Pigeon peas: A Multipurpose Crop for Hawaii

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Pigeon pea (*Cajanus cajan*) is a multipurpose legume with a long tradition of cultivation in Hawaii (Valenzuela and Smith, 2002). Frederick Krauss from the University of Hawaii was among its earliest promoters in the state, with several extension publications authored in the 1930s proclaiming its value as a soil builder. Pigeon peas are among the top ten legumes grown globally, along with common beans, peas, chickpeas, broad beans and lentils. Sir Albert Howard, an early pioneer of organic farming, was also an advocate of the value of pigeon peas to improve soil fertility, as observed in his travels through India.

Figure 1A.Recently planted pigeon pea field, established with drip irrigation in early June at the long-term UH organic research plots in Waimānalo, O'ahu.

While today in Hawaii we think of pigeon peas as a valuable cover crop or alley crop, throughout the tropics it is also grown for food (dry or green seeds), feed (seed, leaves and young branches), firewood, medicine, fencing, roofing, shade, and to make baskets (Shanower et al., 1999; Upadhyaya et al., 2006). Globally over a billion people in 82 countries rely on pigeon peas as a main source of protein, and it is grown as a cash crop by small farmers in Africa, India, and the Caribbean. In India alone, pigeon peas are grown in about 4 million hectares (ca 8 mn acres).

Figure 1B.Proper field preparation and drip irrigation resulted in a full plant stand of pigeon peas, resulting in excellent ground cover, root growth, and biomass production.

In terms of its ecological services, in Hawaii pigeon peas should receive greater consideration for use as an alley crop, in agroforestry systems, in home-gardens, and as a cover crop. The plant has a similar erect growth habit to that of sunnhemp (*Crotalaria juncea*) (Valenzuela and Smith, 2002).

Important characteristics of pigeon peas in terms of its value as a cover crop include:

- Excellent source of organic nitrogen
- Increased organic matter and improved soil structure and quality
- Nutrient recycling
- Tolerates low fertility soils and drought conditions
- Valuable as a windbreak, especially the taller varieties
- Provide shade such as for young coffee trees and seedling nurseries
- Good forage for animal production systems (production, nutritional quality, and palatability)

- Use in annual production systems (vegetables, herbs, cut flowers and ornamentals, dry land taro), intercropping, agroforestry
- Deep-rooted

Other uses for pigeon peas

- The different parts of the pigeon pea plant reportedly have 39 different medicinal and cosmetic uses in 13 countries (Upadhyaya et al., 2006).
- Pigeon peas are a rich source of carbohydrates, minerals, and vitamins. Seed protein content ranges between 18-25%, and carbohydrate content from 51-58%. Other minerals include calcium, phosphorus, magnesium, and vitamins A and C (Odeny, 2007).
- Pigeon peas are considered a valuable forage crop, a 'cheap' feed for poultry, and for use in integrated crop-livestock systems (Krauss, 1936; Upadhyaya et al., 2006; Franzluebbers, 2007)

Figure 2A. View of pigeon peas used as a windbreak, prior to planting the 'cash' crop. Picture taken in mid June at the long-term Organic Research plots, Waimānalo.

Figure 2B. View of the same pigeon pea windbreak two months later (mid-August), with a view of the 'cash' crops at the mid-growth stage; from the far left to right, beds of daikon, sweet corn, and two 100 ft. beds of carrot.

Adaptation

- Adapted to low fertility. For instance, in Nepal, pigeon peas are considered a "low-input" keystone crop (along with taro), important for national food security (Gauchan et al., 2003).
- Drought tolerant. Optimal rainfall is between 600-1000 mm (24-40 inches). In contrast to other legumes, which rapidly close their stomata, pigeon peas allow for stomatal adjustment in response to water stress, allowing for osmotic adjustment until a critical internal water status occurs. In addition, in contrast to other legumes, solutes and other compounds in pigeon pea help to maintain integrity of the cells, preventing protein denaturation. (Subbarao et al., 1995; Subbarao et al, 2000).
- Heat tolerant. Optimal growing temperature is between 18-30C (64-85F).
- Stress tolerant. Pigeon peas can tolerate long-term stress during its growth cycle, especially the long-duration varieties (Sinclair, 2004).
- Flood sensitive. Pigeon pea does NOT tolerate flooding or water logging.
- New adapted varieties. ICRISAT and other researchers in India have developed varieties that are more drought resistant, with resistance to diseases such as Fusarium, and with varied growth characteristics to fit different production systems and cropping cycles (Winslow et al., 2004).

- Early and late varieties. Varieties may be selected based on the time period required for seed production, ranging from >60 days to over 200 days. These varieties are referred to as short (determinate) to long (indeterminate) duration maturity varieties, respectively (Subbarao et al., 1995; Mligo and Craufurd, 2007). The different variety types can be selected to match particular environmental conditions or cropping systems (Mligo and Craufurd, 2005).
- Day-length response. Pigeon peas flower under short-day conditions. Flowering is delayed under long days and under cooler growing conditions (Mligo and Craufurd, 2005).

Figure 3. Pigeon pea used as a windbreak in a field of trellised eggplants at the UH organic research plots. The lower canopy of the pigeon pea plants has been pruned to improve air circulation at the ground level, and to mulch the alleys with the leaf and stem clippings.

Contribution to soil fertility

- In terms of Nitrogen fixation, pigeon peas are nodulated by a wide range of Rhizobia strains including Bradyrhizobium (cowpea group), and fast-growing rhizobia. Pigeon peas are considered to have greater N fixation rates, compared to other legume species (Chikowo et al., 2004).
- Nitrogen fixation rates in an African study were estimated to range from 40-97 Kg/Ha (ca. 40-100 lb/Acre) (Mafongoya et al., 2006). Other research from Africa and India also show N contributions from pigeon pea to the following crop in the rotation to be in the range of 40-60 Kg/Ha of Nitrogen (Odeny, 2007; Chauhan et al., 2004). In Florida N fixation from pigeon peas was estimated to be 250 kg N/Ha (ca 250 lb/Acre) (Reddy et al., 1986a).
- Estimates indicate that leaf-drops can contribute up to 40 Kg/Ha of Nitrogen to the system (Mafongoya et al., 2006).
- When used as an alley-crop in Zambia, N contributions to the companion crops, with two cuttings per season at a 1 m (3 ft) height were 40-50 Kg N/Ha (ca 40-50 lbs/Acre) from dry matter, and 10 Kg N/Ha from the leaves (Boehringer and Caldwell , 1989).
- Top-growth biomass production has been reported as high as 35 tons of fresh weight green matter per acre. Dry matter top growth production is about 2.5 tons/acre, contributing about 25 Kg (50 lb) of nitrogen per ton of dry matter.

Figure 4. Pigeon pea residues were used to establish a heavy mulch to grow taro at the UH organic research plots,Waimānalo. The mulch cools down the soil and conserves moisture, provides an ideal environment and feedstock to promote earthworm activity, smothers weed growth, and contributes slow-release nutrients to the system.

- Fresh weight of top growth of pigeon peas obtained at the low-elevation UH organic plots in Waimanalo, Oahu during a fall planting were 15,000 Kg/Ha (15,000 lbs/Acre) when mowed at 14 weeks after planting, and at summer plantings top growth reached 43 to 80,000 Kg/Ha when flail mowed at 23 weeks after planting. Plant heights were 150 cm (58 inches) for the fall planting (at 14 weeks), and 250-280 cm (97-110 in) for the summer planting (at 23 weeks after planting). The Nitrogen tissue content of the foliage, collected prior to flowering was about 2.5% N (Valenzuela and Smith, 2002).
- Top growth reported from other areas included 6 tons/Ha (ca. 6,000 lbs/Acre) (22 months, Bolivia); 4.8 tons/Ha (7 months, Zambia), 3.5-6.5 tons/Ha (Florida); and 5.1 tons/Ha (5 months after planting, Nigeria) (several sources).
- Pigeon peas develop a deep-rooting taproot up to to 2 m (6 ft) in depth. The deep root system helps to break hardpans, improves water infiltration, and mines nutrients and moisture from the lower soil layers (Mafongoya et al., 2006). Sir Albert Howard referred to the use of pigeon peas in India as a "subsoil cultivator" (Agricultural Testament).
- In Bolivia, the root biomass of pigeon peas at a 15 cm (6 inch) depth was determined to be over 5 tons/Ha. The amount of nutrients released from root decomposition amounted to over 40 kg/Ha (ca. 40 lb/Ac) of Nitrogen and over 80 Kg/Ha of Phosphorus, representing a potential valuable pool of nutrients for the following crops in the rotation (Barber and Navarro, 1994).
- Research in India showed that a rotation with pigeon peas helped to reduce bulk density of the soil, helping to increase the root volume and root weight of the following crop in the rotation (Singh et al., 2005).

Figure 5A. The residues left over after turning over a pigeon pea cover crop, will contribute organic matter and nutrients to the 'cash' crop that will follow the pigeon peas, as part of this rotation (Chinese cabbage and broccoli, see Fig. 5B). On the far left a windbreak of pigeon pea remains, and a row of edible ginger is planted on the right hand side.

Figure 5B On the left Chinese cabbage, and on the right several broccoli beds that were planted, following the early pigeon pea cover crop (see Fig. 5A). A windbreak of pigeon peas can still be seen on the far left hand. This picture was taken on December 27th, about 70 days after the picture on Fig. 5A was taken.

- Phosphorus uptake. Research in India with rotation systems showed that pigeon peas not only increased the Nitrogen status of the soils but that it also increased the amount of Phosphorus available for the follow-up crops in the rotation (FFTC, 2000). In soils with a high Phosphorus fixation rate, pigeon peas were better able to uptake P and to maintain adequate growth while other crops such as corn and soybeans were not able to survive under such low P conditions (Sinclair, 2004). Medium- and long-duration varieties are better adapted to grow under low P soil conditions than short-duration varieties. The lower P soil levels, reduced the Nitrogen fixation rates in pigeon pea, especially in the short duration varieties (Adu-Gyamfi et al., 1989).
- The roots of pigeon pea excrete organic acids such as citric, piscidic, and tartaric acid, which help to mobilize Phosphorus in the soil. Varietal differences also exist in terms of P soil recovery (Shibata and Yano, 2003; Sinclair, 2004). The intercropping of pigeon pea with cereal crops increased P uptake by the companion cereal crops (Raghothama,1999).
- Pigeon pea develops effective mycorrhizal associations, improving nutrient uptake efficiency (Chikowo et al., 2004). For instance, mycorrhizal associations enhanced the ability of pigeon peas to uptake phosphorus by a rate of 10x compared to the 1x uptake without root inoculation (Shibata and Yano, 2003).

Figure 6A. View of a 'short-duration' (early, determinate) pigeon pea cultivar, obtained from India. This variety was planted on early July, and by late October, as observed here, the plants were in full bloom, at the low elevation UH Waimānalo Experiment Station.

Figure 6B. View of a 'long-duration' (late, undeterminate) pigeon pea cultivar obtained from India, and grown at the UH Waimanalo Experiment Station. This variety was planted on early July, along with the short-duration variety shown on Figure 6A, and by late October was still in its vegetative state, and didn't reach full bloom until early the following year.

Other Environmental Services

Because of its tolerance to drought, heat, and low fertility soil conditions, pigeon peas may be an important crop to mitigate the effects of climate change.

- Carbon sequestration. The ability of pigeon peas to sequester Carbon, in multiple cropping systems, is another advantage to help mitigate the effects of climate change. Research conducted in India showed that pigeon pea-based cropping systems resulted in greater Carbon sequestration (increased soil C by >2.5 tons/Hectare) compared to the non-pigeon pea

systems (Singh et al., 2005). Similar results were observed in research conducted in Africa (Snapp et al., 1998).
- Long-term yield declines and poor soil structure problems such as sub-surface compaction were reversed after including pigeon peas in a crop rotation sequence (Singh et al., 2005).
- An intercropping and rotational system with pigeon peas was identified in Africa for soil fertility regeneration (Snapp et al., 1998). Research in Bolivia also showed that pigeon peas was among the most effective species to restore the fertility of degraded soils, among the several grass and legume species that were evaluated (Barber and Navarro, 1994).

Use in intercropping or multiple cropping systems

- In many areas of the tropics pigeon peas are grown in intercropping systems with crops such as millet or corn.
- In Hawaii pigeon peas at one time were interplanted with pineapple, as a 'soil builder."
- In many areas pigeon peas are considered as compatible in intercropping systems because of their relative initial slow growth, minimizing competition with the companion cash crop (Snapp et al., 1998). Short- and long-duration varieties may be selected based on the compatability traits required for growth with the intercrops (Waddington et al., 2004).
- Mulches from pigeon pea residues can be effective for weed suppression (Ekeleme et al., 2003).
- Cover cropping. Pigeon peas have been used effectively as a cover crop in coffee, corn, and other crops. Benefits of the pigeon pea cover crop included improved soil fertility, weed competition, and increased arthropod diversity (Odeny, 2007).
- Overall the use of pigeon peas in multiple cropping systems resulted in greater resource use efficiency, crop productivity, more stable or resilient systems over time, and in less economic risks to small farmers in the tropics (Francis, 1986; Yadav et al., 1998; Waddington et al., 2004; Waddington et al., 2007).
- Crop-livestock systems. Pigeon peas have been evaluated in the South Eastern U.S. for its use as a cover crop, and as a forage, in integrated crop-livestock systems (Franzluebbers, 2007).

Other production considerations

- Some pigeon pea varieties have reported resistance to root-knot nematodes, Meloidogyne incognita (Reddy et al., 1986b; Baldwin and Creamer, 2003)
- Host of the sting nematode, Belonolaimus longicaudatus.
- Some varieties are slow growing in the early growth stages, and are thus susceptible to competition from weeds.

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