight reduction in seed weight as planting time was delayed. The number of seeds per pod was not affected by various planting dates. A negative relationship between percentage of good seeds and date of planting was obtained. As planting date was delayed, the percentage of good seed was reduced (Table 18). Plant population had no significant effect on seed weight, number of seeds per pod, or percentage of good seeds.

Table 15. Fifty percent flowering stage of pigeon pea as affected by dates of planting and plant populations in two crop seasons. Gainesville, Florida.

Cultivar or line	Planting date							
	1979†				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
	Days after planting							
FL 45c	75	83	70	76	--	--	--	--
FL 74205	76	83	72	77	--	--	--	--
FL 88ab	71	75	63	69	--	--	--	--
FL 67	70	74	65	70	--	--	--	--
FL 81a	72	85	72	76	--	--	--	--
FL 95a	71	74	65	70	--	--	--	--
FL 90c	70	72	63	68	71c*	73c	65d	69‡
FL 81d	70	74	69	71	68d	74b	67b	70
Norman	101	90	78	90	98a	86a	73a	86
FL 68	--	--	--	--	73b	74b	66c	71
FL 24c	--	--	--	--	68d	72d	64e	68
Avg.	75	79	69		76	76	67	

Population	Planting date							
	1979 †				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
Plants/m^2	Days after planting							
3.3	75	79	69	74	--	--	--	--
6.6	75	79	69	74	--	--	--	--
13.2	75	79	69	74	--	--	--	--
4.0	--	--	--	--	76a*	76a	67a	73a
8.0	--	--	--	--	76a	76a	67a	73a
12.0	--	--	--	--	75a	76a	67a	73a
Avg.	75	79	69		76	76	67	

* Means followed by the same letter within the same date are not significantly different at 5% level according to DMRT.

† There was no variation observed between replications.

‡ There was an interaction effect between cultivar or lines and date of planting.

Table 16. Plant height of pigeon pea as affected by dates of planting and plant populations in two crop seasons. Gainesville, Florida.

Cultivar or line	Planting date							
	1979				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
	cm							
FL 45c	206c*	160de	132e	166†	---	---	---	---
FL 74205	186d	157de	143cd	162	---	---	---	---
FL 88ab	168e	144f	112g	141	---	---	---	---
FL 67	183d	170c	133e	162	---	---	---	---
FL 81a	219b	181b	146b	182	---	---	---	---
FL 95a	188d	162d	141d	164	---	---	---	---
FL 90c	161f	156e	117f	145	163d	158b	124c	148†
FL 81d	208c	174c	144bc	175	186b	158b	129b	158
Norman	260a	248a	192a	233	253a	190a	167a	203
FL 68	---	---	---	---	173c	150c	116d	147
FL 24c	---	---	---	---	156e	144d	124c	141
Avg.	198	172	140		186	160	132	

Population	Planting date							
	1979				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
	cm							
3.3	194b	169b	138c	167†	---	---	---	---
6.6	200a	171b	140b	170	---	---	---	---
13.2	200a	177a	142a	173	---	---	---	---
4.0	---	---	---	---	183b	158a	133a	158†
8.0	---	---	---	---	188a	160a	132a	160
12.0	---	---	---	---	188a	161a	131a	160
Avg.	198	172	140		186	160	132	

* Means followed by the same letter within the same date of planting are not significantly different at 5% level according to DMRT.

† There was an interaction effect between cultivar or lines and date of planting, and or between population and date of planting.

Table 17. Leaf area index of FL 90c pigeon pea as affected by dates of planting and plant populations in two crop seasons. Gainesville, Florida.

At one month old

Population	Planting date							
	1979				1980			
	24 May	22 June	15 July	Avg.	3 June	24 June	15 July	Avg.
Plants/m^2								
3.3	0.01b*	0.07a	0.06b	0.05†	---	---	---	---
6.6	0.01b	0.08a	0.09b	0.06	---	---	---	---
13.2	0.02a	0.15a	0.21a	0.13	---	---	---	---
4.0	---	---	---	---	0.11b	0.11b	0.05c	0.09†
8.0	---	---	---	---	0.21a	0.17a	0.07b	0.15
12.0	---	---	---	---	0.23a	0.16a	0.09a	0.16
Avg.	0.02	0.10	0.12		0.18	0.15	0.07	

At two months old and 50% flowering stage for 1979 and 1980, respectively.

Population	Planting date							
	1979				1980			
	24 May	22 June	15 July	Avg.	3 June	22 June	15 July	Avg.
Plants/m^2								
3.3	1.75b	0.84b	1.45b	1.35c	---	---	---	---
6.6	2.80b	1.17b	2.02b	2.00b	---	---	---	---
13.2	4.51a	2.48a	4.24a	3.74a	---	---	---	---
4.0	---	---	---	---	4.57b	3.51b	2.30a	3.46b
8.0	---	---	---	---	5.58a	4.45a	2.72a	4.25a
12.0	---	---	---	---	6.36a	4.40a	2.46a	4.41a
Avg.	3.02a	1.50b	2.57a		5.50a	4.12a	2.49b	

* Means followed by the same letter within the same date of planting are not significantly different at 5% level according to DMRT.

† There was an interaction effect between date of planting and population.

Table 18. Seed weight, number of seeds per pod, and good seeds of FL 90c and Norman pigeon peas as affected by dates of planting and plant populations at Gainesville, Florida in 1979.

Cultivar or line	Planting date											
	24 May	22 June	19 July	Avg.	24 May	22 June	19 July	Avg.	24 May	22 June	19 July	Avg.
	--- 100-seed weight,g ---				-- Number of seeds/pod --				------ % good seed ------			
FL 90c	12.4a*	11.0a	11.0a	11.5†	3.9a	4.0a	3.9a	3.9a	88a	52b	48a	63†
Norman	8.1b	8.0b	6.9a	7.7	3.6b	4.5b	3.4b	3.5b	90a	89a	46a	75
Avg.	10.3	9.5	9.0		3.8a	3.7a	3.7a		89	71	47	

Popula - tion	Planting date											
	24 May	22 June	19 July	Avg.	24 May	22 June	19 July	Avg.	24 May	22 June	19 July	Avg.
Plants/m^2	--- 100-seed weight ----				--- Number of seeds/pod ---				---- % good seed ----			
3.3	10.1a	9.4a	9.1a	9.5†	3.8a	3.7a	3.7a	3.7a	90a	72a	46a	69a
6.6	10.1a	9.8a	8.7a	9.5	3.8a	3.7a	3.7a	3.7a	86a	71a	45a	67a
13.2	10.5a	9.4a	9.1a	9.7	3.8a	3.8a	3.6a	3.7a	91a	71a	50a	70a
Avg.	10.3	9.5	9.0		3.8a	3.7a	3.7a		89	71	47	

* Means followed by the same letter within the same date of planting are not significantly different at 5% level according to DMRT.

† There was an interaction effect between cultivar or lines and date of planting, and/or between cultivar or lines and population.

Table 19. Grain weight per pigeon pea plant at harvest as affected by dates of planting and plant populations. Gainesville, Florida, in 1980.

Cultivar or line	Planting date			
	3 June	24 June	15 July	Avg.
	Grain weight, g/plant			
FL 90c	18†	31†	33b*	27‡
FL 81d	23	33	29bc	28
Norman	20	23	23d	22
FL 68	9	25	25cd	20
FL 24c	21	39	40a	20
Avg.	18	30	30	

Population	Planting date			
	3 June	24 June	15 July	Avg.
Plants/m^2	Grain weight, g/plant			
4.0	25†	40†	43a*	36‡
8.0	16	28	27b	23
12.0	13	23	20c	18
Avg.	18	30	30	

* Means followed by the same letter within the same date date of planting are not significantly different at 5% level according to DMRT.

† There was an interaction effect between cultivar or lines and plant population within the same date of planting.

‡ There was an interaction effect between cultivar or lines, population, and date of planting.

The average grain weight produced per plant was lower from the 3 June than from 24 June and 15 July plantings in 1980. Each cultivar-line produced similar amounts of grain during the last two plantings (Table 19). Plant population produced a greater variation in grain weight per plant. There was in inverse relationship between population and grain weight. As population increased, grain weight decreased.

Row-population

Grain yield production and other agronomic characteristics of FL 81d pigeon pea as affected by date of planting, row width, and plant population are presented in Tables 20 and 21, and Fig. 10.

Plantings made on 24 June and 15 July produced significantly higher grain yields than that on 3 June 1980. Although no significant differences were observed between 24 June and 15 July, plants seeded on 24 June had less chance of receiving freeze damage before seed maturity. Furthermore, within the same planting date, no significant differences were observed due to row width or population (Tables 20 and 21). This is an indication that FL 81d was not greatly affected by either of these factors. Data shown in Fig. 10 suggest that planting on 24 June yielded highest when planted in 61-cm row width at a population of 8 plants/m^2.

From the three sample plants per plot, no significant differences in grain production per plant due to variation

Table 20. Grain yield and some agronomic characteristics of FL 81d pigeon pea planted on three dates for three row widths at Gainesville, Florida, in 1980.

Row width	Planting date											
	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.
--- cm ---	----- Grain, kg/ha -------				Grain weight per plant, g				--Dry matter per plant, g--			
41	1,020a*	1,510a	1,560a	1,360a	29a	31a	30a	30a	200a	137a	130a	156a
61	1,250a	1,770a	1,670a	1,570a	23a	32a	28a	27a	192a	137a	104b	134a
91	1,260a	1,500a	1,740a	1,500a	31a	28a	27a	29a	162a	123a	123ab	146a
Avg.†	1,170b	1,590a	1,650a		28a	31a	28a		184a	132b	119b	

Table 20 continued .....

Row width	Planting date											
	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.
--- cm --	----- Harvest index -----				% pod maturity at Nov. 9				------	% good seed		------
41	0.14a	0.22a	0.22a	0.19a	93a	80a	34a	69a	88a	85a	83a	85a
61	0.14a	0.23a	0.26a	0.21a	93a	80a	27a	67a	86a	85a	82a	83a
91	0.16a	0.22a	0.22a	0.20a	91a	80a	27a	66a	84a	87a	81a	85a
Avg.	0.15b	0.22a	0.23a		92a	80a	29b		86a	86a	82b	

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† Planting date average means followed by the same letter within the same agronomic charcteristics are not significantly different at 5% level according to DMRT.

Table 21. Grain yield and some agronomic characteristics of pigeon pea planted on three dates for three plant populations at Gainesville, Florida, in 1980.

Population	Planting date											
	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.
Plants/m^2	---- Grain, kg/ha -------				Grain weight per plant, g				- Dry matter per plant, g --			
4	1,210a*	1,530a	1,570a	1,440a	38a	45a	42a	42a	235a	175a	166a	192a
8	1,140a	1,620a	1,760a	1,500a	25b	25b	23b	24b	185a	120b	104b	134b
12	1,190a	1,630a	1,640a	1,490a	20b	22b	19b	21b	132c	102b	86b	107c
Avg.†	1,180b	1,590a	1,650a		28a	31a	28a		184a	123b	119b	

Table 21 continued .....

Population	Planting date											
	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.	3 June	24 June	15 July	Avg.
Plants/m^2	----- Harvest index -----				% pod maturity at Nov. 9				------ % good seed ------			
4	0.16a	0.25a	0.26a	0.22a	93a	80a	29a	67a	87a	86a	83a	85a
8	0.14a	0.20b	0.22a	0.19b	92a	80a	30a	67a	87a	85a	82a	84a
12	0.15a	0.21b	0.23a	0.19b	92a	81a	29a	67a	83b	86a	80a	83a
Avg.	0.15b	0.22a	0.23a		92a	80a	29b		86a	86a	82a	

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† Planting date average means followed by the same letter within the same agronomic characteristics are not significantly different at 5% level according to DMRT.

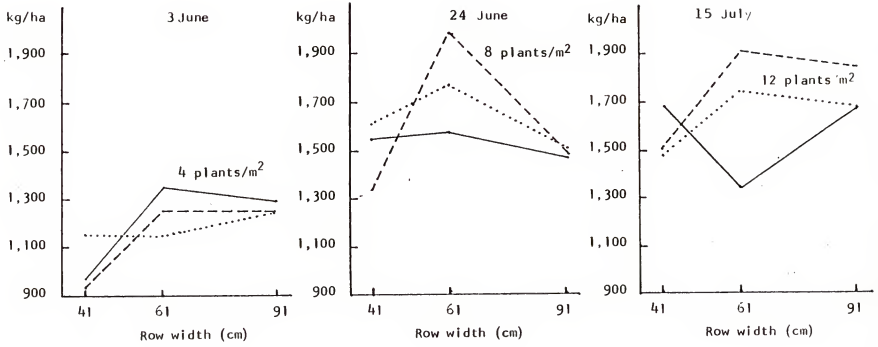

Fig. 10. Grain yield of FL 81d pigeon pea grown in three row widths, three plant population, and three dates of planting. Gainesville, Florida, 1980.

in planting time or variation in row width was observed (Table 20). An inverse relationship between plant population and grain production per plant was noted. As plant population increased, grain production per plant decreased. The 4 plants/m^2 population had significantly greater grain production per plant than that of 8 and 12 plants/m^2. No significant differences were observed between 8 and 12 plants/m^2 populations (Table 21).

Dry matter production per plant decreased as planting time was delayed, or as population was increased. Row width had no significant effect on dry matter production per plant (Table 21).

A HI was computed from three plant samples per plot. This index indicated a significantly lower value for 3 June plants when compared with two later plantings (Table 20). Row width had no significant effect; however, population of four plants/m^2 had significantly higher HI than both 8 and 12 plants/m^2. The lower HI value of the 3 June plants was due mainly to longer vegetative growth before seed production.

As planting was delayed, the percentage of mature pods on 9 November was reduced. Pod maturity was lower for 15 July plants when compared with the two earlier plantings. Row width and plant population had no significant effect on pod maturity (Tables 20 and 21).

Percentage of good seed was slightly lower in the 15 July planting, but no significant differences were observed.

Percentage of good seed was not affected by row width or plant population (Tables 20 and 21).

SUMMARY AND CONCLUSIONS

Forage and Green Manure Experiments

Field and laboratory studies were conducted in 1979 and 1980 to identify the yield potential of pigeon peas as a forage crop for North Florida. Cutting height, number of harvests, protein content, and IVOMD of forage were studied.

There were some significant differences among pigeon pea cultivar-lines in terms of dry matter forage production, ranging from 3.46 to 6.08 t/ha. Cutting at 50-cm height was better than cutting at 25 cm; the 50-cm height produced more plant survival, more dry matter production, more digestible organic matter, and more crude protein than cutting at 25 cm.

The percentage of IVOMD in forage dry matter ranged from 41.4 to 68.8%, with total digestible organic matter production ranging from 0.85 to 3.77 t/ha. Crude protein concentration ranged from 17.3 to 31.9%, with total crude protein production ranging from 350 to 1,660 kg/ha.

Leaves contained much higher percentages of IVOMD and crude protein content than stems/branches, which suggested that cultivar-lines which have a high proportion of leaves will produce higher values of IVOMD and crude protein.

Within the growing period of 170 to 200 days, three harvests seem to be appropriate. Depending on plant vigor,

first clipping can be done as early as 69 days after planting; thereafter, clipping can be done every 50 to 60 days.

The 10 pigeon pea cultivar-lines grown for forage in 1980 were also grown as green manure crops to determine dry matter production and N content. The highest yield obtained was 9.0 t/ha of dry matter during the 156-day growing period. Nitrogen concentration ranged from 2.0 to 2.8% for all pigeon pea entries.

Grain Experiment

To provide more information on pigeon pea as a grain crop for North Florida, a series of field experiments was conducted in the 1979 and 1980 growing seasons. Factors studied were cultivar, date of planting, row width, and plant population.

Grain yields at different dates of planting indicated that the optimum time to plant was the June 22 and June 24 planting dates. The best time of planting range was projected to be from June 15 to July 5 for Florida lines similar maturity pigeon peas. Within these dates, the Florida lines should produce high grain yields and give little risk of freeze damage. Earlier plantings produced lower grain yield per hectare, taller plants, higher percentage of pod maturity, higher LAI, and lower harvest index. On the other hand, later plantings had shorter plants, lower percentage of pod maturity, lower LAI, higher harvest index, and greater chance of freeze damage.

Row widths, 41, 61 and 91 cm apart, had no significant effect on plant height, days to 50% flowering, pod maturity, harvest index, and number of seeds per pod.

Populations of 3.3, 6.6 and 13.2 plants/m^2 in 1979 and 4.0, 8.0 and 12.0 plants/m^2 in 1980 had no significant effects on plant height, days to 50% flowering, pod maturity, number of seeds per pod, and seed weight. However, as plant population increased LAI increased, and dry matter production decreased.

Although the row width and plant population studies were not conclusive as to the best to use, a population of 8 plants/m^2 planted in rows 61 to 90 cm apart would be a good compromise to use for grain until futher experiments can be conducted.

Conclusions

Pigeon pea shows promise as grain, forage and green manure crop for Florida. It produces a subtantial amount of forage of fair quality, that could be especially useful in the dry fall months. Pigeon pea fixes N amounts comparable to the best of other legumes.

Pigeon pea for grain should be planted from June 15 to July 5. The grain yield of pigeon pea was comparable to other grain legumes. Although a marketing system for pigeon pea does not yet exist, the market system for cowpea, lentil, and other dry beans can be adapted to pigeon pea. Pigeon pea can be grown on more marginal soils than other grain legumes, therefore, increasing the area of cultivalble land.

APPENDIX

Table 22. Dry matter forage production of pigeon pea entries of two cutting heights for three harvests at Gainesville, Florida, in 1979.

Cultivar or line	Cutting height, cm								
	25	50	25	50	25	50	25	50	Avg.
	1st harvest		2nd harvest		3rd harvest		Total		
	Oven dry forage, t/ha								
Norman	2.32	2.03	2.75	3.61	0.98	1.22	6.05	6.86	6.45ab*
122	2.46	1.97	2.22	3.36	1.03	0.92	5.71	6.25	5.98ab
123	2.44	1.91	2.21	3.20	0.89	0.92	5.54	6.03	5.78ab
124	2.24	1.87	2.23	3.52	0.95	1.13	5.42	6.52	5.97ab
125	2.40	1.57	2.67	3.15	0.82	0.75	5.89	5.47	5.68b
127	1.81	1.79	1.17	2.71	0.37	0.77	3.35	5.27	4.31c
128	2.16	1.94	1.80	3.09	0.88	1.31	4.84	6.34	5.59b
129	2.50	1.90	2.14	3.24	0.97	0.97	5.61	6.11	5.86ab
130	2.19	1.75	2.15	3.38	1.17	1.28	5.51	6.41	5.96ab
131	2.35	2.23	2.69	3.62	1.03	1.84	6.07	7.33	6.70a
Avg.†	2.29a	1.89b	2.20b	3.29a	0.91a	1.07a	5.40a	6.25a	
Date of harvest	7-23	7-23	9-7	9-7	11-2	11-2			

* Means followed by the same letter are not significantly different at 5% level according to DMRT.

† Means followed by the same letter within the same harvest are not significantly different at 5% level according to DMRT.

Table 23. Dry matter forage production of pigeon pea entries of two cutting heights for four harvests at Gainesville, Florida, in 1980.

Cultivar or line	Cutting height, cm									
	25	50	25	50	25	50	50	25	50	Avg.
	1st harvest		2nd harvest		3rd harvest		4th harvest	Total		
	Oven dry forage, t/ha									
Norman	1.78	1.24	2.84	2.50	1.16	1.65	0.28	5.78	5.66	5.72a*
121	0.77	0.35	2.63	2.23	0.59	1.75	0.20	3.99	4.53	4.26bc
122	1.60	1.17	2.12	2.17	0.83	1.37	0.16	4.54	4.86	4.70ab
123	1.58	1.06	2.67	1.91	1.20	1.43	0.16	5.45	4.56	5.01ab
124	1.26	1.03	2.11	2.16	1.55	1.83	0.19	4.93	5.20	5.06ab
125	1.78	1.10	2.42	2.13	1.13	1.54	0.18	5.33	4.95	5.14ab
126	1.45	0.83	1.39	1.13	1.16	0.72	0.06	4.00	2.73	3.37cd
127	0.95	0.66	1.01	1.13	0.59	0.69	0.21	2.55	2.69	2.62d
130	1.35	1.03	2.25	2.20	1.12	1.09	0.19	4.72	4.50	4.61ab
132	1.53	1.33	2.53	2.18	1.30	1.92	0.17	5.35	5.61	5.48ab
Avg.‡	1.40a	0.98b	2.20a	1.97a	1.06†	1.40†	0.18	4.66a	4.53a	
Date of harvest	7-9	7-9	8-25	8-14	11-7	10-2	11-7			

* Means followed by the same letter are not significantly different at 5% level according to DMRT.

† There was an interaction effect between cutting height and cultivar or lines.

‡ Means followed by the same letter within the same harvest are not significantly different at 5% level according to DMRT.

Table 24. Plant survival of pigeon pea entries as affected by cutting height on each harvest for two crop seasons at Gainesville, Florida.

Cultivar or line	Year																
	1979							1980									
	Cutting height																
	25	50	25	50	25	50	Avg.	25	50	Avg.	25	50	Avg.	25	50	Avg.	50
	1st harv.		2nd harv.		3rd harv.			1st harv.			2nd harv.			3rd harv.			4th harv.
	%																
Norman	100	100	90	100	61	87	74ab*	97	99	98a	88	95	91a	49	86	68	80ab
121	--	--	--	--	--	--	--	50	46	48c	42	41	41b	3	32	17	31d
122	100	100	80	100	56	80	68ab	98	98	98a	71	94	83a	19	88	53	59c
123	100	100	80	98	49	78	64ab	98	99	98a	85	95	90a	41	85	63	63bc
124	100	100	75	100	59	81	70ab	93	96	94ab	83	90	86a	46	89	68	74abc
125	100	100	76	100	55	63	59b	96	99	98a	78	89	83a	30	84	57	73abc
126	--	--	--	--	--	--	--	95	86	91ab	50	70	60ab	11	53	32	9e
127	100	100	43	95	13	47	30c	89	85	87b	44	46	45b	7	23	15	4e
128	100	100	74	100	39	86	63ab	--	--	--	--	--	--	--	--	--	--
129	100	100	76	100	58	80	69ab	--	--	--	--	--	--	--	--	--	--
130	100	100	87	100	68	90	79a	95	94	94ab	91	91	91a	53	88	70	78abc
131	100	100	86	99	54	78	66ab	--	--	--	--	--	--	--	--	--	--
132	--	--	--	--	--	--	--	98	98	98ab	81	91	86a	49	86	68	86a
Avg.*	100a	100a	77b	99a	51b	77a		91a	90a		71a	80a		31	71		56

* Means followed by the same letter in the same column, or in the same line within the same harvest and crop season are not significantly different at 5% level according to DMRT.

Table 25. Plant height before harvest of pigeon pea entries of two cutting heights for three harvests at Gainesville, Florida, in 1979.

Cultivar or line	Cutting height, cm								
	25	50	Avg.	25	50	Avg.	25	50	Avg.
	1st harvest			2nd harvest			3rd harvest		
	cm								
Norman	134	137	136ab*	112	152	132a	108	135	122abc
122	138	139	139a	115	149	132a	115	125	120abc
123	131	136	134abc	112	150	131a	101	128	115cd
124	115	121	118d	102	139	121a	100	131	116bcd
125	124	123	124cd	107	135	122a	105	126	116bcd
127	117	122	120d	105	143	124a	92	128	110d
128	131	135	133abc	106	137	122a	113	141	127a
129	127	131	129abcd	113	144	129a	114	134	124ab
130	128	131	130abc	113	151	132a	113	134	124abc
131	124	127	126bcd	111	149	130a	102	126	114cd
Avg.†	127a	130a		109b	145a		106b	131a	

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† Means followed by the same letter within the same harvest are not significantly different at 5% level according to DMRT.

Table 26. Plant height before harvest of pigeon pea entries of two cutting heights for four harvests at Gainesville, Florida, in 1980.

Cultivar or line	Cutting height, cm									
	25	50	Avg.	25	50	Avg.	25	50	Avg.	50
	1st harvest			2nd harvest			3rd harvest			4th harvest
	cm									
Norman	117	121	119a*	135	131	133†	109	127	118a	66a
121	61	58	59a	78	84	81	75	83	79d	56d
122	115	115	115b	126	130	128	90	117	103b	61bc
123	114	113	114b	132	128	130	95	120	108ab	63abc
124	97	99	98e	109	115	112	100	125	113ab	60cd
125	109	104	106c	116	119	117	101	124	113ab	61bc
126	103	103	103d	105	112	109	104	121	112ab	59cd
127	93	93	93f	85	111	98	81	104	93c	65ab
130	108	109	109c	124	123	124	98	119	108ab	63abc
132	104	107	105cd	128	119	123	99	129	114a	65ab
Avg.‡	102a	102a		114	117		95b	117a		62

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† There was an interaction effect between cutting height and cultivar or line.

‡ Means followed by the same letter within the same harvest are not significantly different at 5% level according to DMRT.

Table 27. In vitro organic matter digestibility of pigeon pea forage as affected by cutting height on each harvest for two crop seasons. Gainesville, Florida.

Cultivar or line	Year														Two-year avg.
	1979							1980							
	25	50	25	50	25	50	Avg.	25	50	25	50	25	50	50 Avg.	
	1st harv.		2nd harv.		3rd harv.			1st harv.		2nd harv.		3rd harv.		4th harv.	
	% IVOMD														
Norman	50.5	48.2	49.9	43.7	56.8	57.5	51.1a*	51.1	54.8	46.2	54.8	46.1	48.6	63.3 51.7a	51.4a
121	--	--	--	--	--	--	--	65.7	63.1	45.1	53.9	47.0	52.9	62.8 55.3a	--
122	49.2	50.9	48.4	47.5	56.5	58.8	51.9a	57.0	59.7	44.1	54.0	48.1	53.6	66.0 54.2a	54.0a
123	47.9	50.0	46.6	44.5	57.3	59.8	51.0a	54.3	54.2	48.7	55.5	47.7	52.7	66.9 53.7a	52.4a
124	54.0	52.7	45.5	51.8	57.3	55.3	52.8a	56.2	61.5	47.4	54.9	43.4	50.0	63.4 53.4a	53.1a
125	48.4	48.3	52.8	48.6	58.2	57.4	52.3a	56.3	57.6	46.6	54.3	46.3	52.7	66.4 53.8a	53.0a
126	--	--	--	--	--	--	--	53.2	58.0	47.1	51.6	44.8	50.3	68.8 52.9a	--
127	50.0	51.3	47.9	45.8	58.0	57.1	51.7a	54.3	59.8	46.5	52.0	46.5	55.6	61.6 53.4a	52.5a
128	47.4	47.9	44.4	44.9	56.3	56.8	49.6	--	--	--	--	--	--	-- --	--
129	42.8	41.4	52.7	47.1	57.3	58.3	49.9a	--	--	--	--	--	--	-- --	--
130	48.4	51.5	50.1	50.8	54.0	56.6	51.9a	54.3	60.3	48.0	55.2	45.6	50.6	66.3 53.9a	52.9a
131	46.2	49.2	45.2	50.2	60.1	56.1	51.2a	--	--	--	--	--	--	-- --	--
132	--	--	--	--	--	--	--	51.2	58.1	44.9	54.9	47.4	52.5	65.5 53.1	--
Avg. †	48.5a	49.1a	48.4a	47.5a	57.2a	57.4a	51.3	55.3a	58.7a	46.4a	54.1a	46.3a	51.9a	65.1 53.5	52.6

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† Means followed by the same letter within the same harvest and season are not significantly different at 5% level according to DMRT.

Table 28. Crude protein content of pigeon pea forage as affected by cutting height on each harvest for two crop seasons. Gainesville, Florida.

Cultivar or line	Year															Two-year avg.
	1979							1980								
	25	50	25	50	25	50	Avg.	25	50	25	50	25	50	50	Avg.	
	1st harv.		2nd harv.		3rd harv.			1st harv.		2nd harv.		3rd harv.		4th harv.		
	% crude protein															
Norman	19.5	21.5	22.5	19.8	21.2	23.0	21.2a*	21.3	25.4	21.1	22.5	20.1	20.1	22.0	21.7a	21.5b
121	--	--	--	--	--	--	--	27.1	31.9	21.3	25.0	21.1	21.5	22.7	24.2a	--
122	19.5	22.5	19.3	20.9	24.8	23.6	21.7a	24.8	27.2	17.7	22.9	20.5	20.1	23.3	22.2a	22.0b
123	17.3	22.5	19.3	19.2	23.7	25.9	21.3a	20.1	25.1	19.9	23.7	19.4	20.3	23.2	21.4a	21.4b
124	21.8	26.7	21.6	25.2	25.0	23.1	23.9a	27.5	28.7	21.0	25.3	19.2	20.8	23.1	23.5a	23.7a
125	20.3	21.1	23.6	22.5	24.4	24.1	22.7a	23.8	27.2	19.4	22.6	18.0	21.2	23.7	22.0a	22.4b
126	--	--	--	--	--	--	--	24.5	26.8	21.7	23.5	18.8	22.0	25.8	23.1a	--
127	20.7	24.0	19.0	20.1	23.6	23.8	21.8a	24.7	25.9	19.6	23.4	19.5	22.3	23.3	22.5a	22.2b
128	20.1	21.4	18.1	20.8	24.7	23.8	21.5a	--	--	--	--	--	--	--	--	--
129	18.5	18.7	22.7	21.3	25.5	25.3	22.0a	--	--	--	--	--	--	--	--	--
130	19.1	22.3	20.4	23.1	22.1	24.6	21.9a	24.3	25.9	21.3	23.7	19.2	21.3	24.0	22.7a	22.3b
131	18.5	22.8	19.9	23.1	23.8	21.4	21.6a	--	--	--	--	--	--	--	--	--
132	--	--	--	--	--	--	--	23.6	25.3	21.3	22.6	18.7	19.4	22.8	21.8a	--
Avg.†	19.5a	22.3a	20.6a	21.6a	23.9a	23.8a	21.9	24.2a	26.9a	20.4a	23.5a	19.5‡	20.9‡	23.4	22.5	22.22

* Means followed by the same letter within the same column are not significantly different at 5% level according to DMRT.

† Means followed by the same letter within the same harvest and season are not significantly different at 5% level according to DMRT.

‡ There was an interaction effect between cultivar or lines and cutting height.

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BIOGRAPHICAL SKETCH

Farid A. Bahar was born on 3 April 1942, in Belawa, South Sulawesi, Indonesia. He started his agricultural training in Ujung Pandang Agricultural High School, then enrolled to the Faculty of Agriculture, Bogor Agricultural University, in Bogor, Indonesia, where he received the Engineer (Ir.) degree in 1968.

From early 1969 to the present, Mr. Bahar has conducted research through the Maros Research Institute for Food Crops in South Sulawesi. In 1973, the International Rice Research Institute in the Philippines provided him with a scholarship which led to a Master of Science degree in Agronomy at the University of the Philippines at Los Banos. At the end of 1978, the Indonesian government sent him to University of Florida, Gainesville, for advanced training which led to completion of requirements for a Ph.D. degree in agronomy.

In 1971, Mr. Bahar married Mapparimeng Bausat. They have two children: a son, Farman, and a daughter, Falma.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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