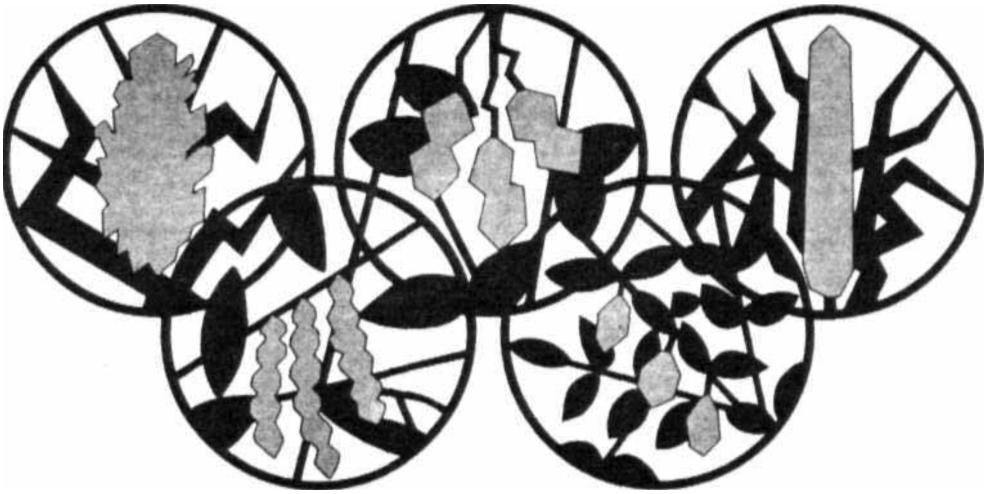
Pigeonpea Botany and Production Practices

Compiled by

Faujdar Singh and D.L. Oswalt



Skill Development Series no. 9

ICRISAT

Human Resource Development Program

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

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Contents

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.] belongs to the genus *Cajanus,* subtribe *Cajaninae,* tribe Phaseoleae, and family abaceae. It is also known as redgram, tur, arhar, gandul (Spanish) and pois d'Angole (Sharma and Green 1980), congo bean (English), pois de Congo (French), and ervilba de Congo in Angola (Baldev 1988). *Cajanus* is derived from a Malay word 'katschang' or 'katjang' meaning pod or bean. Many species of the closely related genus *Atylosia* successfully cross with pigeonpea (van der Maesen 1980).

Origin and Distribution

The pigeonpea name was first reported from plants used in Barbados. Once seed of this crop were considered very important there as pigeon feed (Plukenet 1692). Based on the range of genetic diversity of the crop in India, Vavilov (1951) concluded that pigeonpea originated in India. Several authors considered eastern Africa to be the center of origin of pigeonpea, as it occurs there in the wild form (Zeven and Zhukovsky 1975). However, De (1974) and Vernon Royes (1976) reviewed the pigeonpea origin and agreed in favor of India. Van der Maesen (1980) concluded that India was the primary center of origin and Africa was the secondary center of origin of pigeonpea. It is cultivated in many countries in the tropics and subtropics. Its drought tolerance and the ability to use residual moisture during the dry season make it an important crop (Sheldrake 1984).

Pigeonpea is cultivated on about 4.23 million hectares in the world, with an average annual production of 2.96 million t. Its average productivity is 700 kg ha^{-1}. The major pigeonpea growing area (3.58 m ha) was in India with a production of 2.72 m t or a productivity of 760 kg ha^{-1} (FAO 1990; personal communication by ICRISAT Economics Group). Africa, mainly Kenya and Uganda, accounts for 4% of the world's production. The Caribbean and Central and South America produce 2% of the total pigeonpea of the world (Sharma et al. 1981).

Pigeonpea Plant

The pigeonpea plant is erect and branching (Fig. 1). The stem is woody, leaves are trifoliate, and compound. It possesses a strong taproot system. The plants grow into woody shrubs, 1-2 m tall when annually harvested. It may attain a height of 3-4 m when grown as a perennial plant in fence rows or agroforestry plots.

Seedling

When sown under optimal moisture and temperature (29°C-36°C), the seed testa splits open near the micropyle on the 2nd day. The tip of the radical elongates and emerges from the seed coat. On the 3rd day the hypocotyl appears as an arch and continues to grow upward. The hypocotyl turns light purple. The seedling epicotyl elongates 3-7 cm before the first trifoliate leaf emerges (Reddy 1990).

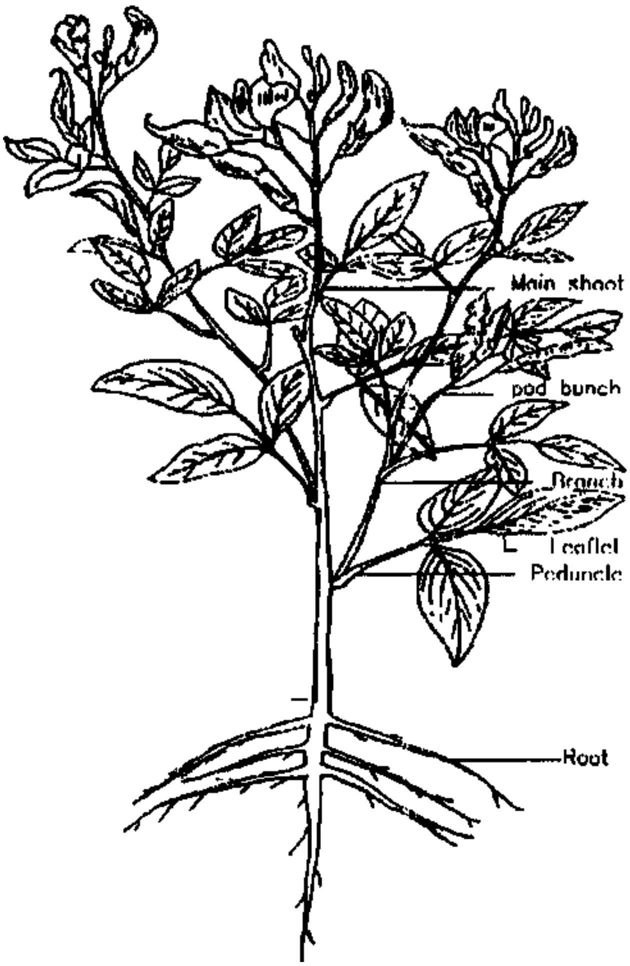

Figure 1. A stylized pigeonpea plant.

Root

Pigeonpea has a taproot system. The root growth, under ideal conditions, begins on the 2nd day after sowing of the seed. The testa splits open near the micropyle. The radical elongates and emerges from the seed coat (Chauhan, In press). The primary structure of the root is tetrach. Secondary thickening takes place as a result of cambial activity (Bisen and Sheldrake 1981). The main root of older plants becomes thick and woody. Pigeonpea roots are deep and wide spreading in the soil, with well-developed lateral roots. They may extend down more than 2 m, but extensive development takes place in the upper 60 cm of the soil profile (Sheldrake and Narayanan 1979; Natarajan and Willey 1980). Short-duration genotypes develop a smaller root system than long-duration genotypes (Sheldrake and Narayanan 1979). Lateral roots were found much longer in spreading types than in the erect types (Mahta and Dave 1931).

Modules

Pigeonpea is nodulated by the cowpea group of rhizobia, mainly on the upper 30 cm of the root system. Nodulation starts approximately 15 days after sowing (DAS) and continues up to 120 days. It declines towards pod filling (Kumar Rao 1990).

The nodule development is through the meristematic zone, arching around the apical end and the medulla contains many bacteroid-filled cells. Sometimes the latter are highly vacuolated (Bisen and Sheldrake 1981). The nodules differ in size from 2-4 mm. They may be spherical, oval, elongate, or branched.

Stem

The pigeonpea has a strong woody stem. The primary vascular tissue of the stem is organized into strands connecting the nodes; each strand is associated with a ridge on the stem. Collenchymatous bundle caps underlie the epidermis of the ridges (Bisen and Sheldrake 1981).

During the vegetative phase, the xylem parenchyma, and the medullary rays contain starch. This disappears in the reproductive phase, showing that the reserves are mobilized for pod development (Sheldrake 1984).

There are cells within the phloem region and the outer part of the pith containing densely staining material. These cells are joined end to end, forming ducts. Such secondary ducts differentiate at an early stage in the primary tissue and are also formed within the secondary phloem. They occur in the stem, pods, and roots. The plant's damaged tissues secrete droplets of a clear fluid exudate from the secondary ducts on to the cut surface. This turns red on exposure to air and covers the wound with a reddish varnish-like material. This exudate has a stringent taste and may have a role in protection against pests (Sheldrake 1984).

Branches

The branching pattern in pigeonpea depends on genotype and spacing between rows and plants. At a wide spacing, it may form a bush and at narrow spacing it may remain compact and upright. For agronomic purposes pigeonpea plants can be grouped as compact (erect), semispreading (semierect), and spreading types. Based on the flowering pattern it may be determinate or nondeterminate (Fig. 2). The determinate type completes the vegetative phase and then enters into the reproductive phase. In this type, the apical bud of the main shoot develops into an inflorescence, and the sequence of inflorescence production is basipetal (developing in the direction of base). The nondeterminate type shows continuous vegetative and reproductive phases. In this type, the flowering starts at nodes behind the apex and proceeds both acropetally and basipetally. Another group is semideterminate between the determinate and nondeterminate types. It includes late-maturing genotypes where branching starts from different angles, but most of the pods are at the upper region of the plant.

Figure 2. Branching pattern in pigeonpea.

Leaves

The first two leaves in the seedling called primary leaves, are simple, opposite, and caduceus (Fig. 3). The later leaves are pinnately trifoliate with lanceolate to elliptical leaflets that are acute at both ends and are spirally arranged. The leaflets are borne on a rachis, which is swollen at the base (pulvinus). The leaf size varies from 6-17 cm in length and are about the same width. The rachis varies from 2-4 cm and the terminal leaflets are 4-8 cm by 2-3.5 cm. The lateral leaflets are slightly smaller. There is genetic variability in the size, shape, and color of leaves.

The leaves are pubescent with more on the lower than the upper surface. The hair types are simple or glandular. The latter are spherical and contain a yellow oily material, probably responsible for the fragrance of pigeonpea plants (Bisen and Sheldrake 1981).

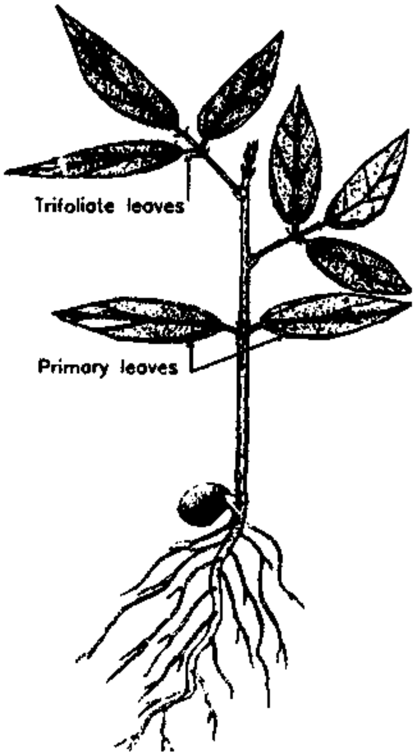

Figure 3. Pigeonpea seedling showing primary and trifoliate leaves. (Source: Reddy 1990)

Inflorescence

In most cultivars, flowers are borne on terminal or auxiliary racemes (4-12 cm) and are carried on a long peduncle (Fig. 4a). The raceme inflorescence form a terminal panicle in nondeterminate types and a somewhat corymb-shape bunch in the determinate types. These are grouped together at the end of branches in late types and distributed along the branches in early, medium, and indeterminate types (Sharma and Green 1980). The number of racemes plant"[1] in the pigeonpea world collections ranged from 6 to 915 (Remanandan et al. 1988). Flowering proceeds acropetally (in the direction of apex) both within the raceme and on the branch.

Flower

The flowers (Fig. 4a) are clustered at the top of the peduncle. The peduncles are 1-8 cm long. Flowers are frequently yellow. The bracts (Fig. 4d) are small with a thick middle nerve. They are ovate-lanceolate with hairy margins and curved inwards to form a boat like structure to enclose one to three young lateral buds (Fig. 4b). The pedicel is thin, 5-15 mm long, and covered with hair.

The flowers are mostly yellow (Fig. 4c) and papileonaceous or completely bisexual and zygomorphic (Sundaraj and Thulasidas 1980). The color of the flowers vary from yellow to yellow with purple veins and from yellow to diffused red. The flowers are usually 2 cm in length.

Calyx

The calyx is gamosepalous with five lobes. The calyx tube is campanulate (bell-shaped) with nerved teeth. The upper two teeth are subconnate. The lower three are free and spreading (Fig. 4e). The upper lobes are paired, free or partly free, and the lower one is the longest.

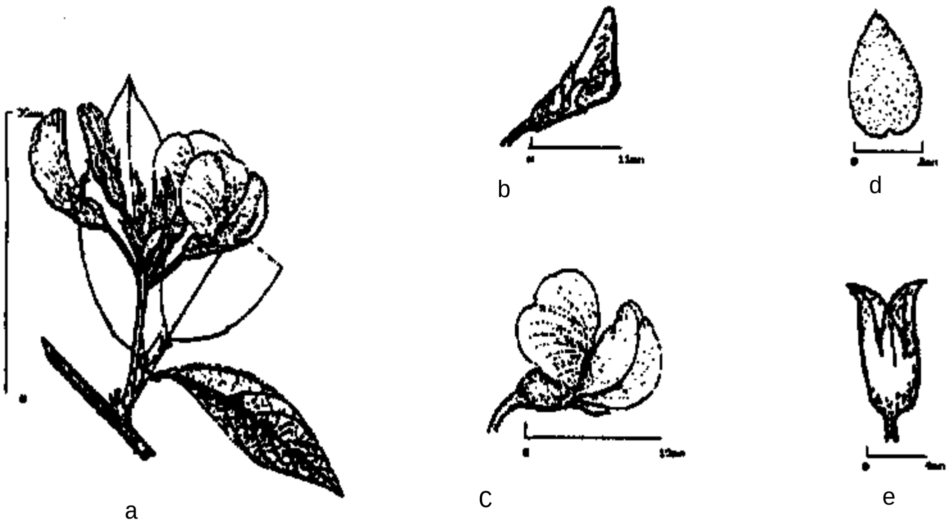

Figure 4. Pigeonpea inflorescence (a), bud (b), flower (c), bract (d), and calyx (e). (Source: Reddy 1990)

Corolla

The corolla is zygomorphic (yoke-shaped flowers symmetrical about one plane) and bright yellow. The petals are imbricate and of three prominent types; the standard, wings, and a keel. The standard is broad, large, auricled, and erect (Fig. 5a). The wings are obliquely obovate with an incurved claw (Fig. 5b). The keel petals are obtuse (round), incurved (Fig. 5f), and boat shaped (Fig. 5c). The keel covers the androecium (stamens) and gynaeceum (female organs) of the flower. Normally the standard and wings are bright yellow. The keel is greenish yellow. Aestivation is a descending imbricate or one whorl outside is free and the one inside has both margins overlapped. The other whorls overlap by only one margin.

Androecium

Stamens are 10, diadelphous (in two bundles 9+1) with 9 fused in a column and 1 free (Fig. 5d). The free stamen filament (4-7 mm) is attached at the base. The other filaments are fused together for the greater part and enclose the gynaeceum. The upper free portion of the filaments terminate in anthers. The anthers are uniform, about 1-mm long. The two halves of the anthers are joined by a relatively large, sterile connective tube that is basifixed (Fig. 5e). The anthers are light or dark yellow, dorsifixed. Of the 10 stamens, four have short filaments and six, including a posterior one, have long filaments. The short anthers have blunt lobes and the long ones pointed lobes. The pollen produced by short stamens is generally used for self fertilization (Bahadur et al. 1981).

Gynaeceum

The ovary is superior, subsessile, flattened dorsoventrally with a long style (Fig. 5f). It has a very short stalk, densely pubescent and glandular punctate (dotted or pitted) with two to nine ovules, marginal placentation, monocarpellary, and unilocular. The style is long, filiform, upturned beyond the middle region, and glabrous. It is attached to a thickened, incurved, and capitate (swollen) stigma (Fig. 5g).

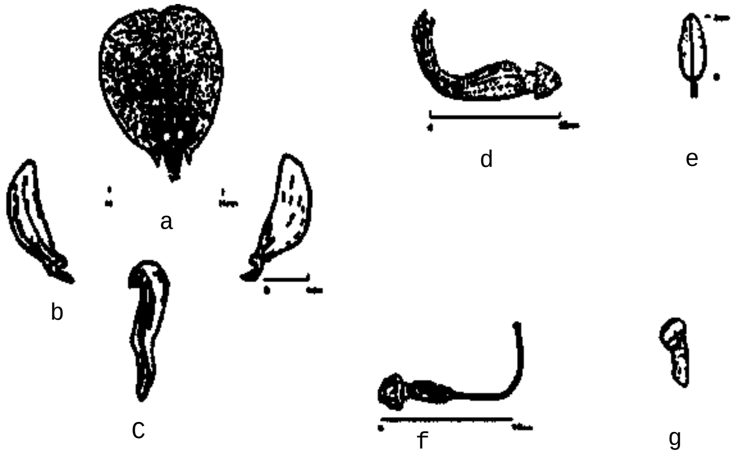

Figure 5. Pigeonpea corolla: standard (a), wings (b), keel (c), androecium (d), anther (e), gynaecium (f), and stigma (g). (Sources: Reddy 1990; and Baldev 1988)

Flowering and Pollination

Pigeonpea is a short-day plant, though a combination of photoperiod and temperature can affect the time of flowering and maturity of pigeonpea genotypes according to date of sowing (Green et al. 1979). In a fully developed bud, anthers surround the stigma and dehisce a day before the flower opens. Anthesis in pigeonpea starts from 0600 and continues till 1600. The peak anthesis period recorded at ICRISAT is between 0900 and 1000 (Sharma and Green 1980). The duration of flower opening depends on the climate and environment. This varies from 6 to 36 h. Fertilization occurs on the day of pollination.

Pigeonpea is an often cross-pollinated crop. The extent of cross-pollination ranges from 3 to 40% (Khan 1973), with an average of 20%. A plant produces many flowers of which only 10% set pods (Pathak 1970).

Pod Development

The pedicel of the flower contains small vascular bundles surrounded by a ring of fibers. During the 1st week of anthesis, the endosperm undergoes rapid development. The nuclei take up a parietal position, forming a large vacuole in the center of the embryo sac. The embryo sac elongates at the chalazal region and forms a haustorium. The haustorium penetrates into the nucellar tissue. This is instrumental in absorbing food material that is used by the developing embryo. By the end of the 2nd week there are still large amounts of endospermous tissues and within the embryo, distinct cotyledons are seen. Further development of the seed involves rapid growth of the cotyledons, and almost complete degeneration of the endosperm. In the cotyledons, synthesis of starch and protein starts about 17 days after pollination and continues for 14 days (Sehgal et al. 1987). In each raceme 1 to 5 pods may mature, and rarely up to 10.

Pods are of various color; green, purple, dark purple, or mixed green and purple. Pods with deep constrictions in shape are beaded, while others are somewhat flat. The seeds per pod range from two to seven, and sometimes up to nine. The seeds are in separate locules and the cross walls develop during the 1st week after fertilization. The pod wall develops more rapidly than the young seeds. Seed development is visible 7 days after pollination. A pod is formed 15-20 days after fertilization. Seeds reach physiological maturity in 30 days and are ready for harvest at a lower moisture content in 40 days (Rao and Rao 1974). There is little or no shattering of mature pods in the field.

Seed and its Germination

The color of the seed ranges from silver, white, cream, fawn, black, pink, or red to purple. They are blotched or speckled. Pigeonpea 100-seed mass ranges from 2.8 to 22.4 g with the cultivated varieties ranging from 7.0 to 9.5 g. Seed shapes are oval, pea-shaped, square, or elongate. The most common is a pea-shaped seed found in large-seeded late varieties. The number of seeds pod^{-1} ranges from 2 to 8. The cultivated genotypes possess 3-4 seeds pod^{-1} (Reddy 1990) .

The cotyledons are yellow. Germination is hypogeal and there is no known dormancy. The seedlings emerge from depths of up to 5 cm.

Production Practices

Climate

Pigeonpea is predominantly a crop of tropical areas mainly cultivated in semi-arid regions of India and Kenya. It is also cultivated in subhumid regions of Uganda, the West Indies, Myanmar, and the Caribbean regions. Reddy and Virmani (1981) concluded that pigeonpea can be grown between 14°N and 28°N latitude, with a temperature ranging from 26° to 30°C in the rainy season (June to October) and 17° to 22°C in the postrainy (November to March) season. The amount of daily global solar radiation varies from 400 to 430 cal cm^{-2} day^{-1} in the rainy season and 380-430 cal cm^{-2} day^{-1} in the postrainy season. Mean annual rainfall ranges from 600 to 1400 mm, of which 80%-90% is received in the rainy season. The length of growing season extends from 120 to 180 days. Isoclimes similar to India exist in western Africa and southern Sudan, a suitable environment for growing pigeonpea.

Pigeonpea is very sensitive to low radiation at pod development, therefore flowering during the monsoon and cloudy weather, leads to poor pod formation.

Soils

In India, pigeonpea is cultivated on Entisols, Alfisols, Enceptisols, and Vertisols. The Entisols found in the alluvial- soil belt of the Indo-Gangetic region are deep loams, slightly alkaline (pH 7.5-8.5), with about 150-200 mm available water storage capacity in 2 m of soil. The Vertisols are characterized by 40-60% clay in the surface soil horizons, pH around 8.0 with a water holding capacity between 150-300 mm, and the available water in the top 1.5-2.0 m of soil. Alfisols are neutral in reaction (pH 6.5-7.0) and relatively shallow with a low-clay content. They are often sandy loam and can retain about 100 mm available water in the root profile (Reddy and Virmani 1981). Pigeonpea, being sensitive to water logging, requires a well-drained soil. It does not grow well in saline soil, but can withstand drought reasonably well. Responses to lime indicated by increase in shoot growth and nodulation, have been reported in soils with pH below 5.0 (Edwards 1981).

Land Preparation

Land preparation for pigeonpea requires at least one plowing during the dry season followed by 2 or 3 harrowings. The "summer" plowing helps in minimizing the weed flora and to conserve moisture (Chandra et al. 1983). Well-drained soils are necessary for good root and nodule development. Contour beds or a ridge-and-furrow system are useful in preventing water logging by draining excess surface water, and in preventing soil erosion.

Organic manure may be applied 2-4 weeks before sowing. In acidic soils 2-4 t ha^{-1} of lime is incorporated 3-4 weeks before sowing to neutralize the acidity. In light soils, a basal application of aldrin 5% dust @ 30 kg ha^{-1} prevents termite infestation (Chandra et al. 1983).

Responses to Nutrients

Responses to general fertilizer applications in pigeonpea are quite meager.

Nitrogen (N)

Kulkarni and Panwar (1981) reviewed the studies in India on the pigeonpea response to N. They concluded the effect was almost negligible. However, in some situations a starter application of 20-25 kg N ha^{-1} was beneficial.

Rhizobium inoculation

Responses to *Rhizobium* inoculation have been inconsistent (Panwar and Misra 1973; Panwar 1975). Increases in grain yield of pigeonpea inoculated with effective *Rhizobium* ranged from 19 to 68% (Kumar Rao 1990).

Phosphorus (P)

Responses to phosphorus applications have been positive and in some cases highly significant in pigeonpea (Pathak 1970). Kulkarni and Panwar (1981) summarized the phosphorus response studies in India. They concluded that applications of 17-26 kg P ha^{-1} increased seed yield by 300-600 kg ha^{-1}. Responses of pigeonpea to P fertilization would not be expected in soils with more than 5 mg kg^{-1} extractable P by Olsens bicarbonate extraction; although lower values would not necessarily predict a response (Johansen 1990).

Potassium (K)

Pigeonpea does not respond to potassium chloride applications unless it is grown on low available potassium soils (Kulkarni and Panwar 1981).

Zinc (Zn)

Most of the pigeonpea cultivars are susceptible to zinc deficiency. Therefore, foliar applications of 2-4 ppm zinc as 0.5% zinc sulfate with 0.25% lime have been effective to over-come zinc deficiencies (Saxena and Singh 1970).

Nutrient deficiency symptoms

The deficiency symptoms of macro- (Table 1) and micro-nutrients (Table 2) are listed.

Table 1. Deficiency symptoms of major nutrients in pigeonpea.

Nutrient	Deficiency symptoms on plant
Nitrogen (N)	Young leaves uniformly become pale-green, greenish-yellow or pale-yellow. Old leaves show an interveinal chlorosis and only veins remain green, leaves soon abscise (shed).
Phosphorus (P)	Difficult to diagnose, it delays flowering. In general plants are stunted due to failure of internode elongation. The foliage remains dark-green and old leaves shed.
Potassium (K)	Leaf tips turn yellow or brown. Yellowing spreads from the tip outward along the margin and may coalesce with similar yellow areas at extremities of the lateral veins. The leaf tip becomes scorched as symptoms become severe. The scorching may spread around the leaf margin. There is a yellow band between the scorched area and healthy-green tissues in the early stages. The affected leaves not showing these symptoms are generally dark-green and plants are stunted.
Calcium (Ca)	Light-green patches, irregular in outline, appear randomly in interveinal areas or around the leaf margin. Patches may turn brown, particularly on the young and severely affected leaves; such leaves abscise. Stems are weak and prostrate.
Sulfur (S)	Even yellowing across lamina of mainly young leaves. Eventually old leaves become yellow.
Magnesium (Mg)	Beginning in older leaves, in-rolling of leaf margins. Interveinal regions light-green. Mesophyll of interveinal regions become light-green, leading to eventual necrosis.

(Sources: Nichols 1964 and 1965; Johansen 1990)

Table 2. Deficiency symptoms of micro nutrients in pigeonpea.

Nutrient	Deficiency symptoms on plant
Zinc (Zn)	Stunted growth, narrowing of leaves with pale-green or yellow appearance. Interveinal chlorosis starting from tip of leaflets and spreading to the remaining area leaving only the midrib green. Curling and shedding of leaflet when it becomes two-thirds chlorotic.
Iron (Fe)	Interveinal areas of young leaves become pale-green, veins and adjacent tissues remain dark-green. In severe cases, the entire area of the leaflet becomes chlorotic with small necrotic patches.
Manganese (Mn)	Fading of the green lamina of the middle leaves without affecting the veins. The small white and brown spots, first appearing in the chlorotic areas, coalesce and form brown necrotic lesions. It reduces size, number and area of leaflets, and delays flowering by arresting the growth of apical shoots.
Boron (B)	Boron helps in division and elongation of cells. Its deficiency results in dieback, rosetting, multiple branching, and death of seedlings.
Molybdenum (Mo)	Nitrogen fixation requires molybdenum for incorporation of the nitrogenase enzyme. Like nitrogen deficiency it causes general yellowing of the plant.

(Source: Katyal 1981; Nichols 1964 and 1965)

The nutrients required for selected levels of grain yield in pigeonpea are given in Table 3.

Table 3. Estimated nutrients required (kg ha^{-1}) to produce selected levels of grain yield of pigeonpea.

	Grain yield (kg ha^{-1})							
Nutrients	500	1000	1500	2000	2500	3000	3500	4000
N	132	148	164	181	197	213	230	246
P	10	11	13	15	17	18	20	22
K	31	36	41	47	52	58	63	69
Ca	38	39	40	41	42	43	44	45
Mg	27	28	29	29	30	31	32	33
Mn	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13
Zn	0.16	0.19	0.22	0.25	0.28	0.31	0.35	0.38
Cu	0.07	0.07	0.07	0.08	0.09	0.09	0.10	0.11

(Source: Calculations based on Dalai 1980)

Economic level of fertilization

Pigeonpea cultivated in the arid and the semi-arid tropics is a high-risk crop. The farmers are reluctant to use even major nutrients with proven responses to nutrient application (Chaudhary and Bhatia 1971; Dalai and Quilt 1977).

Kulkarni and Panwar (1981) concluded that an application of 20 kg N, 17 kg P, and 17 kg K ha^{-1} could give a satisfactory yield on medium-black, red, and mixed black and red soils. This gave a cost-benefit ratio of Rs. 1.28-4.07 $Rupee^{-1}$ cost of fertilizer. However, in red and laterite soils 20-17-17 kg ha^{-1} gave a cost-benefit ratio of Rs. 6.35-RS.8.80 $Rupee^{-1}$ cost of fertilizer (ICAR 1979). In India, diammonium phosphate (DAP) is the most commonly used fertilizer for pigeonpea. This is used at a rate of 100 kg ha^{-1}. It supplies about 18-20-0 (Tandon 1987). At ICRISAT, 10 kg ha^{-1} N (ammonium sulfate) and 17 kg P ha^{-1} (single super phosphate) are applied in many experiments. The single super phosphate has the advantage of containing sulfur (S).

Cropping Systems

A cropping system is defined as a combination of crops in space and time. The objective of any given system should be to provide the farmer a high and sustainable level of returns. In agronomic terms, the system makes efficient use of the basic resources necessary for plant growth (Willey et al. 1981). Pigeonpea is grown both under sole and intercropping systems.

Sole cropping

Early-maturing (100-120 days) genotypes are grown as a sole crop. These genotypes have a higher harvest index with an average of 34% compared to medium-maturing genotypes at 24% (Sheldrake and Narayanan 1979). Therefore, from the cropping system point of view, early-maturing genotypes are better able to 'complement' by providing an increased opportunity for a second crop (Willey et al. 1981). Postrainy season pigeonpea are also cultivated as a sole crop. This avoids the wet conditions associated with the rainy season, gives less incidence of pests and diseases, and makes better use of residual soil moisture. Moreover, postrainy season sole crops were found more efficient than the rainy season sole crops (Willey et al. 1981).

Pigeonpea intercropping

Pigeonpea is commonly intercropped with a wide range of crops. In India, it was estimated that 80%-90% of the pigeonpea were intercropped (Aiyer 1949). Willey et al. (1981) grouped pigeonpea intercrops into three broad categories:

a) With cereals (sorghum, maize, pearl millet, setaria, finger millet, and rainfed rice).

b) With legumes (groundnut, cowpea, mung bean, black gram, soybean, and phaseolus bean).

c) With long-season annuals (caster, cotton, sugarcane, and cassava).

Chandra et al. (1983) listed highly productive intercrops of pigeonpea for different regions in India (Table 4).

Table 4. Important intercrops for pigeonpea.

Inter crop	Sowing pattern	Ratio of component crops
Cereals		
Sorghum + pigeonpea	Paired rows at 30:30:60 cm	2:1
Pearl millet + pigeonoea	Paired rows at 30:30:60 cm	2:1
Maize + pigeonpea	Paired rows at 40:40:80 cm or uniform rows at 60 cm	2:1
Pigeonpea + upland rice	Uniform rows at 60-75 cm	2:2
Legumes		
Pigeonpea + groundnut	Uniform rows at 75-90 cm	2:2
Pigeonpea + soybean, mung bean or black gram	Uniform rows at 75 cm or Uniform rows at 50 cm	2:2 2:1

The advantages of intercrops are (Willey et al. 1981):

a. Intercropping confers greater yield stability than sole cropping. For instance, if one crop fails or grows poorly, the other crop can produce to some extent.

b. Under stress conditions, intercropping gives less yield depression than sole cropping.

c. Intercropping may reduce the incidence of weeds. The poor canopy cover and slow growth of pigeonpea in the early stages makes a sole crop susceptible to weed. Therefore, a fast-growing intercrop not -only gives a potential additional yield benefit, but also reduces the need for weeding (Shetty and Rao 1979).

Varieties

Some of the important varieties of pigeonpea released in India for the different maturity groups (Tables 5a, 5b, 5c, and 5d).

Table 5a. Extra-short-duration varieties of pigeonpea released in India.

Variety	Pedigree	Year of release (State)	Time to maturity (days)	Characteristics
UPAS-120	Selection from P 4758	1976 (UP)	120-140	Nondeterminate, yield 1.5-1.8 t ha^{-1}.
Pant A3	-	1975 (UP)	120-130	Semierect, determinate, dwarf 3-4 seeds pod^{-1}, 8 g $(100\ seed)^{-1}$.
Prabhat	T I X T 190	1975 (UP)	110-120	Determinate, dwarf (100-120 cm), clustered fruiting, yield 1.2-1.5 t ha^{-1}.
ICPL 87 (Pragati)	T21 x JA 277	1986 (Penin. India)	120-130	Determinate, 10.5 g $(100\ seed)^{-1}$, brown seeded, potential yield 2.5-3.0 t ha^{-1}.
ICPL 151 (Jagriti)	ICP 6997 x Prabhat	1990 (NW India)	120-130	Determinate, 10.5 g $(100\ seed)^{-1}$, cream color, potential yield 2.5-3.0 t ha^{-1}.
C02	Selection from P 4728	1977 (Tamil Nadu)	120-130	Brown seeded, 7 g $(100\ seed)^{-1}$, average yield 1.2-1.5 t ha^{-1}
AL 15	Mass selection from P8-9	1981 (Punjab)	130-140	Small seeded 6-8 g $(100\ seed)^{-1}$, potential yield 2.0 t ha^{-1}, average yield 1.4 t ha^{-1}.

Table 5b. Short-duration varieties of pigeonpea ralaasad in India.

Variety	Pedigree	Year of release (State)	Time to Maturity (days)	Characteristics
Pusa Ageti	Brazil 1-1 x T190	1971	150-160	Dwarf compact plant, determinate, bold seeded 9 g (100 seed)$^{-1}$, 4-5 seeds pod^{-1}, potential yield 2.5 t ha^{-1}.
T21	TI x T190	1961 (UP)	150-170	Semispreading, loose plant and indeterminate branching. Small seeded, 7 g (100 seed)$^{-1}$.
HY2	PI 4628	1978 (AP)	140-150	Semierect tall, purple stem, white seed, bold, 11-12 g (100 seed)$^{-1}$, potential yield 2.5-2.7 t ha^{-1}, average 1.3-1.9 t ha^{-1}.
Pusa 84	Pusa Ageti x T21	1980 (N zone)	140-150	Medium tall, semispreading, 3-4 pod^{-1}, 7.5 g (100 seed)$^{-1}$, brown seeded.
C01	Local (Tamil Nadu)	1970 (TN)	135-140	Photoinsensitive, brown seeded, 7 g (100 seed)$^{-1}$, average yield 1.5 t ha^{-1}.

Table 5c. Medium-duration varieties of pigeonpea developed in India.

Variety	Pedigree	Year of release (State)	Time to maturity (days)	Characteristiscs
HY 1	PI 3704	1975 (AP)	160-170	Spreading, purple stem, white seed, 9-10 g (100 seed)$^{-1}$, potential yield 1.9-2 t ha^{-1}, average 1.2-1.5 t ha^{-1}.
HY 3A	PI 2817-1A	1980 (AP)	160-170	Erect tall plant (230-240 cm), green stem, white bold seeded, 18-20 g (100 seed)$^{-1}$, 4-5 seeds pod^{-1}, potential yield 3.0-4.0 t ha^{-1}, average yield 1.6-2.0 t ha^{-1}.
HY 5	PI 3701	1980 (AP)	160-170	Semierect, purple stem, medium height (170 cm), brown seeded, 12.9 g (100 seed)$^{-1}$, 4-5 seeds pod^{-1}.
Mukta (R60)	Brazil 1X NPWR 15	1971 (Bihar)	180-200	Medium tall (200-220 cm), semi-spreading, profuse branching, 4-5 seeds pod^{-1}, brown bold seeds, 10 g (100 seed)$^{-1}$' wilt resistant, yield 3.0 t ha^{-1}, average yield 1.65 t ha^{-1}.
AS 71-37	Local selection	1981 (MP)	165-195	Medium tall (172-194 cm), 3-4 seeds pod^{-1}, 10 g (100 seed)$^{-1}$, potential yield 3.0 t ha^{-1}, ave. 1.65 t ha^{-1}.
BDN 1	Local selection	1978 (Maharashtra)	160-179	Semispreading, wilt resistant height (200-220 cm), 9-10 g (100 seed)$^{-1}$
S20	Kanke 1XB7	1976 (West Bengal)	180-190	Semicompact, 11 g (100 seed)$^{-1}$. Potential yield 2.5 t ha^{-1}, average yield 1.7 t ha^{-1}.

Table 5d. Late-duration varieties of pigaonpaa ralaaaad in India.

Variety	Pedigree	Year of release (State)	Time to maturity (days)	Characteristic
C11	Local selection	(AP)	200-220	Medium tall, profuse branching, spreading, brown seed, 8.5 g (100 seed)$^{-1}$.
Bahar	D1258 X Local	1973 (Bihar)	220-240	Compact, semierect plant, brown round selection 4-5 seeds pod^{-1}, yield potential 3 t ha^{-1}, average yield 2.25 t ha^{-1}.
Laxmi (Kanke-3)	BR-183X Local	1974 (West Bengal)	180-220	Perennial, semispreading, field tolerant to wilt, potential yield 2 t ha^{-1}, average yield 1.75 t ha^{-1}.
Gwalior 3	Local selection	1960/ 1980 (MP)	270>	Tall 250-300 cm, spreading, light brown seed, 7-8 g (100 seed)$^{-1}$.

(AP = Andhra Pradesh; MP = Madhya Pradesh; TN = Tamil Nadu; UP = Uttar Pradesh)

(Source for Tables 5a, 5b, 5c, and 5d: Chandra et al. 1983)

Sowing Time and Depth

In the rainfed and dry areas pigeonpea are sown with the onset of the monsoon. Earlier sowing gives higher yields in India. When sowing extra-early and early-maturing varieties in the 1st fortnight of June, the field is available for postrainy season crops by the end of November. Therefore, sowing should not be delayed beyond June.

The sowing of medium and late-maturing varieties, under rainfed conditions, should be done during June or July at the onset of the monsoon. This should be preferably before the 2nd week of July. Late sowing causes considerable reduction in yield due to photoperiodicity and excessive soil moisture stress which coincides with the reproductive growth (Chandra et al. 1983). The postrainy season sowing in India should be done in September. In sowings later than 15 October, yields drastically decline (Narayanan and Sheldrake 1979).

Kaul and Sekhon (1975) concluded that grain yield and yield attributing characters were significantly influenced by date of sowing. Sowings on June 1 and June 15 were significantly superior over June 30 and July 15. Significant reduction in grain yield with delay in sowing beyond June 15 was due to reduction in plant height, pods plant^{-1} and total dry matter production. However delayed sowing gave a high harvest index due to a sharp decline in dry matter production.

In eastern Africa, pigeonpea are sown in October/November, at the onset of short rains (Chauhan 1990).

An optimal seeding depth for pigeonpea was 4-5 cm (Khan and Ashley 1975; Tayo 1983).

Methods of Sowing and Spacing

Three systems of sowings are practiced for pigeonpea. The common is flat sowing, the other methods are broadbed-and-furrow for extra-early group and ridge-and-furrow for the late maturity group. The latter two methods are useful in fields with poor surface drainage and water logging. The raised beds or ridges also provide better aeration and nodulation in comparison to the flat sown crop. Experiments at the Indian Agricultural Research Institute, New Delhi, have shown that pigeonpea sown on a ridge-and-furrow system in fields prone to water logging gave 30% more yield compared to flat sowing (IARI 1971). At ICRISAT a broadbed-and-furrow system is used for sowing extra-early genotypes, and ridges-and-furrows are used for medium- and late-duration genotypes.

Plant spacing depends on maturity duration and cropping system. Extra-early pigeonpea are grown 30 cm between rows with about 10 cm space between plants. The intercropped spacings (Table 4) depends on the type of intercrop and time to maturity (days) of the genotype.

In traditional production systems, the plant density could be less than 5 plants m^{-2} (Pathak 1970). These crops mature on residual moisture stored in the soil profile. Natarajan and Willey (1980) found that 10 plants m^{-2} was higher yielding than 5 plants m^{-2}.

Seed Rate and Seed Treatment

The seeding rate of pigeonpea depends on the desired plant density for a genotype (early, medium or late), cropping system (pure crop, mixed crop, or inter crop), germination rate of seed, and mass of seed.

The plant density recommended for extra-early solecrop pigeonpea is 330 000 plants ha^{-1}, whereas, for early- and medium-maturity varieties it ranges from 80 000 to 100 000 plants ha^{-1}. The plant density for tall and highly branched late varieties could be 50 000-60 000 ha^{-1}. The calculation for seed requirement is given in MP 1.

Good quality and pure seed (registered or certified) of the selected variety should be used from a reliable source. Before sowing, the seed should be treated with thiram @ 1.5 g kg^{-1} of seed plus penta-chloro-nitro benzene (PCNB) [Brassicol® a.i. 1.5 g kg^{-1}] seed. This will avoid seed rot and seedling blight diseases (Chandra et. al. 1983). At ICRISAT we recommend seed treatment with 3 g thiram kg^{-1} + 3 g carbendazim kg^{-1} seed.

Weed Management

Pigeonpea is a slow-growing crop and mostly cultivated during the rainy season. The crop suffers from early weed infestation. Therefore, it is necessary to keep the crop weed-free during the early growth period (4-6 weeks). The weeds can be controlled mechanically or with chemicals. A combination of chemical and mechanical control is more economical. At ICRISAT Center, it was observed that a preemergence application of prometryn (Gesgard® or Caparol® a.i. 1.25 kg ha^{-1}) effectively controlled the initial weeds. A hand weeding 3-4 week after sowing is required to remove the late emerging weeds. When herbicide is not applied, two or three hand weedings are required from the 1st to 6th week of crop growth. Later the crop will be able to smother the weeds (Chauhan et al. 1988). At ICRISAT, hand weedings were always found superior to herbicides, but the herbicides were more economical, hence preferred (Chauhan 1990). The other preemergence herbicides effective for pigeonpea are pendimethalin (Stomp® a.i. 1.0-1.5 kg ha^{-1}) or metachlore (Dual® a.i. 1 kg ha^{-1}). The post-emergence herbicides recommended are flausifop-P butyl (Fusilate® a.i. 0.2-0.4 kg ha^{-1}) or bentazon (Basagran® a.i. 1.0 kg ha^{-1}) at 2-4 leaf stage (A. Ramakrishna, 1992, ICRISAT, personal communication).

Irrigation

Pigeonpea is largely grown as a rainfed crop, however, it is well established that flower initiation and pod setting stages are the most crucial to drought stress. Therefore, irrigation at these stages usually helps the crop (Chandra et al. 1983). The drought-stress symptoms on pigeonpea are indicated by the leaves pointing towards the sun at noon (Chauhan et al. 1988).

Sinha (1981) reported the effects of irrigation on early pigeonpea and found it difficult to define the adequate water requirement in relation to yield. When irrigation was applied after flowering and at the pod filling there was an increase in biomass in short-, medium-, and long-duration varieties. However, increase in grain yield and biomass did not follow the same pattern. Thus only vegetative growth was increased when water was available, but beyond a certain limit, dry matter was not increased with an increasing water supply.

Excessive moisture is detrimental to pigeonpea. It promotes vegetative growth and enhances the incidence of *Phytophthora* and *Alternaria* blight. Therefore, irrigation should be given only when the crop experiences drought stress after flowering and at the pod filling stage (Chandra et al. 1983).

Responses to irrigation are more consistent in postrainy season sown pigeonpea. This crop relies on moisture stored in the soil profile. Two or three irrigations, 1 month after sowing, increased seed yield by about 150-160% over the nonirrigated control at ICRISAT Center (Rao et al. 1983).

Harvesting and Threshing

Pigeonpea should be harvested when 75-80% of the pods are at physiological maturity. Vanangamudi et al. (1986) suggested harvesting of pigeonpea, about 25 days after anthesis when pods turn brown and are dry. Delayed harvesting, during bad weather, may increase the risk of damage to mature seed. However, Balakrishnan and Natarajaratnam (1988) suggested harvesting after the 42nd day of anthesis when the dry mass of the seed is low and moisture content is between 20 and 24%. The mature pods could be identified as they are brown and have a dry testa.

Traditionally pigeonpea plants are harvested by cutting the stem at the base, with an axe or sickle. The harvested plants are tied in bundles and transported to a threshing floor. These are stacked in upright bundles to dry. The pods and grain are separated by beating the dry plants with sticks or by using a thresher.

Another way to harvest pigeonpea is by hand picking the mature pods. This allows the crop to flower and pod for a second or sometimes a third harvest. Hand picking may not be economical beyond a second flush. When hand picking of pods is not feasible, the upper branches with mature pods are cut (good for determinate types). Care should be taken in leaving as much of the foliage as possible while removing the pods and allowing the plant to regrow and promote another flush of pods. However, this method delays the second harvest and usually results in a lower yield than hand picking (Chauhan et al. 1988).

At ICRISAT, pigeonpea is harvested when over 80% of the pods become brown. The harvested plants are left in the field a week for sun drying and threshed in a small plot thresher. The seeds are cleaned and dried either in a drier at 35°-43°C or in the sun to 6-8% moisture content before final recording of yield.

Recording Observations

Recording of observations depends on the objectives of the experiment. Some important observations for recording in pigeonpea are discussed in Management Procedures (MP 2).

MP 1. Determination of Seed Rate for a Given Plant Density

Seed rate ha^{-1} depends on plant spacing, seed mass, and germination percentage of the seed sample. Further, it may be desirable to sow 15-20% more seed than the required to ensure an adequate plant population.

Example. Suppose the required plant density is 333 000 plants ha^{-1}, 100-seed mass of the variety is 10 g and germination is 90%. The seed requirement ha^{-1} and a plot of 15 m^2 (3 m x 5 m) with eight rows of 5 m length and 0.375 m between rows can be calculated.

Calculations:

a. The seed required for 100 germinable seed for this lot is

$$\frac{100 \text{ seeds}}{0.90} = 111 \text{ seeds}$$

So to obtain 100 seedlings at least 111 seed should be sown as germination of the seed lot was 90%.

b. The seeds required for 333 000 plants ha^{-1}

$$= \frac{333\ 000 \text{ seeds ha}^{-1} \times 111 \text{ seeds}}{100 \text{ seeds}} \quad 369\ 630 \text{ seed ha}^{-1}$$

c. Mass (kg) of 369 630 seeds @ 10 g for 100 seeds will be

$$\frac{369\ 630 \text{ seeds} \times 10 \text{ a}}{1000 \text{ g kg}^{-1} \times 100 \text{ seeds}} = 36.9 \text{ kg or } 37 \text{ kg ha}^{-1}$$

d. To sow 20% additional seed the requirement will be

$$37 \text{ kg ha}^{-1} \times 1.20 = 44.4 \text{ kg ha}^{-1}$$

e. The seed required m^{-2} w be

$$= \frac{44.4 \text{ ka ha}^{-1} \times 1000 \text{ a kg}^{-1}}{10{,}000 \text{ m}^2 \text{ ha}^{-1}} = 4.44 \text{ g m}^{-2}$$

f. The seed requirement for plot (15 m^2) will be

$$= 4.44 \text{ g m}^{-2} \times 15 \text{ m}^2 \text{ plot}^{-1} = 66.6 \text{ g or } 67 \text{ g plot}^{-1}$$

g. The seed requirement row^{-1} will be
(The area of row is 5 m x 0.375 m = 1.875 m^2 row^{-1})

h. Seed requirement row^{-1} = 4.44 g m^{-2} x 1.875 m^{-2} row^{-1}

$$= 8.32 \text{ g row}^{-1}.$$

Table 6. Pigeonpea seed requirement (kg ha^{-1}) at different plant densities, germination percentages, and 100-seed mass.

100-seed mass (g)	Plant density ha^{-1}								
	333 000			100 000			60 000		
	Germination (%)			Germination (%)			Germination (%)		
	80	90	100	80	90	100	80	90	100
7.0	29.1	25.9	23.3	8.8	7.8	7.0	5.3	4.7	4.2
8.0	33.3	29.7	26.6	10.0	8.9	8.0	6.0	5.3	4.8
9.0	37.5	33.3	29.9	11.3	10.0	9.0	6.8	6.0	5.4
10.0	41.6	36.9	33.3	12.5	11.1	10.0	7.5	6.7	6.0
11.0	45.8	40.7	36.6	13.8	12.2	11.0	8.3	7.3	6.6
12.0	49.9	44.4	39.9	15.0	13.3	12.0	9.0	8.0	7.2
13.0	54.1	48.1	43.3	16.3	14.4	13.0	9.8	8.7	7.8
14.0	58.3	51.7	46.6	17.4	15.5	14.0	10.5	9.3	8.4

(Note: Extra seed (20%) not included in the above calculation, for 20% extra seed multiply by 1.2).

MP 2. Recording Morphological Characters

Days to emergence. Days are counted from date of sowing (irrigation, rain, or adequate moisture) until 80% of the seedlings have emerged.

Plant type. It depends upon the number of primary and secondary branches and angle of branches on the stem. It ranges from upright-compact to spreading type.

a. **Compact types:** Few branches borne at narrow angles to the stem.

b. **Spreading:** Many branches and broad plant canopy.

c. **Semispreading:** This is intermediate between compact and spreading types.

Days to 50% flowering. Days from date of emergence until 50% of the plants in a plot have at least one open flower.

Days to 75% maturity. This is days after emergence until 75% of the pods are physiologically mature.

Flowaring pattarn (Fig. 3).

a. **Nondatarminata** (NDT): The inflorescence develop as axillary racemes from all over the branches, and flowering proceeds acropetally (from base to apex) both within the racemes and on the branches.

b. **Datarminata** (DT): The apical buds of the main shoot and branches develop into inflorescence. Inflorescence are produced basipetally (apex to base), they are short statured and bear clusters of pods at the top.

c. **Samidatarminata** (SDT): Flowering starts at nodes behind the apex and proceeds both acropetally and basipetally.

Plant height (cm). Height is recorded at maturity from the base of the plant to the top (five plants are averaged). Another way to take height across the plot is to put a marked pole (cm) and note the height at the center of plot.

Primary branchas (number). Branches emerging from main shoots.

Secondary branchas (number). Branches borne on primary branches.

Number of pods plant^{-1}. Pods are counted at harvest on five randomly selected plants and the average is recorded.

Number of seeds pod^{-1}. Seeds in 10 randomly selected pods are counted and the average is recorded.

100-seed mass. One-hundred seeds from the bulk harvest of each treatment are weighed on an electronic balance.

Seed yield $plant^{-1}$ (g). For genetic studies of crosses and segregating populations the individual plant yield of seed is recorded on each treatment.

Net-plot yield (kg). It is recorded from the net plot for pods harvested, threshed, cleaned, dried, and weighed at 7-8% moisture content.

Yield (kg ha^{-1}). The net-plot yields are converted to kg ha^{-1} ignoring decimals and rounding to the nearest 10 kg. For example, a yield of 1986 kg ha^{-1} will be taken as 1990 kg ha^{-1} and a yield 1984 kg ha^{-1} will be considered as 1980 kg ha^{-1}.

Biological yield. The biological yield includes mass of stem, pods, seed, and leaves.

Shelling ratio or seed to husk ratio (%). This is expressed as:

$$\frac{\text{Seed yield (g)} \times 100}{\text{Pod yield (g)}}$$

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (g)} \times 100}{\text{Biological yield (g)}}$$

Seed color. Pigeonpea mainly has orange seed (over 50%). It varies from red, brown, light-brown to white. The light-colored seeds are generally bright-green at the filling stage, hence are preferred for vegetable purposes.

Seed shape. The most common seed shape is oval. It ranges from elongate, globular to more square. The globular (pea-shaped) trait is preferred for vegetable purposes.

Dry stalk weight (kg ha^{-1}). After threshing and separation of seed, pods, and leaves, the stalks are weighed to estimate their economic value.

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Evaluation

Select the most appropriate answer and check the correct answer at the end of the booklet.

1. The pigeonpea belongs to the genus
   a) *Atylosia.* b) *Cajanus.*
   c) *Arachis.* d) *Cicer.*

2. The word pigeonpea first originated from
   a) USA. b) Barbados,
   c) Zambia. d) India.

3. The primary center of origin of pigeonpea is
   a) Africa. b) Europe.
   c) Asia. d) Australia.

4. The average productivity of pigeonpea is
   a) 200 kg ha^{-1}. b) 500 kg ha^{-1}.
   c) 760 kg ha^{-1}. d) 900 kg ha^{-1}.

5. Pigeonpea have
   a) adventitious roots. b) staminal roots.
   c) seminal roots. d) tap root.

6. The extensive pigeonpea root development in the upper soil area is to a ___________ depth.
   a) 20 cm b) 40 cm
   c) 60 cm d) 80 cm

7. Nodulations in pigeonpea are by rhizobia belonging to the
   a) meliloti group. b) trifolii group.
   c) japonicum group. d) cowpea group.

8. The greatest number of nodules in pigeonpea are observed during the
   a) seedling stage.
   b) vegetative phase.
   c) early reproductive phase.
   d) maturity stage.

9. The branching pattern that completes the vegetative phase first and then enters into the reproductive phase is the
   a) nondeterminate. b) determinate.
   c) semideterminate. d) none of the above.

10. When flowering starts at nodes behind the apex and proceeds both acropetally and basipetally it is
    a) nondeterminate. b) determinate.
    c) semideterminate. d) none of the above.

11. Late-maturing pigeonpea genotypes start branching from different angles, and when most of the pods are at the top, the plants are
   a) nondeterminate.   b) determinate.
   c) semideterminate.   d) none of the above.

12. The first two leaves in pigeonpea seedlings are
   a) pinnately trifoliate.   b) simple and opposite.
   c) compound.   d) both a and c.

13. The flowering on pigeonpea, within the raceme and on the branches proceeds
   a) basipetally.   b) acropetally.
   c) determinate.   d) nondeterminate.

14. The pigeonpea flowers are
   a) incomplete.
   b) complete, bisexual, zygomorphic.
   c) monoecious.
   d) dioecious.

15. The calyx is
   a) polysepalous.   b) gamosepalous.   c) free.

16. The broad, large, and auricled petal is the
   a) wing.   b) keel.   c) standard.

17. An obliquely obovate petal with an incurved claw is the
   a) wing.   b) keel.   c) standard.

18. An obtuse (round), incurved, and boat-shaped petal is the
   a) wing.   b) keel.   c) standard.

19. The aestivation of the pigeonpea inflorescence is
   a) ascending imbricate.   b) descending imbricate.
   c) free.

20. Pigeonpea anthers are 10 and
   a) monoadelphous.   b) diadelphous.

21. Anthesis in pigeonpea usually takes place from
   a) 0800-1200.   b) 0600-1600.
   c) 0900-1300.   d) 1000-1800.

22. The peak anthesis period recorded in pigeonpea is from
   a) 0800-0900.   b) 0700-0800.
   c) 0900-1000.   d) 1100-1200.

23. In pigeonpea after pollination, the pod is visible in
   a) 1 week.   b) 2 weeks.
   c) 3 weeks.   d) 4 weeks.

24. Pigeonpea seed attains physiological maturity in ______ after flowering.
   a) 20 days   b) 30 days
   c) 40 days   d) 50 days

25. The deep constricted pod of pigeonpea is
a) beaded. b) flattish.
c) shrunken. d) shrivelled.

26. The germination in pigeonpea is
a) epigeal. b) hypogeal.

27. The application of organic manure in pigeonpea should be ______ weeks before sowing.
a) 1-2 b) 2-4 c) 5-6 d) 8-10

28. To increase the pigeonpea production in acidic soil it is necessary to apply
a) organic manure. b) single superphosphate.
c) lime. d) gypsum.

29. The recommended rate to apply phosphorus (P) for pigeonpea production is ______ kg ha^{-1}.
a) 5-10 b) 12-16 c) 17-26 d) 30-35

30. Uniform pale-green young leaves and interveinal chlorosis of older leaves are deficiency symptoms of
a) phosphorus. b) potassium.
c) nitrogen. d) zinc.

31. Small stunted plants with dark-green leaves are due to the deficiency of
a) potassium. b) phosphorus.
c) nitrogen. d) calcium.

32. Appearance of light-green patches in interveinal areas or around the leaf margin which turn brown are the deficiency symptoms of
a) potassium. b) phosphorus.
c) nitrogen. d) calcium.

33. Yellowing on leaf tips followed by scorching and stunting of plants are the main deficiency symptoms of
a) potassium. b) phosphorus.
c) nitrogen. d) calcium.

34. Stunted growth, narrowing of leaves with pale-green appearance, interveinal chlorosis starting from tip and spreading to other area of leaves except the midrib. The curling and shedding of leaves is the deficiency symptoms of
a) phosphorus. b) potassium.
c) zinc. d) iron.

35. When interveinal areas of young leaves become pale-green but veins and adjacent tissues remain dark-green, it is the deficiency symptoms of
a) zinc. b) nitrogen.
c) iron. d) calcium.

36. Fading of the lamina of the middle leaves without affecting the veins with small white and brown spots, and brown necrotic lesions with a reduction of leaf number, area and size, late flowering and the arrest of the apical shoot growth are deficiency symptoms of

a) zinc. b) iron.
c) calcium. d) manganese.

37. Formation of dieback, rosetting, multiple branches, and death of seedlings are deficiency symptoms of

a) iron. b) manganese.
c) zinc. d) boron.

38. An important element in nitrogen fixation is

a) iron. b) boron.
c) zinc. d) molybdenum.

39. An economic dose of fertilizer for pigeonpea with N, P, and K are ____________ kg ha^{-1}.

a) 10-20-30 b) 20-17-17
c) 20-20-50 d) 30-40-60

40. A combination of crops in space and time to provide a high and stable level of returns is

a) a crop rotation. b) crop management.
c) a crop sequence. d) a cropping system.

41. The most suitable genotypes of pigeonpea for monocropping are

a) late-maturing types. b) medium-maturity types.
c) early-maturity types, d) extra-early types.

42. Postrainy season pigeonpea are cultivated as

a) a mixed crop. b) an intercrop.
c) a cash crop. d) a monocrop.

43. The best time of sowing of extra early pigeonpea at ICRISAT is in the 1st fortnight of

a) May. b) June. c) July. d) August.

44. An optimal depth for pigeonpea sowing is

a) 2-3 cm. b) 4-5 cm.
c) 7-8 cm. d) 9-10 cm.

45. Late sowing of pigeonpea increases

a) yield. b) biomass.
c) root mass. d) harvest index.

46. The most common practice of pigeonpea cultivation is on

a) broadbed-and-furrows. b) ridges-and-furrows.
c) bunds. d) flat beds.

47. A broadbed-and-furrow system of cultivation is most suitable for

a) early-maturing pigeonpea. b) medium-maturing pigeonpea.
c) late-maturing pigeonpea. d) extra-early-maturing types

48. The row and plant spacing in extra-early pigeonpea are
a) 50 and 40 cm. b) 40 and 60 cm.
c) 75 and 20 cm. d) 30 and 10 cm.

49. The plant population recommended for late-maturing pigeonpea varieties is
a) 80 000 ha^{-1}. b) 100 000 ha^{-1}.
c) 600 000 ha^{-1}. d) 200 000 ha^{-1}.

50. To prevent seed rot and seedling blight diseases, it is recommended to treat the seed with
a) thiram.
b) carbendazim.
c) thiram+carbendazin.
d) penta-chloro-nitro-benzene (PCNB).

51. For an effective weed control it is necessary to apply ______ herbicides.
a) presowing b) preemergence c) postemergence

52. An important herbicide for weed control in pigeonpea is
a) fluchloralin. b) alachlor.
c) 2-4D. d) glyphosate.

53. When preemergence herbicide is applied, the first hand weeding is required ________ weeks after sowing,
a) 1-2 b) 3-4 c) 6-7 d) 8-9

54. At noon when leaves are pointing towards the sun it is stress symptoms of
a) nitrogen, b) phosphorus, c) drought. d) wilt.

55. The critical periods for drought stress in pigeonpea are the
a) seedling and vegetative stages.
b) flowering and seedling stages.
c) flowering and pod-filling stages.
d) maturity and flowering stages.

56. Pigeonpea should be harvested when ____% of the pods are mature.
a) 40-50 b) 50-60 c) 70-80 d) 80-90

57. Before storage it is necessary to dry pigeonpea seed to a moisture content of
a) 10-15%. b) 10-16%. c) 8-10%. d) 6-8%.

Correct responses to the questions.

1. b); 2. c); 3. c); 4. c); 5. d); 6. c); 7. d); 8. c);
9. b); 10. a); 11. c); 12. b); 13. b); 14. b); 15. b);
16. c); 17. a); 18. b); 19. b); 20. b); 21. b); 22. c);
23. a); 24. b); 25. a); 26. b); 27. b); 28. c); 29. c);
30. c); 31. b); 32. a); 33. a); 34. c); 35. c); 36. d);
37. d); 38. d); 39. b); 40. d); 41. d); 42. d); 43. b);
44. b); 45. d); 46. d); 47. d); 48. d); 49. a); 50. c);
51. b); 52. a); 53. b); 54. c); 55. c); 56. c); 57. d).