PIGEONPEA SELECTION AND BREEDING

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Origin and importance of pigeonpea

Pigeonpea [*Cajanus cajan* (L.) Millsp] is believed to be native of Indian subcontinent where the greatest genetic variability of the species is found. Africa has also been considered by some authors as a possible center of its origin, since ample variability can be found there as well. Most likely, however, pigeonpea is originated from that subcontinent but it was taken to Africa and Asia thousands of years ago, from where it was accidentally introduced into the American continent, possibly during the period of slave trading, were it spread widely (FULLER; HARVEY, 2006). It is probably in this period that the genotypes which originated the materials cultivated in Brazil, specially in its northeastern region, were introduced (SANTOS et al., 1994).

Pigeonpea is cultivated mainly in tropical countries where it is recognized by different denominations such as “pigeon-pea”, “gandul”, “red gram”, “tur”, “arhar” and “pois-d’Angole”. It constitutes a significant part of the diet of human populations in Burma, Uganda, Kenya, Dominican Republic, Panamá and Porto Rico. It is also cultivated in southern United States, mainly in Texas, for regeneration of disturbed lands. Reddy et al. (1998) estimated that ninety per cent of the world production of pigeonpea comes from India where it is cultivated for various purposes, such as grain or pod for human consumption, forage and energy production. They estimate that the world cultivated area with pigeonpea is of, approximately, 3.4 million hectares which results in an annual grain production of 2.7 million tons and which represents an average yield of 790 $kg.ha^{-1}$. In Venezuela and Brazil, where this crop is also important, breeding programs have been developed with the aim of improving grain and forage quality and productivity as well as for other specific purposes such as soil amelioration.

Morphologic and agronomic characterizations

Bailey (1977) imputes to Augustin Pyramus De Candolle (1778 – 1841) the classification and description of the genus *Cajanus*. The taxonomic description of *Cajanus*

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cajan, Millsp (syn. *Cytisus cajan*, L. *Cajanus bicolor*, DC. *Cajanus indicus*, Spreng) evidentiates the ample genetic variability of this legume species, whose plants can be: multi-branched pubescent bushes 1.2 to 4 m tall, with lanceolated or narrow elliptical leaflets 4 to 10 cm in length, and sharp ended and lightly hairy (both surfaces) leaflets, with 2 cm long yellow or orange flowers (Figure 1) with brownish back but other color combinations are also found, very pubescent pods 5 to 7.5 cm long and approximately 1.3 cm wide, round seeds approximately 0.6 cm in diameter often brown with a small white hilum. Recent studies indicated the existence of even higher degree of variability. Current information on the status of this crop can be found on the web site of The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) – (http://www.icrisat.org/PigeonPea/PigeonPea.htm) a leading institution in the world as far as research with plants of *Cajanus* genus is concerned and which is located in India.

Taxonomic descriptors proposed by ICRISAT (1984) and others, provided by the “International Board for Plant Genetic Resources” (IBPGR), were used as a reference for the characterization of new pigeonpea lines developed in Brazil (GODOY et al., 2003 and 2004), with some adaptations and simplifications. The descriptors used were: growth habit, plant height at 50% flowering, number of primary and secondary branches, stem width at 40 cm height from soil surface and at 50% flowering, leaflet shape and hairiness, primary and secondary flower colors, flower stripe pattern, flowering pattern, primary and secondary seed colors, hilum color and width and seed shape.

The pigeonpea plant is erect and branched, with a strong stem and composed leaves with three leaflets. Its root system is constituted by a strong taproot that can grow up to 2 m deep and a great number of secondary roots concentrated mainly in the top first 70 cm of soil. The roots nodulate in consequence of their association with *Rhizobium* sp. of the cowpea group (SINGH; OSWALT, 1992). Pigeonpea stems are strong and woody; they contain starch as reserve in the vegetative phase, which gradually disappears in the reproductive phase. The plant branching pattern varies according to genotype and inter-plant spacing. In general, the plants can be classified as erect, half-erect or prostrated. Meanwhile, its flowering pattern can be determinate or indeterminate.

Photo: Godoy, R. (2005)

Figure 1 – A flowering pigeonpea plant.

Singh and Oswalt (1992) consider pigeonpea a short day plant, but combinations of photoperiod and temperature can influence markedly its bloom and seed maturation patterns. Flowering in this species, however, is associated with ample genetic variability which leads to the existence of gradations in terms of response to photoperiod. Even genotypes insensitive to photoperiod can be found. In a fully developed flower, the anthers involve the stigma and its dehiscence occurs one day before anthesis. Fertilization occurs on the day of the pollination; pigeonpea is a self pollinating plant and the percentage of cross-pollination in absence of pollinator agents (insects) is negligible. However, when present, certain types of insects may increase the degree of cross-pollination to 40% or more, even though only 10% of the flowers eventually originate pods. Seed development is quite noticeable about seven days after fertilization and a pod is completely formed in approximately twenty days after fertilization. Genotypes do vary in terms of degree of seed dormancy (GODOY; SOUZA, 2004).

Pigeonpea does not require specific soil or climatic conditions, so much so that it can be cultivated between latitudes 45° N and S, with temperatures varying from 17° C to 38° C.

Even though it is generally recommended cultivation in low fertility soils, several lines tested in Brazil responded well to increases in soil fertility levels. In São Carlos (SP), Brazil, in a very poor soil, three pure lines developed by EMBRAPA, namely, g3-64, g146-94 and g167-97 produced in three months, respectively, 2,380, 3,890 and 4,420 $kg.ha^{-1}$ of plant dry matter; however, in a higher fertility soil in the same area these lines yielded, in the same period 16,680, 13,320 and 14,870 $kg.ha^{-1}$ dry matter. Another important agronomic characteristic of the species is its tolerance to droughts, possibly associated with its vigorous root system.

Genetic variability

The high genetic variability presented by *Cajanus cajan* offers great opportunity for the selection and the development of cultivars persistent and grazing-tolerant by cattle under field conditions, among other desirable traits. Godoy et al. (2003 and 2004) found within three pigeonpea cultivars and twenty eight pure lines, thirteen stem colors, intermediate or thick stems, in plants that had erect or semi prostate growth habit and heights varying from 65 to 195 cm at flowering. These genotypes presented from seven to twenty five primary branches and up to three tertiary branches and three different leaflet shapes. Flowers with four and ten secondary colors were also found, and four different stripe patterns. Pods presented three different shapes and eleven colors and the seeds, six primary and four secondary colors. Wide differences were also found with respect to their reproductive cycle. Among lines, flowering beginning varied from 69 to 131 days and 100% flowering varied from 90 to 158 after seedling emergence. Within lines, flowering lasted from 5 to 42 days.

Heritability studies on some of the main genetic traits of pigeonpea have been reported by Menezes (1956), Werner (1979), Santos et al. (1994), among others, so that the degree of heritability of most of these traits were determined. Therefore, pigeonpea is a crop species with many and important features, with an ample and available genetic variability and for which appropriate breeding methods are well established. It is, however, surprising the scarcity of breeding projects, mainly in Brazil, aiming at the development of pigeonpea cultivars as alternatives for many agricultural problems such as soil compaction, nematode infestation, pasture degradation, and forage production in low fertility, acid soils.

Pigeonpea breeding

Pigeonpea breeding can be done similarly to the way done with most leguminous crops. Presently in Brazil, however, successful programs can still be conducted through selection of lines presenting desirable characters, since a good number of pure lines are available. In the near future however, cross-breeding these lines as well as other materials eventually available may be necessary, with the objective of incorporating, for example, disease and nematode resistance or tolerance into high-yielding forage cultivars.

Artificial hybridization and self-pollination procedures were well described by Sharma and Green (1980): firstly, the female has to be prepared. Flowering in pigeonpea usually continues until 75 to 80% of the pods are already mature. However, only 10 to 20% of the flower buds develop into pods. At the onset and during peak flowering, 50% or more of the flowers may set pods but as the flowering period progresses, pod setting diminishes considerably. Crossing success, therefore, is higher if early developing buds are chosen on the female parent. Only 2 to 10 buds should be emasculated on each branch. Tightly closed buds, approximately two-thirds the size of mature buds, should be emasculated. At the correct stage the bud should show a bright corolla color without any greenish hue. The selected bud should be firmly held between the thumb and the middle finger with the index finger used to support the flower. The curved side of the standard is held toward the crosser and the sepal covering the keel is removed. The corolla is opened by inserting one of the tips of a fine pointed forceps at the base of the keel and moving upward to the tip of the standard. The bud will open with slight pressure of the supporting index finger, and the well-developed yellow anthers can be removed from the staminal column with a forceps.

The stigma is receptive before anthesis thus pollination can be done immediately after emasculation. Pollen source buds from male parent should be collected between 8 and 10 am. These should be large, unopened buds in which the anthers will dehisce on the day collected. They can be used throughout the day if kept covered in Petri dish on moist filter paper. When a flower is emasculated, the staminal column of the pollen bud is used to brush pollen on the stigma of the female. If pollen buds are plentiful, the staminal column of the pollinator bud is left in contact with the pollinated stigma by trapping it between the edges of the corolla. Single flower buds can be used for two to three pollinations when necessary. For selfing, cloth bags or fine-mesh nylon cloth bags are effective in excluding vector insects; cross-pollinated flowers can be identified with colored threads.

Sharma and Green (1980) consider natural hybridization as also a major source of variability in released cultivars, as well as in landraces in farmer's fields. Both sources of variability have been extensively used by Indian breeders for selection of improved types.

In the EMBRAPA Pigeonpea Program no hybridization has yet been done. The program was initiated in 1988, with a preliminary agronomical evaluation of a collection gathered from various Brazilian institutions. This evaluation was performed at the Southeast - Cattle Research Center (lat. 22º 01' 04" S; long. 47º 53' 27" W) in São Carlos (SP), Brazil, in a very low fertility soil, since in a previous project, pigeonpea had been selected as an appropriate species for that situation. There were sixty nine accessions and one control, the cultivar Kaqui. The same procedure was subsequently adopted when a collection of pigeonpea accessions was received from ICRISAT.

The experimental methodology used, their results and conclusions were reported by Godoy et al. (1994 and 1997). In the first experiment, the g3 accession was selected for its high forage yield, low tannin content and high leaf retention in winter. This accession, as well as the other components of the collection, had a certain degree of mechanical mixture and segregation and were therefore submitted to a selection process under isolated conditions. Ten seeds of the most common seed color observed in the field in each accession were planted in a greenhouse, and the seeds from plants with the predominant morphological characteristics in the field were selected. Ten seeds of those plants were then planted and the process repeated until 100% of the plants with those characteristics were obtained. For the g3 accession it occurred after three selection cycles in the year of 1994. The pure line was then named g3-94. Using this same process, forty pure lines were selected.

The g3-94 line was re-evaluated along with sixteen other lines and three controls, namely, the commercial cultivars Kaqui, Fava Larga and Anão, in five locations within the State of São Paulo, Brazil. Methodology, results and conclusions were reported by Godoy et al. (1994). Again, the line g3-94 excelled in performance and forage yield. Finally, this line was submitted to animal grazing trials, according to the methodology reported by Rodrigues et al. (2004). It was concluded that the g3-94 line represented a viable alternative to complement dairy cattle feed in the dry season (Figure 2) since it reduced the need of concentrate use and, consequently, reduced feeding costs by 21%.

Photo: Godoy, R. 2005.

Figure 2. Dairy cattle in a pigeonpea (line g3-94) protein bank. São Carlos (SP), Brazil.

In 2007, the line g3-94 was legally registered and protected in the Ministry of Agriculture, Livestock and Food Supply, in accordance with the Brazilian Plant Variety Protection Law, under the name of cultivar BRS Mandarim. It is interesting to notice that in the process of obtaining pure lines, several morphological changes occurred in the plants, differing the BRS Mandarim cultivar from the accession, g3 (Epamig 1822) from which it was originated. These differences are listed in Table 1.

In the first field evaluation made in São Carlos (SP), the g3 accession (EPAMIG 1822) yielded in five harvests, from February 1989 to March 1991, 11,855 kg/ha dry matter. Under the same conditions, the pure line obtained (g3-94) yielded in six harvests, from April 1999 to June 2001, 16,486 kg/ha dry matter. So, it made possible one extra harvest and a gain of 39% in dry matter yield.

Table 1. Morphological comparison between a pigeonpea cultivar (BRS Mandarim) and the accession from which it derived (g3 – EPAMIG 1822).

Morphological trait	***BRS Mandarim***	***g3 (EPAMIG 1822)***
Leaflet shape	Broadly elliptical	Broadly and narrowly elliptical
Primary flower color	Chrome yellow	Chrome yellow
Secondary flower color	Mimosa yellow	Mimosa yellow and mimosa yellow with purple stripes
Stripe pattern	Uniform	Uniform and dense
Green pod color	Light green	Light green and light green with dark purple stripes
Mature pod color	Straw	Straw and straw with purple brown stripes
Seed color pattern	Plain	Plain and spotted
Primary seed color	Reddish brown	Reddish brown and cream
Secondary seed color	No	No and reddish brown
Seed shape	Very broadly ovate	Ovate

All other forty lines selected are currently being tested for their capacity to promote soil decompaction and their resistance to pests and diseases. Three lines, g8-94, g5-95 and g124-95 seem promising and appear to have a good ability to penetrate heavily compacted soils with their root systems. On the other hand, the lines g167-97, g124-95, g27-94, g40-95, g154-95, g127-97 and g9m-97 have shown resistance to *Macrophomina phaseolina*, a fungus which causes one of pigeonpea major diseases in Brazil, the ‘crown and root rot’.

Ongoing research at ESALQ/University of São Paulo regarding nematode resistance is of special interest. Lines g109-99, g40-94, g146-97, g58-95, g127-97, g17C-94, g66-95, and g59-95 were found to be resistant to *Meloidogyne javanica*. This is particularly important since they could be used to reduce populations of this phytopathogenic nematode in sugar-cane plantations, where they cause significant yield losses. All lines are being tested as to their resistance to other nematodes as well. Molecular studies being conducted at UNICAMP (State University of Campinas) will undoubtedly contribute for the acceleration of the breeding program.

In conclusion, EMBRAPA's pigeonpea breeding program will soon be able to propose new cultivars for specific agricultural uses and, in the future, it will make the association of a number of traits of agronomic interest into single cultivars possible.

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