ORIGIN AND MORPHOLOGY OF PIGEONPEA

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Incountry Legumes Training Course, March 20-25, 1988, Parvanipur, Nepal

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I. INTRODUCTION

Pigeonpea grows well in subtropical and tropical environments extending between 30°S to 30°N latitudes. India, Kenya, Uganda, Malawi, Tanzania, Burma, Puerto Rico, Dominican Republic, Venezula, Burma, and India are the other pigeonpea producing countries. A reliable , global statistics about pigeonpea cultivation and production is not available. However, it is estimated to be grown in about 3.5 m ha annually. India is a major pigeonpea producer where it is grown in 3.2 m ha annually. In Nepal, based on its area and production, pigeonpea at present does not appear to be of great importance since it occupies only 16,100 ha, which amounts to be only 6% of the total area grown under pulses (Bharti, 1987). However it is an important pulse crop of the Terai region where traditionally long-duration pigeonpeas are grown.

II. ORIGIN AND DISTRIBUTION

The place of origin of pigeonpea is disputed and has been the subject of speculation. The presence of pigeonpea seeds in the Egyptian tombs of the XII Dynasty indicated that it was cultivated there about 2400 B.C. van Rheede (1686), Linnaeus (1737), Burman (1737), and Jacquin (1772) mentioned pigeonpea as a native of the East Indies. Rumphius (1747) suggested that pigeonpea was native to Malaya. The Swiss botanist de Candolle (1813) while establishing the genus, mentioned "India Orientalis" as its home and tropical America as another area of cultivation. Later in 1884, he suggested tropical African (Zanzibar to Guinea) origin. Some other workers (Purseglove, 1968; Zeven and Zhukovsk, 1975) also opined that pigeonpea is a native of Africa from where it spread to India and other parts of the globe.

Vavilov (1939) considered India as a primary center of origin of the cultivated pigeonpea. Oza (1972) reviewed the subject and concluded that India was the original home of pigeonpea before it spread to the new world. According to De (1974) the pigeonpea originated in peninsular India and was carried to Africa before 2000 B.C. Reviewing the literature on this aspect Royes (1976) considered that the dispute about the origin of pigeonpea has settled in favour of India. However, Brucher (1977) still advocates the African origin of pigeonpea because of the presence of a single endemic West African species, Cajanus kerstingii Harms. In a recent review van der Maesen (1980) concluded that "floristic, linguistic, and cytological evidence points to an Indian origin of the pigeonpea, from where it was most probably distributed to Africa atleast two millennia B.C." as shown in Figure 1. He also feels that Africa is a definite secondary center of origin since some pigeonpea characters found in African materials are not present in the material from the Indian sub-continent.

Reddy (1973) and De (1974) postulated that the genus Cajanus probably originated from an advanced Atylosia species through selection of single gene mutation. Hains (1920) described the morphology of a wild relative of pigeonpea (A. cajanifolia) which resembles cultivated pigeonpea in all the respects except for the presence of large strophiole (a vegetative outgrowth on the hilum end of the seed) on its seeds. The prominent strophiole has also been found on several accessions of pigeonpea (van der Maesen, 1980). Recently, *A. cajanifolia* has been collected by ICRISAT's Germplasm Botanist from the forests of central India where the locals call it "Ban-Arhar" meaning "wild pigeonpea". *A. cajanifolia* can be pollinated from pigeonpea pollen transferred onto its stigma by insects to produce natural hybrids. Morphological and cytological similarities of *A. cajanifolia* and *C. cajan* led van der Maesen (1980) to postulate that *A. cajanifolia* is presumably the link between the genus *Atylosia* and *Cajanus*.

III. TAXONOMY

Tuvarai and Tuvari, the oldest names of pigeonpea in the Dravidian language, are quoted in the text Gathasaptasati published between 300-400 A.D. (De, 1974). According to van der Maesen (1986) the first scientific nomenclature without very clear illustrations of the crop was by Bauhin and Cherla during 1650-1651. They called pigeonpea *Arbor trifolia indica*. while van Rheede (1686) named it *Thora paerou*, meaning 'common dhal' in Malayalam language.

According to Sloane (1725) "Pigeonpea", the present day popular English name of this crop, was first used by Plukenet (1692) in Barbados where it was grown in barren soils mainly for feeding pigeons. The name *Cajanus* is derived from the Malaysian name Katjang. Linnaeus (1753) gave the first binomal nomenclature to pigeonpea as *Cytisus cajan*. Since then various taxonomists have modified its scientific name from time to time. Thothathri and Jain (1981) and van der Maesen (1986) have written excellent reviews on this aspect. At present the following taxonomical classification is accepted throughout the world:

Tribe = Phaseoleae

Sub-tribe= Cajaninae

Family = Leguminosae

Sub family= Pipilionaceae

Genus = Cajanus

Species = cajan

Bionomials such as Cytisus cajan L., Cytisus pseudo-cajan Jacq., Cajanus cajan Huth., Cajanus cajan Druce., Cajanus inodorum Medic, Cajanus pseudo-cajan Schi. & Gull., Cajanus bicolor DC., Cajanus flavus DC, Cajanus indicus Spreng, and Cajanus luteus Bello, found in the old literature can be considered synonyms of the presently accepted binomal Cajanus cajan (L.) Millsp.

There are 13 closely related genera within the sub-tribe Cajaninae and the genus Cajanus has always been considered to be closely related to the wild species of the genus Atylosia. Infact, morphologically these two genera appear to be quite distinct; Cajanus is cultivated while Atylosia are found in uncultivated, wild, and weedy forms. According to van der Maesen (1986) a species found in Senegal, Togo, and Ghana by Hutchinson and Dalziel (1958) and described as Cajanus kerstingii is a misnomer and should have been classified to the genus Atylosia.

Baker (1876) separated Cajanus and Atylosia on the basis of the prominant strophiole present on Atylosia seeds. The genus Atylosia W. and A. forms a secondary gene pool consisting of 34 species.

van der Maesen (1981) reviewed the relationship between Cajanus and Atylosia and judged that Atylosia to be congeneric with Cajanus and, therefore, they can be merged. The taxonomy of the genera Cajanus and Atylosia has been revised by van der Maesen (1986) and based on morphological, cytological, and chemo-taxonomical data he sunk genus Atylosia into Cajanus. According to him now instead of 13 there are 11 genera in sub-tribe Cajaninae and the genus Cajanus embraces 32 species endemic to Indian, African, and Australian continents.

IV. MORPHOLOGY

Plant type: Botanically pigeonpea is a short-lived perennial shrub with a life span of about 10-12 years (Remanandan, 1981). Generally, pigeonpea is cultivated as an annual crop but true annual types have not been reported so far. A large variation exists for plant type and growth habit. Traditionally indeterminate tall types and lately short determinate types are cultivated. The angles of primary branches determine the spread of plant which in nature vary from compact with acute branch angle to spreading types having obtuse branches. Plant height in pigeonpea vary from 30-400 cm and the aged perennial types may even grow taller. The expression of plant biomass, height, and branches of a genotype is greatly influenced by the environmental conditions. Plantings carried out in shorter days result in small sized plants with considerable reduction in height, branching, and biomass production.

Leaves: The first couple of leaves of a young seedling are simple and opposite. The subsequent leaves are trifoliate, having lanceolate to elliptic leaflets which are acute at both the ends. The pinnate leaves are hairy on both surfaces and vary in color with various shades of green with minute resin glands beneath. The leaves are arranged in a 2/5 phyllotaxis on the main axis and on branches. Petioles are ribbed and end in a leaflet. At the base of the petiole and leaflets pulvini are present. The activity of pulvini helps in adjusting the leaf/leaflet angles throughout the day. When the sunlight is intense and especially when the plants are under water stress, the leaflets in the exposed canopy tend to take up a position parallel to the incident light. At night the leaflets are folded vertically upward (Sheldrake, 1984). As the leaves approach maturity an abscission zone develops at the base of the petiole and leaflets. Saxena and Sharma (1981) reported large variation for leaf weight, petiole weight, petiole length, leaf area, and specific leaf weight in 27 pigeonpea genotypes of diverse maturity groups.

Root system: The pigeonpea plant has deep tap root system often growing over two meter deep with numerous rootlets. The most extensive development of roots takes place in the upper 60 cm

(Sheldrake and Narayanan, 1979a). A number of nodules are formed on the roots by rhizobia belonging to the cowpea group. Nodule formation in pigeonpea is initiated through the development of infection thread in the root hairs. Pigeonpea nodules have a terminal meristem and a green pigmented senescent zone develops from the base of the nodule (Thompson et al., 1981). The bacteroid zone of pigeonpea nodules is generally pink due to leghemoglobin. The number of nodules on field grown plants fluctuates throughout the growing season, but shows a clear tendency to decline towards the end of the reproductive phase (Sheldrake and Narayanan, 1979a). There is a variability among germplasm lines in nodulation and asscociated characters (Thompson et al., 1981). Nodule formation and development are also affected by soil type, season, and duration of the cultivar.

Inflorescence: Generally, the inflorescence is an axillary raceme varying in length from 4 to 12 cm. In the indeterminate cultivars flowering proceeds acropetally while in the determinate types it is basipetal. On an average 4-6 floral buds are found in bunches. In a few cultivars, flowering starts at nodes behind the apex and proceeds acropetally as well as basipetally (Sheldrake, 1984). In some genotypes a few flowers can also be seen on the main stem. Flowering in certain genotypes continues even after pod formation and maturity. The rachis is small and bracts are deciduous, frequently with glandular hairs. The pedicels are green 1-2 cm long with dense pubescence and glandular hairs. Calyx is companulate. Corolla typically is papilionaceous. Standard petal is bi-auriculate. Wing petals are obovate and the keel is boatshaped dorsally split. The stamens are diadelphous having free vexillary stamen. The longer and shorter filaments are alternately arranged. Anthers are ellipsoid and dorsifixed. Stigma is capitate while the ovary is sessile. The majority of the flowers open between 8 A.M. and 3 P.M. At the base of pedicel there is an abscission zone and majority of the flowers drop off without setting pods (Howard et al., 1919; Pandey and Singh, 1981) and only 10-20% of the flowers develop into pods. Depending on the genotypes the flowering may be synchronous or unsynchronous. The phenotypic expression of the inflorescence can be modified markedly by photoperiod, temperature, sowing time, and plant spacing.

For about the first 21 days after anthesis the pod wall develops more rapidly than the young seeds, but thereafter, it makes little further growth (ICRISAT, 1975). Fully developed indehiscent pods are flattened, slightly curved, or straight with diagonal constrictions between seeds and terminating in a slender beak. Pod color varies from yellowish-green to dark green with purple blotches of varying intensities. Pods contain 2-9 seeds and in large pods some ovule abortion may also be observed. The pod wall contains hairs and are well supplied with secretory ducts containing tanin-like substances (Sheldrake, 1984).

Seeds: Pigeonpea seeds vary greatly with respect to their size (2-24 g/100 seeds), shape (round, oval, or flatenned) and color (white, brown, red, purple, or black). The seeds have smooth surface with a small white hilum. The cotyledons are light yellow. In general there is no seed dormancy and the germination is hypogeal.

V. REPRODUCTIVE BEHAVIOR

(1) Natural cross-pollination:

The flowers of pigeonpea are cleistogamous which generally favour self pollination. However, unlike other legumes, a considerable degree of natural out crossing has also been reported in this crop. Occurrence of natural out crossing poses problems in developing pure lines and in maintaining the purity of released cultivars and germplasm accessions. On the contrary, out crossing in pigeonpea can be profitably used for developing high yielding hybrids (Saxena et al., 1986) and for the improvement of breeding populations (Khan, 1973). As a result of frequent out crossing the existing standard adapted pigeonpea cultivars have become heterogeneous for several important agronomic characters (Gupta et al., 1981).

Natural out crossing in pigeonpea takes place as a result of frequent insect visitation from one flower to another within and across the fields. Onim (1981) listed 24 species of insects which are capable of affecting cross fertilization in pigeonpea. Of these Megachile spp. and Apis mellifera are the main pollinating vectors (Williams, 1977; Onim, 1981).

Howard et al. (1919) were the first to report 14% out crossing in pigeonpea and since then several reports have appeared in the literature. The extent of out crossing, has been found to range from 0-70% in various locations. At a particular site a combination of factors determine the extent of out crossing in pigeonpea. These include the number of insect pollinators present in relation to the number of flowers, the flowering habit of the varieties, the location of the field in relation to the insect habitat or barrier crops, and environmental factors such as temperature, humidity, and wind velocity and direction (Bhatia et al., 1981).

(2) Photoperiod responses:

Pigeonpea genotypes are quantitative short day plants (Sengupta, 1955) and vary widely in the length of their growth cycle ranging from 100 to 300 days. Because of its photosensitivity, planting date has a marked effect on the phenology of plant. Singh *et al.* (1971) in India, Spence and Williams (1972) in Trinidad, Abrams and Julia (1973) in Puerto Rico, and Akinola and Whiteman (1974) in Australia studied the effect of planting dates and observed that plantings in the months with shorter daylengths flowered in less time and had reduced plant height and branching than planting under longer days. Photoperiod-sensitive cultivars flower more rapidly when sown after the longest day (Whiteman *et al.*, 1985). Like soybean (Byth, 1968) early maturing pigeonpea cultivars are less sensitive to changes in daylength than the medium and late maturing genotypes (Green *et al.*, 1979). Wallis *et al.* (1981a) studied flowering responses of 37 early maturing lines of pigeonpea under normal and extended (16 hrs) photoperiods in Australia (27°S). They concluded that selection for earliness of flowering in field conditions at 27 to 29 latitudes does not necessarily identify material insensitive to daylength. Turnbull *et al.* (1981) studied the effects of photoperiod and temperature on floral initiation and floral bud development in early maturing pigeonpea lines under controlled environmental conditions. They found that the floral initiation occurred earliest under low temperature (24/16°C) in a 16 hour photoperiod. Reduction in daylength to 8 hours or increase in temperature both resulted in delays in floral initiation. They also reported that the rate of development of the floral primordia increased with increase in both daylength and temperature. From the controlled environment studies McPherson (1985) concluded that the minimum duration from sowing to flower bud initiation occurred between 20° and 24° C while the period from sowing to flowering was at a minimum between 20°and 28°C.

(3) Male sterility:

Reddy et al. (1977) identified five aberrent floral types in 3659 pigeonpea germplasm and 3557 sublines grown at ICRISAT center in 1974. The most interesting of these male sterile types was characterized by translucent anthers caused by non-seperation of tetrads associated with a persistent tapetum and intercellular walls of the two adjacent microsporangia. A single recessive allele (ms1) was responsible for this form of male sterility (Reddy et al., 1978). Wallis et al. (1981b) reported another form of male sterility which had shrivelled, arrow-head shaped, non-dehiscent, brown anthered colored anthers. In this male sterile source the sterility was found to be due to degeneration of the tapetum by vacuolation which occurred during the first division of meiosis (Dundas et al., 1981). Saxena et al. (1983) reported that the brown anthered male sterility was controlled by another recessive gene (ms2). A third male sterile source in photoperiod-insensitive genetic background was reported by Dundas et al. (1982). They also reported that in this male sterile genotype, degeneration of the microsporogenesis takes place at early prophase stage. Saxena et al. (1981) reported the presence of a partial male sterile system in pigeonpea which was caused by partial collapse of fully developed tetrads. In this type the amount of pollen grain produced within each flower was very little.

(4) Pod setting:

In pigeonpea about 90% of the flowers drop without setting pods (Pandey and Singh, 1981). Rawson and Constable (1981) reported that within a pigeonpea plant photosynthates are produced in excess of that required for pod setting. Analyses of growth have shown that all the assimilates accumulated during the reproductive phase are not partitioned into pods rather a high proportion of it goes into vegetative parts (Sheldrake and Narayanan, 1979a). Sheldrake and Narayanan (1979 b) also found no differences in the earlier or later formed pods with respect to either seeds/pod or seed weight. These studies have shown that in pigeonpea neither the source nor the sink is limiting. Sheldrake (1979) developed a working hydrodynamic model which illustrates some of the main factors that might be involved in the control of pod set in pigeonpea. Sheldrake (1984) opined that pest damage, inadequate pollination, competition from earlier formed pods and other sinks within the plant and intrinsic physiological mechanisms connected with the perennial nature of the plants are the factors responsible for poor pod set in pigeonpea.

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Movement of pigeonpea from its center of diversity (prepared e.g. with data from De 1974, and Vernon Royes 1976)

(Source: van der Maesen, 1980)