Pigeonpea

G. Johansen

Introduction

Pigeonpea is cultivated mainly in India, which in 1987 had about 90% of the world's area (3.61 m ha) and production (2.55 mt), according to FAO statistics. However, the true extent of its cultivation outside of India is not accurately recorded because it is usually a minor component of cropping systems, is mainly used for home consumption without passing through marketing systems, and is grown as homestead, border, hedge or inter-crops which are difficult to quantify. The other more important regions where pigeonpea are cultivated include the rest of South Asia, eastern Africa and the Caribbean region; but it can be found in virtually all tropical countries.

ICRISAT has a world-wide mandate for improvement of pigeonpea. In recent years, considerable literature has become available for the crop, and the major references on which this paper is based are listed in the bibliography. An international workshop on pigeonpea improvement is planned to be held at ICRISAT in 1992. This paper presents an extended summary of the main features of the pigeonpea crop, emphasizing recent research developments.

Prospects

Prospects for further expansion of the crop in India are particularly bright due to increasing demand, and hence rising prices, for pulses in general.

Recent development of short-duration genotypes, hybrids and perennial pigeonpea has considerably widened options for pigeonpea cultivation on a world-wide basis. The multiple uses of pigeonpea further add to the crop's potential for introduction into new areas.

Species Information

Botanical Name *Cajanus cajan* (L.) Millsp.

Common Names Pigeonpea, red gram, arhar and tur.

Origin and distribution India is considered to be the primary centre of origin and diversity for pigeonpea. It has been spread by man, first to eastern Africa (approx. 2000 BC), and more recently throughout the remainder of the tropics.

Description Although largely grown as an annual crop, cultivated pigeonpea is essentially a perennial shrub. Long-duration types may take up to 300 days for the first flush of seed to mature, whereas recently bred extra-short-duration genotypes can mature within 90 days of sowing, and still produce high yields. A wide range of growth habits is available in the germplasm and this is currently being exploited at ICRISAT in the design and testing of ideal canopy structures for different cropping systems. Flowering habit can be either determinate or indeterminate; although the former term really refers to synchronous flowering and podding in terminal racemes. Pigeonpea is partially out-crossing (around 20%). Flowering in pigeonpea is profuse but only a small proportion of flowers consequently form pods. The number of ovules per pod varies from 2 to 9 indifferent genotypes. Seed size is normally in the range 6-11 g per 100 seeds but there are genotypes having seeds either smaller than 5 or greater than 15 g per 100 seeds. There is also considerable variation in seed colour and shape.

There are several wild species related to pigeonpea which have various desirable characters, such as pest and disease resistance, salinity resistance and rapid initial growth rate. Some of these readily hybridize with cultivated pigeonpea (e.g.: *Atylosia albcan*) whereas others do not (e.g. *Atylosia platycarpa*), a revision and complete description of the genera *Cajanus* and *Atylosia* is given by van der Maesen (1986).

Genetic Resources and Breeding ICRISAT holds the world germplasm collection of pigeonpea. There are now over 11,000 accessions in medium- and long-term storage. These are characterized in terms of passport information as well as various other descriptors determined from multilocation evaluation trials. Seed samples and associated information from this collection are available to anyone on request.

Most breeding efforts on pigeonpea have been carried out in the Indian national programme or at ICRISAT. For traditional medium-and long-duration types, emphasis is given to improving stability of yield, mainly by incorporating disease resistance (e.g. to fusarium wilt and sterility mosaic disease). Short-duration pigeonpea has attracted increasing breeding attention over the past decade with the major objectives being increased yield per unit of crop duration, shorter duration to better fit into particular cropping systems, lesser plant height to allow easier spraying for insect pests and other management operations, as well as pest and disease resistance. Considerable progress has been made in developing a wide range of short-duration varieties to suit diverse environments and cropping systems, not only in India but also with potential for elsewhere. The out-crossing behaviour, together with the identification of genetic male sterility has permitted the development of pigeonpea hybrids, some of which show considerable yield advantages over comparable varieties. After extensive multilocation testing, the first pigeonpea hybrid, ICPH 8, was identified for release in India this year. Breeding efforts have also improved quality of pigeonpea grain, without a sacrifice in yield. High protein (28% *vs.* the normal 18-22% in cultivated pigeonpea) lines have been developed from crosses with *Atylosia* species.

Environmental Requirements Pigeonpea is a quantitative shortday plant with photoperiod sensitivity increasing, in general, with maturity duration of the genotypes. Some short-duration genotypes are virtually photoperiod insensitive and can flower and reach maturity in long-day, summer environments well away from the equator (e.g. South Korea, New Zealand).

Being a true tropical legume, pigeonpea growth and function is sensitive to low temperature, temperatures below 20°C seriously decelerate most plant processes. Pigeonpea is likewise particularly sensitive to frost damage. This low temperature sensitivity is the major factor limiting adaptation of pigeonpea to subtropical winters (e.g. as rice fallow crops). Vegetative growth rates continue to increase at temperatures even above 35°C but flowering and pod set usually fail at such high temperatures.

Pigeonpea has a reputation of being a drought-resistant crop, mainly because of the deep rooting habit of medium-and long-duration types. Nevertheless, under rainfed conditions these invariably face terminal drought stress. In the medium-duration group, genotypic variability in response to terminal drought stress has recently been identified at ICRISAT, raising hopes of genetic enhancement of drought resistance in this group. Short-duration genotypes in general seem more prone to drought stress than longer duration groups because of shallower rooting systems.

Pigeonpea is also particularly sensitive to waterlogging conditions, due to susceptibility to both phytophthora blight and anaerobic conditions *per se.* The short-duration group is most sensitive.

Agronomy

Cropping Systems Pigeonpea has been traditionally and most widely grown as a long-duration component in various inter-cropping or mixed cropping systems. Common systems in India include inter-crops of pigeonpea with sorghum, pearl millet, cotton and groundnut. Long-or medium-duration pigeonpea is highly compatible with faster-growing, shorter duration crops as competition effects between the two components are minimized over space and time. Such systems also provide stability of production to resource-poor farmers in semi-arid rainfed environments.

A recent variation on this theme is the use of perennial pigeonpea as the tree component in agro-forestry systems. Annual crops are grown between hedges of pigeonpea during the rainy season and pigeonpea, because of its deep rooting capability, can produce grain and fodder during the dry season.

Sole crops of pigeonpea utilizing short-duration varieties are becoming increasingly popular in India, and show potential elsewhere. They are most commonly used in sub-tropical regions in a rotation with winter crops, mainly wheat. In tropical regions, where winters are warm enough to support continued growth of pigeonpea, it is possible to take ratoon harvests of short-duration pigeonpea in sole-crops. Newly developed extra-short-duration pigeonpea (< 100 days to maturity) shows potential for use as catch crops in limited rainfall environments of fitting into novel crop rotations.

Planting Recommended cultural practices vary markedly according to the particular cropping system in which pigeonpea is grown. Followings are some general considerations determining cultural practices. Pigeonpea is normally grown as a rainfed crop and sowing is recommended as early in the long-day rainy season as possible. Delayed sowing invariably, reduces yield due to such factors as exposure of seedlings to excessive soil moisture conditions and earlier exposure of the crop to short-day and lower temperature conditions. Recommended spacings range from 30x10 cm in short-duration sole crops to 1 m within-row spacing and several metres between-row spacings in inter-cropping and agro-forestry systems. Major considerations are canopy habit of pigeonpea, desired inter-cropping ratios, and permissible competition effects between inter-cropping components. The most important factor in land preparation for pigeonpea cultivation is to ensure good drainage. Pigeonpea is particularly sensitive to waterlogging conditions.

Weeding As initial growth rate of pigeonpea is slow compared to most other crop species, weed competition can be a serious yield reducer of pigeonpea. Various herbicide formulations are available to supplement or replace mechanical weeding. However, an important recent observation is that presence of weeds can alleviate some diseases (wilt and phytophthora) and waterlogging damage in pigeonpea.

Fertilisers As indicated earlier, fertiliser requirements of pigeonpea are minimal compared to other crops, particularly on the relatively fertile soils of India and because it is well adapted to acquiring N and P from natural sources. However, introduction of pigeonpea into areas with less fertile soils would necessitate detailed assessment of nutrient limitations and requirements. Although pigeonpea is generally well-adapted to semi-arid, drought-prone environments, short-duration sole crops have been shown to benefit substantially from judicious supplemental irrigation. This particularly applies to short-duration multiple harvest systems where the crop is required to continue growing into a dry period. Appropriate measures must also be taken for protection against the major pests and diseases.

Pigeonpea is nodulated by the ' cowpea' group of *Rhizobium*, which is anemic to most soils where either cultivated or wild tropical legumes grow. Thus responses of pigeonpea to *Rhizobium* inoculation are often marginal or absent. However, starter doses of N are usually beneficial in enhancing seedling growth prior to the symbiosis becoming fully established.

Pigeonpea responds less to P fertiliser application than other crops. Marginal P responses in pigeonpea are reported. A reason for this low responsiveness is the special ability of pigeonpea to solubilize Fe-P, as mentioned above. As pigeonpea is primarily grown on neutral to alkaline soils, mainly in India, the nutrient imbalances associated with such soils are more commonly reported for pigeonpea. These include deficiencies of zinc (Zn) and sulphur (S). In the few instances where pigeonpea growth has been studied in acid soils, it appears that it responds to acid soil conditions similar to other tropical legumes.

Pigeonpea is relatively sensitive to salinity damage. recent findings of substantial sources of salinity tolerance in wild species related to pigeonpea, viz. *Atylosia platycarpa* and *A. albicans* offers the feasibility of significantly improving salinity tolerance of cultivated pigeonpea.

Harvesting Pigeonpea grown as an annual crop, whether as an inter-crop or sole crop, is normally harvested for dry grain by cutting the stem at the base and then threshing the pod-bearing branches. However, determinate genotypes are amenable to combine harvesting. the stem material is left to dry for possible future use as fuel wood or building material. For ratoon harvesting of sole crops, it is best to leave as much foliage as possible on the plant when harvesting mature pods, to maximize photosynthetic area for the next flush. For vegetable pigeonpea, green pods are usually hand-picked at the late pod-fill stage but mechanical harvesters and shellers have been developed in the Caribbean.

Yield Average dry grain yields of pigeonpea world-wide, and also for India, are around 0.7 t/ha. In traditional rainfed inter-cropping systems under conditions of drought stress(e.g. Peninsular India), pigeonpea yields are often below 0.5 t/ha. But district average yields for inter-cropped long-duration pigeonpea can exceed 1.0 t/ha in parts of northern India (e.g. Bihar State). Yield potential, in relatively constraint free conditions, can be of the order of 3-4 t/ha for medium-and long-duration types. Yield potential of newly evolved short-duration genotypes can also exceed 3 t/ha for a single flush and well-grown sole crops on farmers field can be expected to produce 1.5-2.5 t/ha. Multiple harvest systems may yield > 5 t/ha from three harvests over an eight-month crop duration. The recent development of hybrids has demonstrated that existing yield potential may be considerably exceeded, at least in the short-duration group.

Pests and Diseases Pod borer (*Helicoverpa armigera*, previously *Heliothis armigera*) is the most devastating insect pest of pigeonpea, on a world-wide basis. Pod-fly (*Melanagromyza obtusa*) is an important yield reducer in cooler season in South Asia. Other important pest damaging reproductive structures include leaf webber *Cydia critica*, spotted borer (*Maruca testulalis*) and blister beetle (*Mylabris pustulata*). The larvae of *Rivellia angulata* can devastate nodules of pigeonpea in Vertisols. Bruchids (e.g. *Callosobruchus* spp) are major pest of stored pigeonpea grain. ICRISAT's research follows an integrated pest management (IPM) approach to combat these pests, with emphasis on host plant resistance.

The major disease constraint of pigeonpea world-wide is fusarium wilt (*Fusarium udum*). Resistance has been incorporated into otherwise desirable plant types. A particular problem of short-duration pigeonpea is phytophthora blight (*Phytophthora drechsleri* f.sp. *cajani*) which strikes when there is standing water in the field. Field resistance has been found and cultural control methods, such as improved drainage of fields and use of fungicides, also offer prospects for its management. Another major yield reducer in South Asia at least is mite transmitted sterility mosaic disease, against which stable sources of resistance have been found and incorporated into high-yielding lines. Other diseases of pigeonpea, but of lesser importance, include alternative blight (*Alternaria alternata* and *A. tennuissima*) cercospora leaf spot (*Cercospora* spp.), macrophomina root rot (*Macrophomina* *phaseolina*), stem canker (*Xanthomonas cajani*) and witches broom (in the Caribbean and Central America). Nematodes have been shown to be significant yield reducers of pigeonpea and a structured research programme on this problem has recently begun at ICRISAT.

Uses

In India, pigeonpea is mostly consumed as "dhal" (decorticated split pea). In the Caribbean and eastern Africa, and also in some regions of India (such as Gujarat and Maharashtra states), either the green whole pods or the shelled peas are eaten as a vegetable. The stems of pigeonpea are extensively used as fuel wood or as building material. The leaves, particularly of perennial plant types that can be ratooned, are used as fodder. Dry grain, and its by-products after dehulling, is also used as animal feed. Pigeonpea can also be used as a host plant for lac-producting insects and the leaves used for growing silkworms. Various medicinal properties have been ascribed to pigeonpea.

Also of significance is the contribution of pigeonpea to cropping systems of which it is a component. Studies conducted over the last decade have demonstrated that pigeonpea can contribute considerable amounts of fixed nitrogen (N) to subsequent crops; up to 40 kg/ha of N equivalents. Further, recent findings have shown that pigeonpea can access iron-bound phosphorus (Fe-P) in the soil, which is not normally available to other crop plants. This is achieved through specifically-acting root exudates. There is additional evidence that phosphorus (P) solubilized by pigeonpea from Fe-P may become available for uptake by subsequent crops. Recent studies have also shown that pigeonpea can improve soil physical properties, by penetration of hardpan by its tap toot system and improvement of water infiltration characteristic of the soil.

With this diversity of potential uses, together with its ability to produce in harsh environments, it is perhaps surprising that pigeonpea is not used more widely. A major constraint to its wider acceptance is its hard seed, requiring specialized milling techniques to make dhal for example. However, there are possibilities, and research is underway, for pigeonpea grain to substitute grain of other legumes. An example is replacement of soybean which generally requires costlier agronomic input than pigeonpea, for making tempe or for animal feed.

Research Needs

For further improvement and expansion of pigeonpea production the following research emphases are suggested:

- Market research to predict possible demand and supply scenarios.

- Development of alternative uses of pigeonpea so as to be competitive with other legume crops such as soybean.

- Agro-ecological zoning to match existing genotypes to specific environments and assist in the design of appropriate breeding strategies.
- Fitting of pigeonpea, especially newly developed plant types (e.g. short-duration, perennial), into new cropping patterns.
- Ideotype development to prioritize desirable traits for new plant types.
- Understand the mechanisms of drought resistance available to pigeonpea, use this knowledge to improve drought-screening techniques and implement appropriate breeding strategies to enhance drought tolerance.
- Understand the mechanisms of waterlogging tolerance and screen germplasm for such traits.
- Screening for low temperature tolerance.
- Incorporate salinity tolerance.
- Identify genotypic differences in nitrogen fixation capacity with the aim of genetically enhancing this trait.
- Better understand and quantify the residual effects of pigeonpea on soil chemical and physical properties.
- Conduct studies of root systems in natural soil profiles to better explain water and nutrient uptake characteristics of pigeonpea.
- Incorporation of resistances found for pod borer, pod fly, fusarium wilt, sterility mosaic disease and phytophthora blight into agronomically desirable plant types.
- Search for higher levels of genetic resistance to phytophthora blight.
- Development of integrated pest and disease management schemes for cropping systems involving pigeonpea.
- Further ecological and epidemiological studies of economically important pests and diseases of pigeonpea.
- Streamlining of host plant resistance screening techniques by developing glasshouse and laboratory methodologies.
- Identification of cytoplasmic male sterility to enhance hybrid development and production.

- Identification of self-pollination traits to facilitate varietal maintenance.

- ›Use of newly evolving cell biological techniques to enable access to potentially useful genes in wild species and develop transgenic plants with desirable characters.

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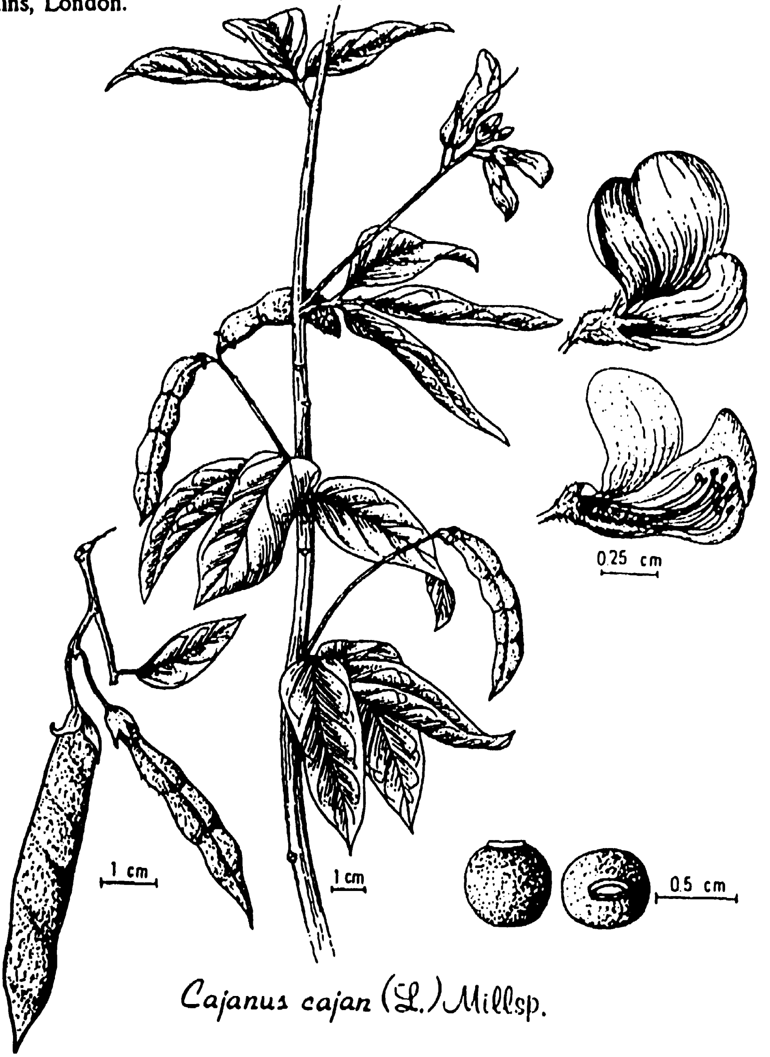

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