Vegetable Pigeonpea - a High Protein Food for all Ages

Information Bulletin No. 83

Part I - The science behind the scenes

(Part II - Vegetable pigeonpea recipes)

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International Crops Research Institute for the Semi-Arid Tropics

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Contents (Part I)

1. Introduction

Most of the food proteins for vegetarians in the semi-arid tropics are derived from legumes that are generally grown under low input and risk-prone marginal environments with repeatedly low and unstable yields. At present, the protein availability in such areas is less than one-third of its normal requirement and with the continuously growing population and stagnation of yield, the protein availability to the masses is likely to decline further. Since the food production balance in most countries will always remain in favor of cereals, the issue of protein availability assumes a greater significance from the point of view of nutrition for the poor. This publication in two books (Part I – The science behind the scenes; Part II – Vegetable pigeonpea recipes) covers both scientific and nutritional aspects of the crop and provides recipes for tasty pigeonpea dishes.

Among legumes, pigeonpea [*Cajanus cajan* (L.) Millsp.] occupies an important place in rainfed agriculture. Globally, it is cultivated on 4.92 m ha, and 3.58 m ha (72.7%) of it is confined to India alone. The crop is known to be grown in 22 countries but it is cultivated in large areas only in a few countries (Table 1). In Asia, Myanmar (560,000 ha), China (150,000 ha) and Nepal (20,000 ha) are the other major pigeonpea growing countries besides India. In the African continent, Kenya, Malawi, Uganda, Mozambique and Tanzania produce considerable amounts of pigeonpea. The Caribbean islands and some South American countries also have reasonable areas under pigeonpea cultivation. In India, de-hulled split cotyledons of pigeonpea are cooked as a thick spicy soup, locally called *dal*, which is eaten with bread and rice, while in southern and eastern Africa and southern America both whole dry and immature seeds are used as vegetable. Its nutritious broken seeds, husks and pod walls are fed to cattle; while its dry stems make an important household fuel wood.

Origin: For a long time, the origin of pigeonpea has remained unclear. A perusal of early literature on this subject indicates that the crop originated either in Africa (Zanzibar or Guinea) or India. The presence of pigeonpea seeds in historical tombs indicated that it was cultivated in Egypt around 2000 BC. The availability of high diversity among germplasm made Vavilov (1939) conclude that India is the primary center of origin of the cultivated pigeonpea. De (1974) and van der Maesen (1980) also reported that the cultivated pigeonpea originated in India and from here it was taken to Africa around 2000 BC.

Taxonomy and distribution: Van der Maesen (1986) reported that the first scientific name of pigeonpea was given by Bauhin and Cherler during 1650-1651 and they called it *Arbor trifolia indica (Thora Paerou),* which means

Table 1. Global area, production and yield of pigeonpea in different countries in 2007.

Country	Area (ha)	Production (t)	Yield (kg ha^{-1})
Bangladesh	4,000	2,000	500
Burundi	2,000	1,800	900
China	150,000	NA	NA
Comoros	440	320	727
Congo	8,000	5,700	713
Dominican Republic	17,000*	16,065*	945*
Grenada	520*	500*	962*
Haiti	6,000*	2,400*	400*
India	3,580,000	2,740,000	765
Jamaica	1,100*	1,300*	1,182*
Kenya	196,261	110,662	5,634
Malawi	123,000	79,000	642
Mozambique	85000	NA	NA
Myanmar	560,000	530,000	946
Nepal	20,703	19,085	922
Panama	4,800*	1,949*	406*
Philippines	813	1,258	1,547
Puerto Rico	272*	218*	802*
Tanzania	68,000	50,000	735
Trinidad and Tobago	400*	953*	2,381*
Uganda	86,000	88,000	1,023
Venezuela	3,344*	3,015*	903*
Total/Mean	**4,917,653**	**3,654,225**	**743**

Source: FAO and other resources.
*Vegetable pigeonpea.

'common *dal*' in the Malayalam language of India. Linnaeus (1753) gave pigeonpea its first binomial nomenclature – *Cytisus cajan*. Van der Maesen (1986) has written an excellent monograph on this aspect and at present the following taxonomical classification is globally accepted.

Order:	*Fabales*
Tribe:	*Phaseoleae*
Sub-tribe:	*Cajaninae*
Family:	*Leguminosae*
Genus:	*Cajanus*
Species:	*cajan*

Based on various morphological, cytological, chemical and hybridization data, van der Maesen (1986) merged genus *Atylosia,* the nearest wild relative of pigeonpea, with genus *Cajanus*. Consequently, genus *Cajanus* now has 32 species and pigeonpea (*Cajanus cajan*) is the lone cultivated species of the *Cajaninae* sub-tribe.

Pigeonpea is known with various vernacular names in different countries (Table 2) and today's most popular name 'pigeonpea' was coined by Plukenet (1692) in Barbados, where the crop was grown in barren lands for feeding pigeons. According to De (1974), *Tuvarai* or *tuvari* are the oldest vernacular names of pigeonpea as these are mentioned in "*Gathasaptasati*", which was published between 300 and 400 AD. Pigeonpea is always credited to be a crop most suitable for subsistence agriculture because it is drought tolerant, needs minimum inputs, and can produce reasonable quantities of food even under unfavorable production environments. Its seeds contain about 20-22% protein and reasonable amounts of minerals and essential amino acids.

2. Important Attributes of Pigeonpea

2.1 Growth and development

The traditional pigeonpea cultivars and most landraces are of medium (160 -180 days) to long (>250 days) maturity durations. However, through breeding efforts, some early maturing types have also been developed and the earliest maturing variety, MN 5, flowers in about 45 days and matures in about 85 days at Patancheru (17^0N). Between the long- and short-duration types, there exists an almost continuous variation for maturity (Table 3) and it plays an important role in diversification of cropping systems and provides excellent opportunities for extending pigeonpea cultivation in new niches. The plants of early maturing varieties are relatively short in height and produce less biomass and, therefore, require high plant density for optimum yields. Such varieties are generally cultivated in pure stands. Pigeonpea has a strong photo-period

Table 2: Some vernacular names of pigeonpea used in different parts of the world.

Country	Vernaculars
ASIA:	
Bangladesh	Arhar, Tur, Tuver
China	Muk tau, Tan Shue, Shan Tou Ken (Tree bean)
India	Red gram, Arhar, Tur, Kandulu, Thogari, Tuvari,Thuvarai, Thora-paerou, Paruppu
Indonesia	Saupapa, Kachng bali, Kachng gude
Japan	Ki-mame
Malaysia	Kachang, Kachang dal
Nepal	Adhad, Arhar, Rar
Philippines	Tabios, Kardis, Kudis, Callos, Kadyos
Sri Lanka	Parippu (Pulse)
AFRICA:	
(General)	Pigeonpea, Pois d'Angole, Pois de Congo
Angola	Ervilha do Congo
Egypt	Ads sudani, Lubia hadjeri sudani
Ethiopia	Yeweof-ater, Ringa
Gabon	Oando, Ossanga, Osang-eli
Kenya,Tanzania	Mbaazi
Mozambique	Dozi, Feijao Boer
Nigeria	Aduwa, Olele, Orele, Alev a batur
San Tome	Feijao Congo
Senegambia	Cajan des Indes
AMERICA:	
(General)	Guandu, Angola pea, No eye pea, Gungo pea,
Brazil	Faijao andu, Feijao guandu
Cuba	Gandul, Gadul
Jamaica	Congo pea, Christmas pea, Guango
Puerto Rico	Gandul, Gandal
Venezuela	Qunichoncho, Quinchonchillo
OCEANIA-Hawaii	Puerto Rican pea
EUROPE:	
France	Embravade, Pois d' Angole, Pois de Bois, Pois cajan, Pois de congo
Germany	Angolische Erbse, Indischer Bohnenstrauch
Netherlands	Wandoe
AUSTRALIA	Pigeonopea

Table 3. Pigeonpea maturity groups developed on the basis of days to 50% flowering at Patancheru (17ºN).

Maturity group	Days to 50% flowering	Reference cultivar
0	< 60	ICPL 88039
I	61-70	Prabhat
II	71-80	ICPL 87
III	81-90	T 21
IV	91-100	ICP 6
V	101-120	Maruti
VI	121-130	Asha
VII	131-140	ICP 7035
VIII	141-160	Bahar
IX	>160	MAL 13

requirement and flowering in this species is induced by long periods of darkness. The photo-period sensitive reaction in pigeonpea germplasm has been found to be positively linked to its time to flower and biomass production. The early maturing pigeonpea genotypes are relatively less sensitive and the long duration types are most sensitive to photo-period responses (Wallis et al. 1981). On an individual plant basis, the photo-period sensitive genotypes produce more biomass and are traditionally grown either as an intercrop or as perennial hedges.

There are two major growth patterns in pigeonpea; the determinate types (Fig.1) have pods in clusters at the top of the canopy. Plant growth ceases after the induction of flowering and pod maturity is more or less uniform. These types, however, are more susceptible to pod borer attack and both *Helicoverpa armigera* (Hűbner) and *Maruca testulalis* (Geyer) can cause serious yield losses. On the contrary, in non-determinate types, the terminal buds are vegetative and the flowers are borne in axillary clusters. In general, these types tolerate biotic and abiotic stresses better than determinate types. Kapoor and Gupta (1991) reported that the growth habit in pigeonpea is governed by two independent

Figure 1. Growth patterns in pigeonpea – determinate (left) and non-determinate (right).

genes. The non-determinate habit was dominant to determinate growth habit and it was controlled by a single gene. Similarly, semi-determinate growth was dominant over determinate and was governed by another gene. Pigeonpea is a short-lived perennial shrub and this unique trait of the species helps in its adaptation to stress-prone environments. Its strong and deep root system, large food reserves, genetic ability to regenerate, and some undefined built-in stress compensation mechanisms help the pigeonpea plants to overcome such stresses and encourage regeneration of vital plant parts as soon as the micro-environment becomes conducive.

2.2 Prevalent cropping systems

In India, pigeonpea is traditionally cultivated as an intercrop with some shorter duration crops such as sorghum [*Sorghum bicolor* (L.) Moench]/(*Sorghum vulgare*), pearl millet [*Pennisetum glaucum* (L.) R. Br.]/(*Pennisetum typhoides)* and groundnut (*Arachis hypogaea*). In peninsular India, six-month varieties of pigeonpea are cultivated, while in the north, varieties that mature in nine months are grown. Under these situations, pigeonpea plants grow slowly for the first 45-50 days and provide no competition to the companion crop. In Myanmar and Nepal also, a similar cropping system is followed, while in China pigeonpea is primarily grown for soil conservation in the southern hills.

In Africa, traditionally, long duration pigeonpeas are grown with short season legumes (such as cowpea) or cereals (such as maize or sorghum). Once the intercrop is harvested, the pigeonpea plants grow rapidly and accumulate a considerable biomass, and the canopy appears as a pure crop with good seed yields. The pods are harvested either for green vegetable or at maturity for dry grains. In the following season, pigeonpea plants are either ratooned to allow sowing of another intercrop or the one year old plants are left in the fields for the second crop of green pods or dry seeds. Under this situation, an intercrop is generally not sown due to severe competition for various natural resources (SN Silim, personal communication).

2.3 Disease resistance

For the survival of perennial vegetable pigeonpea, it is important that the plants are disease-free. Fusarium wilt and sterility mosaic (Fig.2) are the two major pigeonpea diseases. Wilt is very common, while sterility mosaic appears regionally. At present, several varieties with high levels of resistance to both the diseases are available. Among these, ICP 7035, which has resistance to most races of sterility mosaic virus, is the best.

Figure 2. Diseases of pigeonpea – wilt (left) and sterility mosaic (right).

2.4 Pod color

Saxena et al. (1983) studied the effect of pod color on important organoleptic properties of vegetable pigeonpea. They found that seed from pods with purple color had poor texture, flavor and taste but after cooking such differences disappeared. This study concluded that pod color does not play an important role in determining the organoleptic properties of vegetable pigeonpea. In a survey conducted in Gujarat state of India, where immature pigeonpea seed is a popular vegetable, it was observed that in spite of extensive cultivation of a green podded pigeonpea variety, T 15-15, the rural consumers preferred cultivars that had purple streaks on the pod surface. On the contrary, city consumers preferred fresh pods that were green in color (Fig.3). In another consumer survey conducted by Yadavendra and Patel (1983), cultivar ICP 7979 was found to be the best because it had good taste, green colored pods and was easy to shell.

Figure 3. Green colored pods.

2.5 Pod and seed size

In pigeonpea, seed and pod size are generally correlated. The large podded genotypes have relatively large immature and dry seed size. In some vegetable type lines, the immature seed size is large but their dry seed size reduces rapidly with maturity. The number of ovules in a pod varies from 2 to 9, but all the ovules do not develop to their full size due to ovule abortion (Fig.4). The exact reason for the ovule abortion is not fully understood but there appears to be some sort of blockage in food translocation, insect damage or fungal infection that restricts or stops the process of ovule development inside pods.

Figure 4. Ovules inside pigeonpea pods.

3. Seed Quality

3.1 Quality traits

Green pigeonpea seeds are superior to *dal* in nutrition. Singh et al. (1984, 1983) and Singh (1988) reported that the vegetable type pigeonpea had high polysaccharides and lower crude fiber content than *dal*, irrespective of its seed size. The crude fiber content in vegetable type pigeonpea and garden pea *Pisum sativum* (L.) were almost similar. Trypsin inhibitor activity was also higher in pigeonpea than in garden pea but its magnitude was less than soybean (*Glycine max* [L.] Merr). The pigeonpea *dal* is superior to vegetable type with respect to starch and protein (Table 4), while the vegetable pigeonpea grains had higher crude fiber, fat, and protein digestibility. As far as mineral and trace elements are concerned, green pigeonpea was better in phosphorus by 28.2%, potassium by 17%, zinc by 48.3%, copper by 20.9%, and iron by 14.7% (Table 5). On the other hand, the *dal* had 19.2% more calcium, and 10.8% more manganese.

Like other legumes, pigeonpea seeds also contain considerable amounts of some anti-nutritional factors. In dry pigeonpea seeds, certain amounts of poly–phenolic tannin compounds are also present, which inhibit the normal activity of digestive enzymes such as trypsin, chymotrypsin and amylase (Table 6).

Table 4. Comparison of green pigeonpea seeds and *dal* for important quality constraints.

Constituent	Green seeds	*Dal*
Starch content (%)	48.4	57.6
Protein (%)	21.0	24.6
Protein digestibility (%)	66.8	60.5
Soluble sugars (%)	5.1	5.2
Crude fiber (%)	8.2	1.2
Fat (%)	2.3	1.6

Table 5. Mean values for trace and mineral elements (mg 100 g^{-1}) in green seeds of a vegetable variety ICP 7035 and *dal* of a popular variety C 11.

Element	Green seeds (ICP 7035)	*Dal*	SEm (C 11)	Superiority over dal (%)
Phosphorus	264*	206	± 3.95	28.2
Potassium	1,498*	1,279	± 12.74	17.1
Calcium	92.3	114.3*	± 1.98	-19.2
Zinc	3.07*	2.07	± 0.01	48.3
Copper	1.39*	1.15	± 0.08	20.9
Iron	5.16*	4.50	± 0.06	14.7
Manganese	0.99	1.11*	± 0.02	- 10.8
Magnesium	108.3	108.5	± 0.86	-

*Adapted from Singh et al. (1984).

According to Kamath and Belavady (1980), pigeonpea seeds have appreciable amounts of unavailable carbohydrates that adversely affect the bio-availability of certain vital nutrients. Some of the anti-nutritional factors such as phyto-lectins are heat sensitive and are generally destroyed during the cooking process. Some of the flatulence-causing oligo-saccharides such as stachyose, raffinose and verbascose are also present in pigeonpea seeds.

Table 6. Major anti-nutritional factors and toxic substances in pigeonpea seed.

Constituent	Range	Mean
Protease inhibitors (units mg^{-1})		
Trypsin	8.1 – 12.1	9.9
Chymotrypsins	2.1 – 3.6	3.0
Amylase inhibitors (units g^{-1})	22.5 – 34.2	26.9
Oligo-saccharides g(100 g^{-1})		
Raffinose	0.24 – 1.05	0.47
Stachyose	0.35 – 0.86	0.49
Poly-phenols (mg g^{-1})		
Total phenols	3.0 – 18.3	10.7
Tannins	0.0 – 0.2	0.03
Phyto-lectins (units g^{-1})	400	400

Source: Singh (1988).

3.2 Morphological and chemical changes in developing seeds

Under normal growing environments, pigeonpea plants produce profuse flowering and podding. In small seeded varieties, the pod load on each plant is much greater than those of large seeded varieties. To determine an optimum pod growth stage for harvesting a commercial vegetable pigeonpea crop, the pods for picking are selected visually, though this method may not maximize the grain and nutrition yields. Under sub-tropical growing conditions, it takes about 45-50 days from pollination to seed maturity. During this period, both pods and seeds pass through a number of physiological, morphological and chemical changes. Generally, three days after fertilization, the floral petals wither completely and the ovary starts emerging. A young pod of about one centimeter length is visible after about a week. Such pods grow rapidly and achieve their full length in about 25 days (Fig.5). During this period of pod growth, the young seeds (ovules) inside the pods remain intact but do not gain any noticeable size and weight (Fig.6). Soon after achieving the potential pod length, a greater proportion of food reserves of the plant are diverted towards the ovules and rapid increases in their sizes and weights are observed for the next 10-12 days. From nutritional and marketing view points, it is essential that the growing pods are picked at a proper stage to harvest maximum grain yield with high nutritional quality.

Using two vegetable type cultivars ICP 7035 and T 15-15, Singh et al. (1991) conducted a study to record the changes in the levels of principal dietary constituents and minerals at different stages of seed development. To initiate this experiment, they tagged 3,000 flowers of the same age and hand pollinated them within a day. The researchers sampled the fertilized pods on different dates for chemical analysis. They observed that the two cultivars used in the study differed in their dry matter accumulation rate with ICP 7035 being faster than T 15-15. Such differences in the ratio of dry matter accumulation in the two varieties were attributed to their respective seed size. In the growing seeds, the starch content was negatively associated with their protein and sugar content. The amount of crude fiber content in the growing seeds increased slowly with maturation. Soluble sugars and proteins decreased but the starch content increased rapidly between 24 and 32 days after flowering. ICP 7035 had high soluble sugars in each sample studied.

Figure 5. Pod development stages in pigeonpea.

Figure 6. Ovule development inside growing pods.

Besides protein, vitamins such as B-complex and minerals are also important for human growth and development. Meiners et al. (1976) showed that the minerals and trace elements such as calcium, iron, zinc, magnesium and copper did not show significant changes during seed development. Both vegetable pigeonpea and its *dal* are good sources of these mineral nutrients. Some of the minerals also play an important role in improving cooking quality of pigeonpea (Sharma et al. 1977).

4. Genetic Enhancement of Vegetable Pigeonpea

4.1 Breeding objectives

Primary characteristics of vegetable type pigeonpea varieties are large pods and large seeds. It has been generally observed that in most germplasm these two traits are linked together and such lines are invariably photo-sensitive, long duration (>180 days at 17°N) in maturity, and perennial in nature. These cultivars and landraces flower at the onset of short photo-periods and produce fresh pods for about 40-50 days. In some varieties, the pod set is extended up to 60 days. From the processing and marketing points of view, limited periods of fresh green pod supply is a major constraint. Besides these attributes, the vegetable type pigeonpea should be good in appearance, sweet in taste and have desirable organoleptic properties to fetch a good price in the market. Therefore, the objectives in a vegetable breeding program, besides yield, revolve around such traits. For an effective vegetable pigeonpea improvement program the specific breeding objectives may be:

- early podding,
- round-the-year green pod production,
- multiple harvesting of pods,
- long green pods with least stickiness on their surfaces,
- fully developed ovules,
- easy shelling,
- large attractive white mature seeds, and
- long shelf life of green pods and shelled grains.

4.2 Vegetable type pigeonpea germplasm

ICRISAT has a global responsibility for collection, characterization, maintenance and distribution of pigeonpea germplasm. At present, a total of 13,548 germplasm accessions from more than 70 countries have been assembled for use in future breeding programs. Since large pod size is the most important characteristic of vegetable pigeonpea, the accessions with >5.0 mean seeds pod^{-1} are included in this group (Table 7). A perusal of this germplasm collection (231 accessions) showed that this group also had a considerable variation for other agronomic traits. In this collection, days to flower varied from 80 to 229. Similarly, for days to maturity a large variation (133-270) was observed. The plant height among vegetable types ranged from 85 to 285 cm, while pod length exhibited a range from 3 to 11 cm (Fig.7). A majority of the long podded accessions appears to have originated in the African continent where large, white seeded materials are traditionally cultivated. A list of vegetable type germplasm available in the ICRISAT genebank is given in Annexure I and II.

Table 7. Variation for some important agronomic traits within vegetable type pigeonpea germplasm of different regions.

Region	No. of accessions	Days to flower	Days to mature	Plant height (cm)	Seeds pod^{-1}	Pods plant^{-1}	Pod length (cm)
Eastern Africa	106	117 – 229	166 – 270	130 – 270	5.4 – 6.7	26 – 406	5 – 12
Southern Africa	17	131 – 194	163 – 260	185 – 260	5.4 – 6.1	33 – 154	5 – 11
Central Africa	4	141 – 166	215 – 232	200 – 230	5.4 – 5.6	74 – 130	7 –9
Western Africa	13	142 – 156	194 – 218	170 – 250	5.4 – 5.6	67 – 246	7 – 10
Central America	26	106 – 151	167 – 202	85 – 240	5.4 – 7.2	19 – 160	7 – 11
South America	16	132 – 158	182 – 230	100 – 285	5.4 – 6.1	27 – 420	5 – 11
South Asia	39	80 – 175	133 – 235	85 – 230	5.4 – 7.2	55 – 830	3 – 9
South-east Asia	8	134 – 201	190 – 264	140 – 210	5.4 – 5.9	24 – 119	5 – 9
Europe	2	156 – 174	222 – 237	210 – 260	5.4 – 5.8	137	9
Total	231	80 – 229	133 – 270	85 – 285	5.4 – 7.2	19 – 830	3 – 11

4.3 Genetics of important vegetable pigeonpea traits

For effective plant breeding, a good understanding of various genetic systems controlling important qualitative and quantitative characters is essential. In comparison to many field crops, genetic research in pigeonpea is rather limited and fragmentary. For most qualitative characters, there are large differences in the reported traits, and sometimes the observed phenotypic segregation ratios cannot be interpreted confidently. Also, in most cases only a limited number of crosses have been studied, making it difficult to generate information on their allelic relationships. The genetic interpretations in such studies are also greatly influenced by parental materials used in the study; therefore, any generalization about this information will be unrealistic. Both additive and non-additive gene actions of various degrees for yield and other characters (Tables 8 and 9) have been reported by several pigeonpea researchers (Saxena and Sharma 1990).

Pod color: Krauss (1927) was the first to study variation for pod color (Fig.7) and reported an F_2 ratio of 3 maroon blotched:1 light tinted. D'Cruz et al. (1970) reported that streaked pod color was dominant over green pod color, and that a single gene was responsible for streaked pods. A dihybrid F_2 segregation (9 dark:3 maroon blotched:4 green) was reported by Dave (1934) and de Menezes (1956). An F_2 ratio of 15 blotched:1 green was observed by D'Cruz and Deokar (1970). Deokar et al. (1972) found that the color development in unripe pigeonpea pods was due to the interaction of four genes, two of

Figure 7. Range in pod length and color.

Table 8: Summary of gene action for various agronomic traits in pigeonpea as reported in literature.

	Type of gene action		
Character	Additive	Non-additive	Additive + Non-additive
Plant height	*	*	*
Plant width	*	*	
Days to mature	*	*	*
Pods plant^{-1}	*	*	
Seeds pod^{-1}	*	*	
Days to flower	*		
100-seed weight	*	*	*
Seed yield	*	*	
Protein %		*	*

Source: Saxena and Sharma (1990).

Table 9. Gene action for pod and seed size reported in pigeonpea.

Trait	Gene action	Reference
Pod size	Additive	Pandey 1972
	Additive	Saxena et al. 1981
	Additive	Mohamed et al. 1985
	Additive and non-additive	Venkateshwarlu and Singh 1982
	Additive and non-additive	Kapur 1977
Seed size	Additive	Pandey 1972
	Additive	Sharma et al. 1972
	Additive	Sharma et al. 1973
	Additive	Sidhu and Sandhu 1981
	Additive	Reddy et al. 1981
	Additive	Mohamed et al. 1985
	Non-additive	Reddy et al. 1981
	Additive and non-additive	Dahiya and Brar 1977
	Additive and non-additive	Gupta et al. 1981
	Additive and non-additive	Venkateshwarlu and Singh 1982

which were basic, one inhibitory, and one anti-inhibitory. Saxena et al. (1984) observed intra-plant pod color variation in a pure breeding pigeonpea line ICP 3773, where the pods within a plant and within a branch of a plant were either completely green and/or green with purple streaks of variable intensities. They postulated that this pod color variation and its unpredictable expressivity was perhaps governed by the presence, absence, or interaction of one or more unstable genes. They further hypothesized that these genes have the ability to suppress the expression of the other pod color genes. The suppression was complete in green pods and incomplete in streaked pods.

Seed color: The genetics of seed color in pigeonpea is also complicated. The variation in seed coat color (Fig.8) can be controlled by some basic, inhibitory genes and modifier genes, and their interactions. Deokar and D'Cruz (1971) reported the dominance of brown seed over white and it was found to be controlled by a single gene. Deokar and D'Cruz (1971) found a dihybrid seed color F_2 ratio of 9 brown:7 white. Similar results were also reported by Marekar and Chopde (1985). Patil et al. (1972) observed that brown seed color was governed by three dominant genes.

Figure 8. Seed color variation.

Disease resistance: The resistance or susceptibility of a crop plant to a particular disease pathogen is the result of manifestation of host and parasite interaction controlled by co-evolving genetic systems of both the host as well as the parasite. In the Indian subcontinent and in southern and eastern Africa, wilt caused by *Fusarium udum* Butler is the most important disease. Sterility mosaic virus is another important disease in the Indian subcontinent. Plant breeders and pathologists have been successful in identifying good sources of genetic resistance and in breeding cultivars resistant to one or both the diseases.

Pal (1934) reported that the resistance to Fusarium wilt in pigeonpea was controlled by multiple factors, while Shaw (1936) and Pathak (1970) observed two complementary genes conferring resistance to wilt. Joshi (1957), and Pawar and Mayee (1986) reported that a single dominant gene controlled wilt resistance in pigeonpea. Sharma (1986) reported the dominance of resistance over susceptibility, and suggested that the resistant parents had major genes for resistance, while the susceptible parent sometimes had minor or polygene for field resistance.

Singh et al. (1983) studied inheritance of resistance to sterility mosaic virus and postulated that the resistance to this disease was under the control of four independent loci, consisting of two duplicate dominant genes and two duplicate recessive genes. For the expression of resistance, at least one dominant allele at locus 1 or 2 and homozygous recessive genes at locus 3 or 4 are essential. Sharma et al. (1984) reported that susceptibility was dominant over tolerance and resistance, but the resistant lines differed in the expression of their resistance in the crosses with tolerant genotypes. They concluded that inheritance of resistance to sterility mosaic is complicated, and it is determined by a multiple allelic series.

Plant type: Plant type in pigeonpea also has considerable variation. Besides its growth habit (determinate/non-determinate), the nature of branching plays an important role in determining its plant type. Some varieties are erect and compact with narrow branching while in others the angle of branches open giving the appearance of semi-spread or spreading plants (Fig.9). Similarly, a considerable variation is observed for plant height. In conventional germplasm these two characters have a considerable range with a strong environmental effect, depending on the planting time.

Figure 9. Plant types of vegetable pigeonpea.

Cultivated pigeonpea types are mainly recognized as compact or spreading. However, a range of intermediate types with varying degrees of spread are also common. Dominance of the erect growth habit over the spreading type was observed by Shaw (1931). D'Cruz and Deokar (1970) reported that a single dominant gene controlled spreading habit, and that the erect types were homozygous recessive. D'Cruz et al. (1971) observed that branching habit was governed by three duplicate complementary factors. Marekar (1982) reported that the close branching habit was controlled by one basic and two inhibitory complementary genes. Positive associations of yield with plant height, plant spread, and number of primary and secondary branches suggests that spreading, tall, indeterminate types have an advantage. Nevertheless, tall compact and spreading types are widely grown, perhaps because they are ideal for intercropping.

Response to photo-period: Pigeonpea cultivars have a wide range of photo-period and temperature sensitivities, resulting in specificity of their adaptation to different latitudes, planting time and cropping systems. Pigeonpea is known to be a quantitatively short-day plant and most cultivars flower in day-length regime of 11 to 11.5 h (Gooding 1962). No pigeonpea cultivar is truly photo-period insensitive but their degree of sensitivity varies quantitatively; the earlier flowering types being the least sensitive. Saxena (1981) studied flowering behavior under natural (14.8 h maximum) and artificially extended (16 h) photo-periods in four crosses involving photo-period insensitive and sensitive genotypes. He reported that under 16 h photo-period three major genes — Ps_3 (conditioning >106 days to flower), Ps_2 (>82 days to flower), Ps_1 (>70 days to flower) — control the flowering in sensitive parent MS 4A. These genes express hierarchically with Ps_3 overriding the expression of Ps_2, and Ps_2 over Ps_1. Hence, the photo-period insensitive genotypes are triple recessive homozygous and all the three genes express only in the extended photo-period environment. The phenology of photo-period sensitive genotype changes significantly with planting dates. Sowings near the shortest day produce small plants while the plants grow vigorously if planted near the longest day (Fig.10).

Figure 10. Photoperiod responses on plant growth and morphology.

Gene action: In pigeonpea both additive and non-additive gene actions have been reported to control seed yield and other important quantitative characters (Saxena and Sharma 1990). However, the critical information on the extent of non-additive effects, particularly dominance and epistasis components, is not very clear and decisive. Saxena et al. (1981) observed the predominance of additive gene action for yield and yield components. They demonstrated that in pigeonpea, agronomic considerations in field evaluation trials and inclusion of parents with a moderately different phenology have significant influence on the estimates of genetic variances. They suggested that studies on the estimation of genetic variances should be conducted using cultural practices similar to those followed in commercial cultivation. These estimates are likely to be more close to the reality. Reddy et al. (1981) and Sidhu and Sandhu (1981) reported the importance of both additive and non-additive gene actions, while the predominance of non-additive gene action was observed by Dahiya and Brar (1977). Sharma et al. (1972) reported predominance of additive gene action for seed size and the genes controlling small seed size were found to be dominant over the genes responsible for the expression of large seeds. Gupta et al. (1981) also confirmed additive gene action and reported that seed size differences were determined by only 2 or 3 major genes. For days to flower, Pandey (1972), Sharma et al. (1973), and Dahiya and Satija (1978) reported additive genetic variance with partial dominance for earliness while Gupta et al. (1981) reported predominance of additive gene effects for flowering. Plant height was reported to be controlled by both additive and dominance gene effects (Sharma 1981). Genes controlling tall stature were dominant over the genes responsible for the expression of short stature.

Heritability: The heritability estimates provide a guideline on the efficiency of selection as they refer to the proportion of the phenotypic variance that is due to heritable genetic variance. A greater heritability estimate suggests that the concerned character can be easily selected within a given environment. The heritability estimates (Table 10) are generally valid for a given population and the environment in which these were estimated. In pigeonpea, a number of reports on heritability estimates for various quantitative traits have been published. Together, these estimates provide general information about the ease of selection for a particular character. For the sake of convenience, these estimates are grouped as high (>75%), medium (75-50%), and low (<50%). There is a large variation in the estimates of heritability for all the important agronomic traits. However, most of the studies suggest that characters such as

Table 10. Heritability estimates for pod and seed size reported in pigeonpea.

Trait	Heritability	Reference
Pod size	Low	Sharma et al. 1973
	Low	Sidhu and Sandhu 1981
	Medium	Kumar and Reddy 1982
Seed size	Low	Dahiya and Brar 1977
	Low	Sidhu and Sandhu 1981
	Low	Gupta et al. 1981
	Low	Sidhu et al. 1985
	Medium	Kumar and Reddy 1982
	High	Sharma et al. 1972
	High	Joshi 1973
	High	Sheriff and Veeraswamy 1977

Low = < 50%; Medium = 50-75%; High = > 75%.

seed yield, pods plant^{-1}, protein content, etc, have relatively low heritability due to the large influence of the environment on their expression. On the contrary, days to flower, days to maturity, plant height and seed size are known to have relatively high heritability estimates.

Breeding Technologies

Progeny selection

Predominantly, the vegetable pigeonpea breeding programs in most countries are limited to purification of selections from large podded native germplasm. Although the local landraces are generally well adapted in the area, due to insect-aided natural out-crossing and mechanical mixtures, they have become impure for various traits. With 25-70% natural out-crossing and uncontrolled pollination, the pure lines also become highly heterozygous and heterogenous within 3-4 years. These populations provide enough opportunities for breeders to select plants of interest with due consideration to plant type, pod and seed color, etc. To achieve this, one or two branches of the selected plants should be bagged after removing open flowers and young and old pods (Fig.11). An insecticide spray on such branches before selfing is always useful to kill live insect eggs and larvae. At maturity, the selfed branches are harvested separately and evaluated in progeny rows in the subsequent season. Selection should be made among pure lines, and within each selected progeny, another five plants should be bagged for growing single plant progenies to repeat the process of selection. The open-pollinated seeds can be used for field evaluation while the selfed seeds are used as 'Nucleus Seed' for producing 'Breeder Seed'.

Figure 11. Selfing of branches.

Hybridization and selection

Globally, very little work is being carried out to breed vegetable type pigeonpea through hybridization and selection. However, some efforts were made at the University of the West Indies, Dominican Republic, and at ICRISAT to breed new varieties that produce green pods early in the season and allow several flushes of podding. Adoption of such varieties will help in enhancing the income of farmers. To achieve this, selection of parents for hybridization is the first step towards breeding, and this should be done in accordance with breeding objectives. Attempts should be made to cross material as pure as possible. Preferably, early maturing varieties should be used as female parents. Emasculation should be done very carefully. Fresh pollen buds should be collected for pollination from the male parent and pollinated flowers should be tagged with a piece of thread (Fig.12). In the subsequent generation, the selfed plants that resemble the early maturing parent should be removed and the F_1 hybrid plants with flowering around mid-parent value should be selfed. Selection in F_2 generation should be exercised for pod and seed size and their color. These plants can be handled further with the classic pedigree selection method. To the best of the author's knowledge, no other breeding method has been used to breed vegetable type pigeonpea.

5. Choice of Varieties

The most popular vegetable pigeonpea cultivars have long pods with large sweet seeds (weighing about 15 g 100^{-1} seeds or more when dry), which can be

Figure 12. Emasculation and pollination.

easily removed from the pod shell. In Gujarat state of India, there are cultivars that produce dry seeds weighing about 10-12 g 100^{-1} seeds. These cultivars are grown as a normal field crop, but the pods are harvested at the appropriate stage of growth for use as vegetable. Harvesting of green pigeonpea pods for sale as a vegetable is more common near cities where the green pods can be readily marketed. In some cases, a part of the crop is left for harvesting later as dry seeds.

In India, consumers prefer vegetable pigeonpea with green pods. These usually command a higher price than striped ones, or pods of other colors. However, tests at ICRISAT with immature pods have shown that differences in pod color are not related to cooking time, taste, or nutritive quality. Cultivars with white seed coat, which have a bright green color when harvested as a vegetable, are preferred to ones that are colored because the cooking water in the former remains clear. Sweetness of the seed is also a preferred character. Normal sugar levels are around 5.0%; but researchers at ICRISAT have identified varieties, such as ICP 7035, with a sugar content as high as 8.8%. Another cultivar, T 15-15, is widely grown for vegetable pigeonpea. In southern India farmers grow the large-seeded lines Hy 3C and TTB 6, and there are other tribal areas, particularly in the hills, where large seeded landraces are traditionally grown. An example is ICP 7035 (Fig.13), which has large and sweet seeds and a high level of disease resistance. Scientists at ICRISAT have bred some large-seeded lines such as ICPL 87091 (Fig.14), which also have a good yield potential. In selection, earliness in maturity is a character considered appropriate for vegetable pigeonpea, although some medium maturing lines have performed well, and some late maturing large seeded genotypes can be grown for a few years as a hedge around or in gardens. There are also some early maturing cultivars that continue to produce pods for a long time and can,

Figure 13. ICP 7035 plant and pods.

Figure 14. ICPL 87091 plants and pods.

therefore, produce more than one crop in a year, of which ICPL 87091 and ICPL 87 are good examples.

Africa

Considering the importance of pigeonpea in African agriculture, priority was given to breed high yielding disease resistant long duration varieties for deep soils and early maturing types for drought prone areas. The first early maturing variety, ICPL 87091, was simultaneously released in Kenya, Malawi, Tanzania and Uganda. Under this program, a total of nine varieties were released in Kenya, Malawi, Mozambique, Tanzania and Uganda. In eastern Kenya, about 20% of the farmers have adopted new pigeonpea varieties. Farmers have also started adopting new medium maturing pigeonpea varieties such as ICEAP 00554 and 00557 both for grain as well as green vegetable. In Tanzania, about 50% of the farmers in Babati district adopted new varieties and the pigeonpea production area expanded to reach the neighboring districts of Karatu and Mbulu (SN Silim, personal communication). The adoption of long duration, Fusarium wilt resistant and consumer/market preferred variety ICEAP 00040 in northern and central Tanzania, Kenya and Malawi has resulted in increased grain yields and lowered production costs in comparison to local genotypes.

Southern and Central America and the Caribbean regions

The Caribbean region constitutes a chain of island countries, extending from Trinidad in the south to Jamaica in the north. In this region, Dominican Republic is the highest pigeonpea growing country (17,000 ha) with an average yield of 945 kg ha^{-1} (FAO 2007). The other pigeonpea growing countries are Panama (4,800 ha), Venezuela (3,344 ha), Jamaica (1,100 ha), Grenada (520 ha), Trinidad & Tobago (400 ha), and Puerto Rico (272 ha). Pigeonpea in these countries is essentially a small farmer's enterprise but at national levels it is an important crop. Pigeonpea is generally grown as intercrop for consumption as fresh peas.

The first vegetable type variety released in the West Indies was 'Prensado'. It was early in maturity and determinate in growth habit. This variety did not become popular among farmers. Subsequently, three more varieties 'Tobago', St. Augustine' and 'Lasiba' were released, which were similar to traditional types in their phenology and are still cultivated. In the mid-sixties, selections from breeding populations were also made, which produced varieties with good quality grains and high yield under intercrop situations (Ariyanayagam and Spence 1978). Besides routine research on diseases, insects and some agronomic aspects, the important breeding objective for the Caribbean region was to develop varieties that could provide year-round fresh pods for marketing. To achieve this, a photo-insensitive line was partially successful.

In Dominican Republic, pigeonpea is mainly grown by small farmers and about 80% of the annual harvest is exported in the form of canned or frozen green peas. According to Mansfield (1981), the varietal information in Dominican Republic is unclear and farmers generally use a mixture of varieties such as 'Kaki' and 'Saragateado'. In general, four pigeonpea varieties are recognized in Dominican Republic. These are 'Kaki', 'Pinto Villalba', 'USDA' and 'Year-round'. All these varieties are long podded, large and white seeded. The main breeding objectives are to develop high yielding varieties of different maturities and to breed suitable dwarf lines for mechanical harvesting (Abrams et al. 1978). 'Kaki' is the most popular pigeonpea variety in Puerto Rico (Aponte 1963) and 2B Bushy is another early maturing semi-dwarf variety. The pigeonpea breeding programs in Puerto Rico and Venezuela made fairly good progress and released a few vegetable type varieties such as 'Panameno', 'Amarillo', 'Kaki', 'Saragateado', and 'Totiempo' (Rivas and Rivas 1975). There have been recent releases of pigeonpeas in Puerto Rico and the Dominican Republic. 'Guerrero' and 'Cortada' were released in Puerto Rico in 2000 and 'Navideño' was released in the Dominican Republic in 2005. In Guadeloupe, several lines were introduced and suitable lines were identified (Derieux 1971). In Venezuela, a cultivar called 'Panameno' was released in 1972 (Rivas and Rivas 1975).

ICP 7035: It is a perennial germplasm collected in 1973 from Bedaghat township located near Jabalpur city of Madhya Pradesh, India by ICRISAT Pigeonpea Breeders Dr D Sharma and Dr LJ Reddy. ICP 7035 is highly resistant to Fusarium wilt and sterility mosaic diseases. Sometimes, its 2-3 year old plants suffer from *Macrophomina* stem canker. Its flowers are dark red and produce purple colored pods. The seeds of ICP 7035 are large, purple with mottle pattern on their surface and contain significant amount (8.8%) of sugar. It produces excellent vegetable peas. The pods of ICP 7035 are long (7-8 cm) and, on average, contain six seeds in each pod.

6. Cultivation of Vegetable Pigeonpea

Pigeonpea is known to be highly sensitive to environmental factors, especially photo-period and temperature, which results in different phenologies. Early maturing vegetable type varieties are short in stature and require high (200,000 – 300,000 plants ha^{-1}) density in contrast to long duration non-determinate types, which require 40,000 – 50,000 plants ha^{-1} for optimum yields. Hence, for different agro-ecological zones, specific agronomic practices are required, and it may be improper to recommend a single production package of practices for different locations. However, some general guidelines about pigeonpea cultivation are given below:

6.1 Backyard and bund cultivation

For domestic use many people grow pigeonpea plants in their backyards (Fig.15). Such plants are maintained up to 3-4 years and attain a plant height of well over 3 m. The plants start flowering at the onset of short days and immature pods are picked for household use as and when required. Under normal moisture conditions, new flowers are formed and one can see flowers, young pods, immature pods, and harvestable pods at the same time on one plant.

Figure 15. Backyard crop of pigeonpea.

For local market relatively large populations are grown on field bunds, mainly around rainy season paddy fields. Generally 3-4 seeds are sown in a single hill and the plants produce large number of branches on either side of the bunds. In such plantings, even if a few plants die due to some reason, the branches produced on the neighboring plants compensate for this loss and produce good yield. The immature pods are picked manually, and are sold in the market either as whole pods or shelled seeds. Slightly bigger seed lots can also be frozen to meet the demand of local or regional markets.

6.2 Peri-urban commercial crop

Field preparation: To select a field for commercial crop, the field should have a known history of good soil fertility. Since pigeonpea cannot withstand water-logging, low lying fields should never be selected for vegetable pigeonpea production. The sowings on raised beds with appropriate slope is always ideal to avoid flooding of field. Application of 100 kg ha^{-1} of di-ammonium phosphate and other soil amendments for the known soil deficiencies is advisable.

Sowing: It should be undertaken at the onset of rainy season. This will ensure good plant growth and canopy development. For short-duration types, the row-to-row spacing of 50 cm at low latitudes and 60 to 75 cm at high latitudes with plant-to-plant spacing of 25 to 30 cm can be adopted. For medium and long-duration types, the seed should be sown to maintain row-to-row and plant-to-plant spacing of 100 cm and 50 cm, respectively. The seeds are placed about 3-5 cm deep and covered firmly with soil.

Weed control: Slow seedling growth of pigeonpea makes the crop prone to weed competition during the first six weeks of growth. In general, three hand weedings at appropriate intervals are sufficient to control most weeds. Alternatively, spraying of a pre-emergence herbicide such as *Basalin* or *Prometryn*, each @1.5 L ha^{-1}, followed by two hand weedings have been found effective in managing weeds.

Irrigation: Irrigation is generally not recommended if the crop is grown for domestic consumption on deep Vertisols. However, if the crop is grown for seed purposes, either on light Vertisols or Alfisols, irrigations at flowering and early podding stage are always beneficial.

Chemical control of insects: Pod borers such as *Helicoverpa armigera* (Fig.16) and *Maruca vitrata,* pod fly (*Melanagromyza obtusa*) and blister beetle (*Mylabris pustulata* [Thunberg]) are major pigeonpea insects. These may cause severe damage to yields and seed quality. To control the pod borers in pigeonpea, the following insecticides have been found effective at ICRISAT.

Endosulfan 35 EC @.1.0 L ha^{-1}

Monocrotophos 36 EC @ 1.0 L ha^{-1}

Quinalphos 25 EC @ 2.0 L ha^{-1}

Dimethoate 30 EC @ 1.0 L ha^{-1}

The first insecticide spray is generally recommended at flower initiation, and the second and third sprays should be done, if required, at 10-15 day intervals. If Knapsack sprayers are used, then 500 L of spray liquid is recommended to cover one hectare of a pigeonpea field. Since vegetable pigeonpea are consumed fresh, it is always advisable to consult a local expert before finalizing the spray schedule. Also, the quality of insecticides should be ensured before purchase.

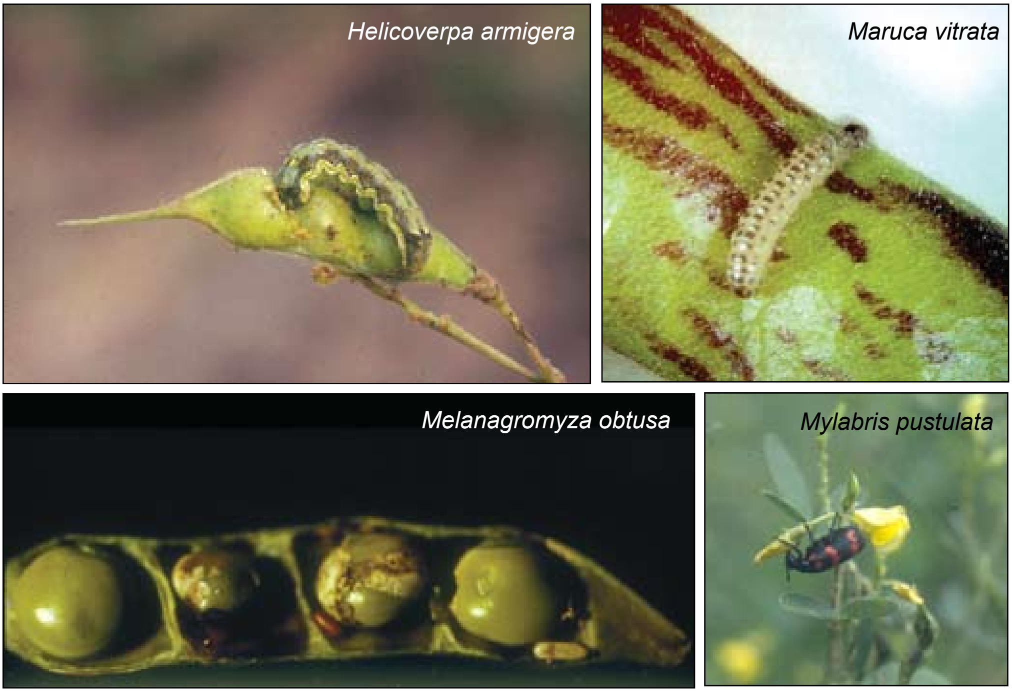

Figure 16. Insect pests of pigeonpea.

Integrated pest management: ICRISAT has developed some integrated pest management practices to reduce pod borer damage in pigeonpea. An outline of such practices (GV Ranga Rao, personal communication) is given below:

i) Monitoring of pests and their population is carried out with the help of pheromone traps. The septa of a pheromone trap consists of a chemical that attracts male moths of *Helicoverpa* pod borers. Therefore, the use of sex pheromone traps at village level helps in predicting the time when the pest population is likely to increase.
ii) Growing of trap crops such as marigold (*Tagetes* spp.) on the borders of pigeonpea fields and in between rows as an inter-crop also helps in reducing pod borer damage.
iii) Planting of tall sorghum variety on the borders and inside pigeonpea field acts as perches for birds that eat pod borer larvae.
iv) Use of 5% neem seed kernel extract spray is quite effective against pod borers.
v) On noticing the eggs and first instar larvae of *H. armigera*, spraying of HNPV (hydro nuclear polyhedrosis virus that infects *H. armigera*) is also recommended @ 250 LE (larval equivalent) ha^{-1}.
vi) Manual shaking of plants helps in dislodging the grown pod borer larvae from pigeonpea plants; these are collected on the ground on a plastic sheet and destroyed.
vii) Since blister beetles are large in size and slow moving insects, they can be controlled by hand picking or by using small insect catching nets. To protect skin from blisters caused by these insects, use of hand gloves in catching insects is always advisable.

Disease management: Fusarium wilt and sterility mosaic are two major diseases of vegetable pigeonpea. Wilt is caused by a soil-borne fungus *Fusarium udum* Butler. This pathogen can survive in fields for three years or more. Therefore, to control the losses caused by wilt, the following management practices are recommended:

- use wilt resistant varieties,
- use disease free fields with no previous record of wilt, and
- follow appropriate crop rotations involving pigeonpea.

Sterility mosaic virus is transmitted through eriophide mite (*Aceria cajani)*. These virus-carrying mites survive on a number of alternative hosts, including pigeonpea stubbles left in fields after harvesting the main crop. The simple disease management options are to:

- grow sterility mosaic resistant cultivars,
- uproot and destroy infected plants at an early stage of disease development, and
- spray Metasystox @ 0.1% to control the mite vectors in the early stages of plant growth.

Harvesting of pods: Near townships and cities, where marketing is easy, the immature pods are harvested for sale as fresh vegetable. Since for vegetable purpose fully grown bright green seeds are preferred, the pods are harvested just before they start loosing their green color. Pigeonpea is a perennial plant that allows continuous flowering and podding. Under sufficient moisture conditions, the plants allow more than one flush of flowers and harvesting of green pods.

7. Production and Maintenance of Quality Seed

The seed of a crop is like a biological capsule that contains complete genetic information in coded form about its parentage. Therefore, maintenance of genetic purity of elite genotypes is essential to get repeated high quality performances. In a self-pollinated crop, most of the traits can be maintained generation after generation with least efforts and resources. On the contrary, in crops where pollination is aided by external factors such as insects or wind, the maintenance of seed quality is not only difficult but also expensive. In spite of it belonging to the group of pulses where self-pollination is a rule, a considerable (20-70%) out-crossing takes place (Saxena et al. 1990) through pollinating insects in pigeonpea. This phenomenon makes the seed maintenance job more difficult than other pulses. Therefore, selfing of plants (Fig.17) is essential. A study conducted by ICAR (1993) revealed that in most cases the farmer-saved seeds were found to be sub-standard with respect to genetic (37-80%), physical purity (15-100%), ability to germinate (15-100%), and general health. In different crops, such seed gave 2-80% lower yield than the quality certified seed. Normally, it is observed that when a variety of a crop is released and it performs well in a particular area, the news about its performance spreads to the surrounding areas. This generally leads to uncontrolled spread of seed from farmer to farmer. Initially, the new variety is grown by a few progressive farmers without any consideration about seed quality production norms, such as isolation distance, etc. In a crop such as pigeonpea, this situation invariably leads to a certain degree of out-crossing with neighboring local cultivars. Therefore, such uncontrolled

Figure 17. Selfing of plants inside nylon net.

dissemination of seed results in rapid deterioration of a cultivar and undermines the breeding objectives for which it was bred.

7.1 Classes of quality seeds

Based on the extent of genetic purity, quality seed production has been divided into different seed categories (Diagram 1) and their seed production technology has been adequately developed. Their brief description is given below:

Nucleus Seed: It is the purest form of seed lot of a given variety. This seed is always maintained by the originating plant breeder or institute. Nucleus seed matches well in all the morphological parameters listed in the variety release document. In each cycle of regeneration, the population is critically monitored for its variety traits. In general, the available quantity of this group of seed is always limited. This seed is used to produce Breeders' seed.

Breeder Seed: It is also produced with high quality seed control standards under the direct supervision of the breeder or institute who developed the variety. The planting materials for Breeder seed production are obtained from nucleus

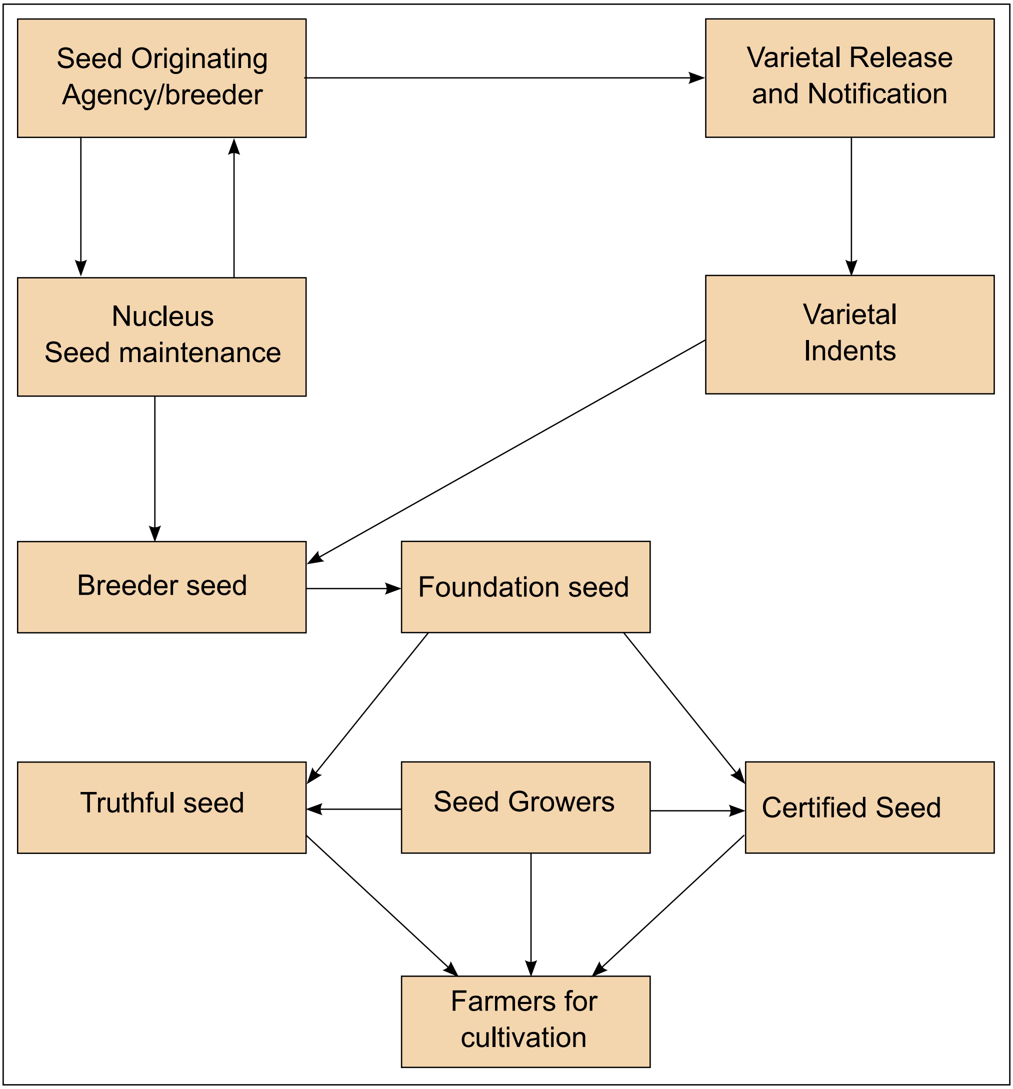

Diagram 1. Different seed grades.

seed. The Breeders' seed crop is grown in isolation with the recommended package of practices. Periodic inspection of Breeders' seed production plot, both before and after flowering, is essential, and all the off-type plants are removed as soon as they are identified. Adequate measures are taken to avoid mechanical mixtures during various operations such as harvesting, threshing, cleaning and packing.

Foundation Seed: The direct large-scale progeny of Breeder seed, produced either by the government or private seed agencies, results in the production of Foundation seed. Since yield is an important factor for a profitable seed business, the production of Foundation seed is generally done in its area of adoption. In this class of seed production also, roguing of off-types is exercised before flowering to avoid any out-crossing with the pollen of the off-type plants. If such plants are sighted at a later stage, they should be removed immediately.

Certified Seed: The requirements for Certified seed are always high. The Certified seed is produced from Foundation seed. The national and state seed agencies are primarily responsible for producing Certified seed. In addition, various other seed producing agencies of public or private origin and progressive farmers can also produce Certified seed from the stock of Foundation seed obtained from recognized seed agencies. The Certified seed lots have to meet the specific standards of purity and germination.

Truthfully Labeled Seed: To meet the expanding demand for quality seed of new varieties in India, yet another seed class, called 'Truthfully Labeled Seed', has been created. It is produced by responsible progressive seed growers, capable of maintaining a sufficient level of variety purity by adopting the recommended isolation distance and other seed purity standards. These farmers sell their seed, identified as 'Truthfully Labeled Seed' to other farmers. This option enhances the process of variety adoption. A number of seed companies in India also produce and market such seeds.

7.2. Seed production methods

Community Seed Production: The natural outcrossing is a strong force that can spoil the genetic purity of an adopted cultivar in a short span of two to three years if appropriate seed production guidelines are not followed. At present, pigeonpea is a popular crop in villages and it is very difficult to find large isolated fields to multiply seed of a given variety. To overcome this seed production constraint, a "seed village" concept has evolved over a period of time where all the pigeonpea growing farmers are persuaded to grow only one variety, and their produce may be purchased by any voluntary organization or sold by the farmers themselves. To achieve this, it is, however, essential that all the farmers in a village are well organized and provided with good quality seed for sowing.

Seed Production by farmers: If the farmers aim to sell their produce as seed, a lot of care should be taken to avoid contamination due to out-crossing or mechanical mixing. Unfortunately, in most cases it does not happen and quality continues to deteriorate season after season. In spite of the poor quality of seed, its exchange among farmers will continue to remain in practice. It is, therefore, essential to salvage the situation. To achieve this, the farmers should be educated to follow simple procedures of maintaining seed purity at farm level. Pigeonpea, being a partially out-crossing crop, requires extra precautions to maintain variety purity. Some of the important steps that would help to maintain variety purity and minimize the contamination of farmers' seed are listed below:

- always purchase good quality seed from a reliable source
- avoid delayed sowings as it may produce less yield and poor quality seed
- select a field in which pigeonpea was not sown in the previous season
- seed production plots should be isolated from other pigeonpea cultivars by at least 200 m
- remove all off-type and late flowering plants as soon as they are spotted
- prevent mechanical mixing and physical injury to seeds
- soon after threshing and cleaning remove off-colored and small and over sized seeds
- sun dry the seed for a few days to bring the seed moisture level to 9.0%
- treat the seed with fungicides and pack it in small polyethylene bags for storage and distribution
- farmers should be advised to refrain from selling their seed if its quality is visibly inferior.

8. Commercial Processing of Vegetable Pigeonpea

Commercial vegetable pigeonpea is commonly processed into canned or frozen peas. Among the countries involved in commercialization of vegetable pigeonpea, Dominican Republic stands on the top where commercial pigeonpea are produced for export to the United States and other countries. The literature on various aspects of processing technologies is scanty and the author could access only one good paper written by Mansfield (1981), who gave details of processing of vegetable pigeonpea technology. This portion of the review is primarily abstracted from this publication and reproduced below:

The steps followed in canning and freezing procedures of vegetable pigeonpea are summarized in Diagram 2.

Step 1. Vining

The harvested green pods should be shelled as quickly as possible to maintain their freshness. This will not only avoid fermenting but also provide necessary oxygen to maintain the quality of pods. Vining (shelling) of small lots of pods is usually done manually and the shelled peas are generally sold in small local markets either as fresh or frozen peas. The bigger lots are used for commercial canning and for this the vining is performed mechanically (Fig.18). Most commercial canners feed the fresh green pods directly into the vining machine while some processors give a pre-heat treatment to pods for producing better pea yields and clear brine of high quality.

Figure 18. Shelling of green peas by machine in China.

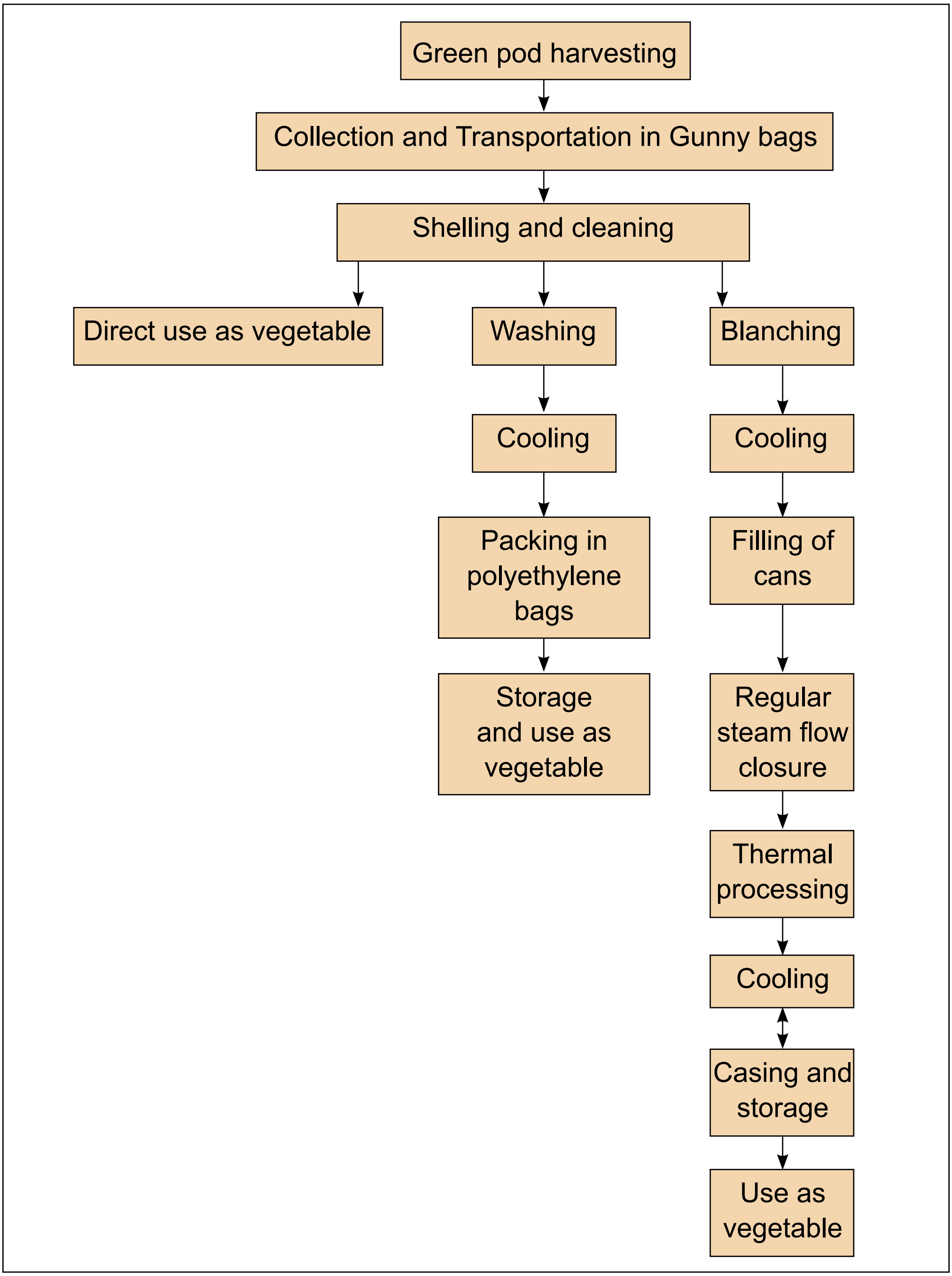

Diagram 2: Processing procedures of vegetable pigeonpeas

Step 2. Cleaning of shelled peas

For local markets, the shelled peas are washed and then cleaning operation is carried out to remove unwanted peas and other inert materials. The mechanically vined peas are cleaned soon after shelling. For this purpose the shelled peas directly fall on to conveyors for cleaning and washing. The dry cleaning operation is performed by passing the shelled peas through an air blast, which helps in removing small pieces of pods or vine, dust, etc. The cleaned lot passes through a mesh screen that allows the peas to drop through it but retains large size peas and extraneous materials. Subsequently, the product passes through a fine mesh that retains shelled peas but removes fine dirt and splits. This dry cleaning operation is followed by washing for removing the floating dirt, skins, split peas and worms. The washing is carried out more than once in various types of flotation washers with cold running water. After washing, the shelled peas are forced to pass through rotary rod washers where splits, undersize, and mashed peas are separated. The washed peas fall on a belt where off-colored and remaining worm-damaged and broken peas are removed manually for further processing.

Step 3. Blanching

Heat treatment or blanching is an essential treatment for both freezing as well as canning. This helps in stabilizing color and flavor besides improving the texture of seeds. According to Mansfield (1981), the blanching operation also helps in obtaining clear brine by discarding mucous substances, starch particles and inter-cellular gases. The best blanching is done by heating the peas to 185^{o} F for five minutes in hot water followed by cooling in cold (80^{o}F) water (Sanchez Nieva et al. 1961). Melmick et al. (1944) showed that steam is excellent in preserving nutrients of fresh peas but this process is not cost effective.

After the above mentioned series of treatments, the processed peas could be used either for canning or freezing. These two follow-up treatments are summarized below:

Step 4(a). Freezing of vegetable pigeonpea

According to Mansfield (1981), the following two methods of freezing peas are used in Dominican Republic. In the automated system, the peas are cooled in water with ambient temperature soon after blanching and then taken to a fluidized bed freezer. In this freezer, operating between -10°F and -20°F, the peas are quick-frozen individually while moving inside a vibrating conveyor screen that receives a rapid moving current of cold air from the lower side. The frozen peas are then hand-picked in wax treated cartons. These cartons are stored at 0°F. In the alternative batch freezing system, a blast freezer is used for small quantities of shelled peas. In this system the blanched peas are dropped in cold water tanks and then the peas are hand picked in polyethylene bags and placed for freezing in a batch freezer between -2°F and -10°F for 4 to 10 hours. These packets are stored at 0°F.

Step 4(b). Canning of vegetable pigeonpea

For canning (Rodrigues et al. 1961), the blanched peas are taken to a volumetric filler through an elevator. Here the cans are filled with peas and 2% brine at near-boiling (195 - 200°F) temperature. No additives are used for canning (Mansfield 1981). For closing the cans, if a near-boiling brine is maintained, then the exhaust or steam closure is not done. This follows a thermal processing to check the growth of any thermophilic bacterium. After the thermal processing, the cans must be cooled immediately to reduce the thermal quality losses by putting the cans in cool water ponds to bring down their temperature to 90 - 105°F (Fig.19).

Figure 19. Canned vegetable pigeonpea on the shelf of a supermarket in the USA.

9. Marketing of Vegetable Pigeonpea

According to Mansfield (1981), the growth for pigeonpea cultivation in the Dominican Republic has been due to the impulse given by canning plants from Puerto Rico. The green pigeonpea pods are collected from the farm gate by the representatives of canning plants. The processed cans are sold to wholesalers for export to the United States, Puerto Rico and other Latin American and European markets. In India, small local markets (Fig.20) in some states sell fresh vegetable pigeonpea. Currently, the supply of vegetable pigeonpea is by and large seasonal, and is affected by demand and growing conditions in various environments.

Figure 20. Vegetable vendor selling green pigeonpea in India.

10. Conclusions

The importance of vegetables in human diet is well accepted. Vegetables are good sources of valuable proteins, vitamins, carbohydrates and dietary fiber for humans. Vegetable pigeonpea augurs well in complimenting nutritional profile of the cereals, and is a good source of protein, vitamins (A, C, B complex) and minerals (Ca, Fe, Zn, Cu). Over green peas (*Pisum sativum*), vegetable pigeonpea has manifold advantages. It has more than five times beta carotene content, three times more Thiamine (vitamin B_1), Riboflavin (Vitamin B_2), and Niacin. The ascorbic acid content is more than two times over peas. Similarly, it scores over peas in terms of minerals such as calcium and copper (more than two times higher), and magnesium. Besides all this, the vegetable pigeonpea's shelling percentage is 72% compared to 53% of green peas. Therefore, pigeonpea has potential to become one of the most nutritionally rich vegetables of the daily cuisine, especially for the poor. In areas like Africa, and the Caribbean, vegetable pigeonpea is already a crop of choice.

With seed production technology of elite vegetable pigeonpea lines in place, it should be possible to expand the cultivation of pigeonpea. At ICRISAT, we are in the process of developing vegetable pigeonpea hybrids. Following the success of grain type cytoplasmic male sterility (CMS) system, a targeted hybrid breeding program for vegetable has been initiated. Elite vegetable pigeonpea lines from Africa and India are being introgressed with CMS trait from A_4 cytoplasm to develop locally adapted hybrids. Forward and backward linkages with processing plants and markets will provide additional stimulus to the farmers to take up vegetable pigeonpea cultivation, and help in food and nutritional security of the poor.

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Annexure I. List of vegetable pigeonpea germplasm with >6 seeds pod^{-1}.

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
13973	Central America		Ojo De Bagua; San Jose De Ocoa	145	120	167	7.4	64	6.1	Brown
8503	Central America			155	125	174	8	52.7	6	Brown
6915	Central America			150	130	195			6	Brown
13962	Central America		Ingenio Esperanza; Esperanza	165	139	178	7.8	50	6	Brown
8504	Central America			150	148	192	9.2	84.7	7.2	Brown
6926	Central America			240	151	214			6.2	
13255	Eastern Africa		Mamburi; Malindi	215	117	166	10.3	165	6.1	Brown
13253	Eastern Africa		Mamburi; Malindi	215	119	166	11.5	205.7	6.5	Brown
13257	Eastern Africa		Kaembein; Malindi	220	119	166	9.5	122.3	6.4	Brown
13258	Eastern Africa		Kaembein; Malindi	225	121	166	11.6	140.3	6.7	Brown
13256	Eastern Africa		Mamburi; Malindi	200	124	166	11.5	257	6.6	Brown
13262	Eastern Africa		Kwale; Kwale	260	136	184	8.6	126.7	6	Brown
12046	Eastern Africa		Ikwiriri; Rufigi	205	146	221	9.5	90	6.2	Brown
12041	Eastern Africa		Mpangutena; Lindi	225	152	224	8.2	162.7	6	Brown
12037	Eastern Africa		Mangamba; Mtwara	220	156	224	10	138.7	6.5	Brown
12068	Eastern Africa		Kwasunga; Korogwe	170	160	224	8.3	48	6.2	Brown
9159	Eastern Africa	Eastern	Majani; Machakos	265	161	250	7.4	95.7	6.3	Brown

Continued

Annexure I *continued*

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
13225	Eastern Africa		Gitambangi; Kitui	130	166	218	9.5	73.7	6.1	Purple; Light brown
12161	Eastern Africa		Ilonga Farm; Kilosa	240	173	244	9.5	145	6.2	Brown
7265	South America			180	154	230			6.1	Orange
6523	South Asia	Andhra Pradesh		180	119	213	9	204.3	6	Brown
3099	South Asia	Andhra Pradesh		230	124	195			7.2	Reddish brown; Brown
8914	South Asia	Gujarat	Wataria; Baruch	185	135	194	3.4	243.7	6.1	Brown
7896	South Asia	Karnataka	Hanumandoddi; Mandya	200	139	202	4.5	201.7	7	Brown
7897	South Asia	Karnataka	Kalamuddanadoddi; Mandya	215	139	204	4.8	260	6.5	Brown
8543	South Asia	Orissa	Tikri; Koraput	195	144	197		153	6	Brown
8692	South Asia	Uttar Pradesh	Laxmanpur; Gonda	200	165	241	6.5	289.3	6.5	Brown
8693	South Asia	Uttar Pradesh	Babapuruva; Gonda	196	175	241	6.5	254.7	6.5	Brown
12771	Southeast Asia		Baras; Rizal	210	201	253	8.9	112.3	6.5	Brown
12765	Southeast Asia	Illocos Sur	Tampugo; Tagudin	220	219	264	8.4	128.3	6.9	Purple
12844	Southern Africa	Nampula	Mulessari	205	119	163	8.2	124	6.1	Brown

Annexure II. List of vegetable pigeonpea germplasm with 5.0 to 5.9 seeds pod^{-1}.

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
15136	Central Africa			200	166	232	7.1	91.7	5.4	Brown
15137	Central Africa			200	159	220	11	130	5.6	Brown
15138	Central Africa			210	160	232	7	84.3	5.6	Brown
15142	Central Africa			230	141	215	9.2	74.3	5.6	Brown
6917	Central America			105	106	177			5.5	Brown
6933	Central America			110	133	220			5.4	Brown
7210	Central America		Rio Piedras	85	112	199			5.4	Brown
7211	Central America		Rio Piedras	98	112	170			5.7	Brown
7261	Central America		Rio Piedras	185	154	230			5.8	Orange
13553	Central America			195	131	188	7.1	160.7	5.4	Brown
13766	Central America		California Couva	150	160	225	8	63.3	5.4	Brown
13763	Central America		St. Machel's road	150	139	178	8.4	62.7	5.6	Brown
13734	Central America		Guaco; La Vega	145	141	183	11.5	52	5.6	Brown
13778	Central America		Upper Canapo	175	153	225	7.6	56.7	5.6	Brown
13740	Central America		Hacienda Dondacion; San Christo	200	160	237	8.1	18.7	5.6	Brown
13755	Central America		El Dorado; Takarikua	160	134	181	8.3	127.3	5.5	Brown
13774	Central America		Couva Highway	150	141	185	7.3	56.7	5.4	Brown
13828	Central America		St. Patricks	130	129	174	11.1	49.7	5.7	Brown

Continued

Annexure II *continued*

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
13831	Central America		Grenada	150	139	178	11.2	50.3	5.6	Brown
13846	Central America		St. Machael	160	141	183	8.6	53	5.7	Brown
13852	Central America		St. Thomas	170	139	178	7.1	80	5.4	Brown
13961	Central America		Ingenio Esperanza; Esperanza	160	136	178	10	65.3	5.9	Brown
13965	Central America		Guaco; La Vega	170	141	206	7	90.7	5.5	Brown
14130	Central America			190	150	202	7	74.3	5.6	Brown
9151	Eastern Africa	Eastern	Makueni; Machakos	220	178	252	9	38.7	5.4	Brown
9157	Eastern Africa	Eastern	Ukia; Machakos	245	173	252	8.8	67.3	5.4	Brown
9162	Eastern Africa	Coastal	Diana; Kwale	165	131	182	9.2	117.3	5.4	Brown
9163	Eastern Africa	Coastal	Tezo; Kilifi	150	131	182	7.2	97.3	5.8	Brown
9189	Eastern Africa	Rift Valley	Kibigori, Kisumu	195	165	220	7.5	39	5.5	Brown
12005	Eastern Africa		Madoto; Kilosa	210	169	232	7.1	125	5.4	Brown
12006	Eastern Africa		Madoto; Kilosa	170	173	224	8.6	54.3	5.4	Brown
12007	Eastern Africa		Mwamogo; Kilosa	190	179	232	7	88	5.7	Brown
12009	Eastern Africa		Ifunda; Iringa	160	155	215	8.3	87.7	5.4	Brown
12011	Eastern Africa		Mbuyuni; Mbeya	165	179	235	7.6	42.7	5.4	Brown
12034	Eastern Africa		Chanikanguo; Masassi	180	156	224	8.2	163	5.8	Brown

Continued

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
12035	Eastern Africa		Lundehunde; Mtwara	190	152	222	8.7	110.7	5.8	Brown
12019	Eastern Africa		Sisikwasisi; Tunduru	180	146	222	7.5	155	5.6	Brown
12015	Eastern Africa		Kilimasela; Songea	195	152	224	8.6	101.3	5.7	Brown
12028	Eastern Africa		Chikunja; Masassi	210	146	224	9.4	69.3	5.6	Brown
12031	Eastern Africa		Tameki; Masassi	230	149	222	8.5	131.3	5.6	Brown
12029	Eastern Africa		Tameki; Masassi			218	8.4	99	5.7	Brown
12045	Eastern Africa		Metaga; Kilwa	195	152	218	8.4	132.3	5.5	Brown
12040	Eastern Africa		Ndumbwe; Mtwara	190	154	218	8.4	161.3	5.6	Brown
12044	Eastern Africa		Ngongonda; Kilwa	205	152	224	7.5	133	5.6	Brown
12051	Eastern Africa		Miembesaba; Kibaha	200	165	224	8.5	77	5.7	Brown
12053	Eastern Africa		Mazizi; Bagamoyo	180	156	224	7.6	69	5.5	Brown
12055	Eastern Africa		Msata; Bagamoyo	230	146	218	7.8	56	5.9	Brown
12059	Eastern Africa		Msata; Bagamoyo	205	154	221	7.4	72	5.4	Purple; Brown
12067	Eastern Africa		Kwasunga; Korogwe	160	179	238	6.4	17.7	5.9	Brown
12075	Eastern Africa		Mijungu; Hanang	190	158	224	7.6	106.3	5.5	Brown
12087	Eastern Africa		Masavi; Kondoa	250	186	238	9.1	51	5.5	Brown

Continued

Annexure II *continued*

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
12090	Eastern Africa		Kolo; Kondoa	220	175	232	8	66.7	5.5	Brown
12114	Eastern Africa		Miyugi; Dodoma	260	173	238	7	161.3	5.6	Purple; Brown
12138	Eastern Africa		Makambini; Kilosa	195	182	238	8.4	90.3	5.5	Brown
12139	Eastern Africa		Makambini; Kilosa	180	179	238	6.9	70	5.7	Brown
12142	Eastern Africa		Dumila; Kilosa	250	179	232	8.7	160.7	5.4	None
12144	Eastern Africa		Dumila; Kilosa	250	179	232	6.3	79.3	5.4	Purple
12151	Eastern Africa		Madoto; Kilosa	210	175	232	8.6	207	5.8	Brown
12162	Eastern Africa		Madoto; Kilosa	220	169	232	8.4	110.7	5.8	None
12165	Eastern Africa		Near Dar Es Salam; Dar Es Salam	185	158	210	8.3	74.7	5.4	Brown
12164	Eastern Africa		Kongowe; Kibaha	150	165	224	7.5	149	5.5	Brown
12780	Eastern Africa		Mwaya-1; Kilosa	225	149	218	9.5	125.3	5.5	None
12793	Eastern Africa		Kijitonyama; Kinondoni	240	173	253	8.7	81.7	5.5	Brown
12799	Eastern Africa		Kwedizinga; Handeni	210	149	215	8.7	92.7	5.9	Brown
12806	Eastern Africa		Serya; Kondoa	220	161	237	7.6	92.3	5.4	Brown
12808	Eastern Africa		Bicha; Kondoa	235	182	253	7.3	104.7	5.8	Brown
12813	Eastern Africa		Manakiyanga; Mpwapwa	250	168	222	5.6	83.3	5.9	Brown

Continued

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
12818	Eastern Africa		Madoto; Kilosa	210	159	218	8.6	155.3	5.6	Brown
12819	Eastern Africa		Madoto; Kilosa	260	156	222	9.1	118.7	5.4	Brown
13103	Eastern Africa		Kilungu; Machakos	260	182	253	8.5	30.3	5.4	Brown
13091	Eastern Africa		Kagio; Kirinyaga	235	177	237	9.4	48.7	5.5	Brown
13107	Eastern Africa		Chamoli; Machakos	240	177	253	8.8	90.7	5.4	Brown
13112	Eastern Africa		Kibwezi; Machakos	230	180	237	8.2	30.3	5.4	Brown
13114	Eastern Africa		Kambo; Machakos	195	207	270	7.8	30.3	5.8	Brown
13126	Eastern Africa		Mumoni; Machakos	240	190	260	7.1	51.7	5.4	Brown
13145	Eastern Africa		Kwajend; Machakos	260	190	253	8.6	36.7	5.4	Brown
13162	Eastern Africa		Wee; Machakos	250	184	253	8	40	5.4	Brown
13175	Eastern Africa		Kyanguli; Machakos	235	180	253	8.1	64	5.6	Brown
13183	Eastern Africa		Utangwa; Machakos	240	180	253	6.9	51	5.5	Brown
13228	Eastern Africa		Kyatumi; Kitui	230	156	226	9	54.3	5.4	Brown
13229	Eastern Africa	Kituri	Kinakoni	160	192	258	8.2	51	5.8	Brown
13241	Eastern Africa		Kagio; Kirinyaga	250	182	253	9.4	66	5.6	Brown
13266	Eastern Africa		Vuga; Kwale	240	140	253	8.1	66.3	5.4	Brown
13267	Eastern Africa		Kobani; Kwale	135	154	222	9.2	56.3	5.8	Brown

Continued

Annexure II *continued*

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
13249	Eastern Africa		N. Gumani; Kilifi	225	137	226	9.2	204.3	5.7	Dark purple; Brown
13254	Eastern Africa		Mamburi; Malindi	205	129	184	8.1	246	5.4	Brown
13259	Eastern Africa		Magarina; Kilifi	125	168	222	8.4	63.7	5.8	Brown; Dark purple
13270	Eastern Africa		Kobani; Kwale	110	159	222	7.5	53	5.6	Brown
13271	Eastern Africa		Waa; Kwale	95	151	222	9	44.3	5.4	Brown
13277	Eastern Africa		Matiliku; Machakos	190	229	278	7.8	53	5.4	Brown
13593	Eastern Africa	Kituri	Kinakoni	200	170	237	9.1	67.7	5.4	Brown
13599	Eastern Africa	Eastern	Makueni; Machakos	215	185	260	7.1	46	5.6	Brown
13610	Eastern Africa		Kaembein; Malindi	235	145	190	7.6	270.7	5.7	Brown
13611	Eastern Africa		Magarina; Kilifi	240	142	190	6.7	188.3	5.9	Brown
13612	Eastern Africa		Matuga; Kwale	225	131	188	7.9	232.3	5.5	Brown
13613	Eastern Africa		Pungu; Mombasa	225	145	202	8.4	110.7	5.6	Brown
13615	Eastern Africa		Muusini; Machakos	235	187	260	6.1	74.7	5.6	Brown
13618	Eastern Africa		Kilili; Machakos	250	190	253	7.3	406.7	5.7	Brown
13624	Eastern Africa	Shewa	Wachigabusha; Sodozuria	220	208	260	7.9	56.7	5.7	Brown
13625	Eastern Africa	Shewa	Bosa; Ofa	210	212	260	6.6	50.7	5.6	Brown
13628	Eastern Africa	Shewa	Tebela; Humbo	250	201	260	8.1	26	5.5	Brown
13632	Eastern Africa	Hararge	Belberrti; Habro	260	190	260	7.2	28	5.4	Brown

Continued

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
14291	Eastern Africa			270	196	245	5.4	35	5.4	Brown
15100	Eastern Africa			200	166	226	7.5	89.3	5.6	Brown
15490	Eastern Africa			210	189	235	7.3	67	5.6	Brown
15497	Eastern Africa		Kalamba; Mubende	180	176	235	8	73.3	5.7	Brown
15511	Eastern Africa		Kirika; Mbale	160	159	215	9.1	167.3	5.4	Brown
15512	Eastern Africa		Kchekasula; Kumi	220	159	220	10	110.3	5.8	Brown
15530	Eastern Africa		Kadagada; Kiboga	210	182	228	8	91.7	5.6	Brown
15519	Eastern Africa		Kyakayaga; Masiroli	240	184	225	10.3	183	5.4	Brown
15523	Eastern Africa		Bulindi; Hoima	190	161	215	7	180.7	5.8	Brown
15525	Eastern Africa		Rwebusiriiza; Kiboga	180	159	215	8	107	5.4	Dark purple; Brown
15528	Eastern Africa		Masooli; Shiboga	190	182	225	8.5	107.7	5.4	Brown
15531	Eastern Africa		Kadagada; Kiboga	190	170	215	8	77	5.6	Brown
15532	Eastern Africa		Bukunda; Masaka	190	195	235	9.5	155.7	5.8	Brown
12846	Europe			210	174	237			5.4	Brown
15134	Europe			260	156	220	9	137.7	5.8	Brown
7266	South America			120	154	230			5.7	Orange
9107	South America			175	153	208	5.2	420	5.7	Brown
9112	South America			165	142	196			5.6	Brown
14077	South America			170	132	182	9.4	122	5.7	Brown

Continued

Annexure II *continued*

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
14074	South America			180	147	184	7.6	56	5.5	Brown
14062	South America			180	132	184	10.1	67.7	5.4	Brown
14094	South America			230	153	216	9.5	80.7	5.7	Brown
14104	South America			170	142	182	11.2	87.7	5.7	Brown
14146	South America		Central Brazil	130	142	193	8.1	54	5.8	None
14147	South America		Central Brazil	140	150	212	7.1	27.3	5.6	Brown
14148	South America		Central Brazil	100	158	212	8.9	29	5.4	Brown
14372	South America			285	155	198	8.2	66	5.6	Brown
14307	South America			230	143	198	8.4	137.3	5.6	Brown
14383	South America			265	147	198	8.1	106	5.4	Brown
14387	South America			210	154	220			5.6	Brown
7889	South Asia	Karnataka	Maisandra; Kolar	225	134	199	3.2	322.7	5.5	None
7867	South Asia	Karnataka	Logondanahalli; Bangalore	205	158	216	8	324	5.6	Brown
7719	South Asia	Uttar Pradesh		152	102	153	3.8	487.7	5.6	Brown
7898	South Asia	Karnataka	Chikka Bagil; Mysore	183	130	185	4.5	473.3	5.5	Brown
7893	South Asia	Karnataka	Hachchapalli; Bangalore	210	135	206	7	170	5.5	Brown
7899	South Asia	Karnataka	Putgana Halli; Mysore	190	134	199	4	328.3	5.5	Brown

Continued

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
7901	South Asia	Karnataka	Errahalli; Hassan	170	128	187	3.4	591	5.5	Brown
7903	South Asia	Karnataka	Thanneerhalla; Hassan	170	134	197	3.6	533	5.4	Brown
7916	South Asia	Karnataka	Hippalgaon; Bidar	180	116	166	3.3	338	5.5	Brown
7925	South Asia	Karnataka	Yaranal; Bijapur	175	120	160	3.4	414.3	5.5	Brown
7926	South Asia	Karnataka	Dhavalgi; Bijapur	171	123	185	3.4	330.7	5.5	Brown
7991	South Asia	Orissa	Bisamcuttak; Koraput	210	132	188	7.3	202.3	5.4	Brown
8535	South Asia	Andhra Pradesh	Chintapalli; Vishakhapatnam	145	112	151	5	277.3	5.5	Brown
8695	South Asia	Uttar Pradesh	Jalalpur; Faizabad	168	158	235	5.4	420.7	5.4	Brown
9607	South Asia	Andhra Pradesh		170	126	163	4.5	410.7	5.6	
9624	South Asia	Andhra Pradesh		190	126	165	5.5	55	5.6	Brown
9639	South Asia	Andhra Pradesh		175	130	178	5.3	830	5.5	Brown
10002	South Asia	Kerala	Kumali 74N; Kottayam	165	150	194	6.7	64.7	5.6	Brown
10003	South Asia	Kerala	Kumali 17N; Idukki	180	153	202	5.9	166.7	5.5	Brown
12262	South Asia	Uttar Pradesh		165	144	204	5.7	329.3	5.7	Brown

Continued

Annexure II *continued*

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
12747	South Asia	Andhra Pradesh	ICRISAT, Patancheru	215	129	177	8.1	196	5.8	Dark purple
14422	South Asia	Andhra Pradesh	ICRISAT, Patancheru	85	80	133	7.6	111.7	5.5	Brown
14424	South Asia	Andhra Pradesh	ICRISAT, Patancheru	105	86	160	7.7	131	5.4	Brown
14738	South Asia	Andhra Pradesh	ICRISAT, Patancheru	130	81	147	9.4	174	5.6	Brown
14993	South Asia	Andhra Pradesh	ICRISAT, Patancheru	110	85	127	6.6	177.7	5.4	Brown
15149	South Asia	Andhra Pradesh		140	88	145	8.5	78.3	5.8	Brown
15176	South Asia	Andhra Pradesh	ICRISAT, Patancheru	200	141	215	7.5	163	5.4	Brown
15195	South Asia	Andhra Pradesh	ICRISAT, Patancheru	210	132	194	8.5	71.5	5.7	Brown
16172	South Asia	Andhra Pradesh	ICRISAT, Patancheru	110	86	138	8.5	87	5.8	Brown
10880	Southeast Asia			160	179	224	9.1	42	5.9	Purple
12766	Southeast Asia		Bauang Sanfernado; La Union	170	190	264	7.6	65.7	5.7	Purple
12772	Southeast Asia		Kawayan; Quezon	210	212	253	9.1	137	5.9	Brown

Continued

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
12775	Southeast Asia		Malatap Labo; Camarinenorte	180	190	260	7.2	75.7	5.9	Brown
13639	Southeast Asia		Station Dinas Pertanian; Baturi	195	139	190	5.3	118.7	5.7	Dark purple
14163	Southeast Asia		Near Soe; Timur	140	160	212	6.5	24.7	5.9	Purple
14865	Southeast Asia		Bodak; Praya; Lombok Tengah	170	160	204	9	193	5.5	None
14973	Southeast Asia		Chandikuning; Baturiti; Tabanan	210	134	190	11	93.7	5.4	Purple
11443	Southern Africa		Makande	210	186	243	8.5	142.3	5.4	Brown
11466	Southern Africa			190	167	235	4.8	50	5.5	Brown
12838	Southern Africa		Rombe	195	131	184	10.2	153.7	5.9	Brown
12841	Southern Africa		Cellula No Juanoula	210	117	163	7.5	267	5.6	Brown
12842	Southern Africa		Mucubela	205	121	163	8.3	137.7	5.8	Brown
13343	Southern Africa		Kantimbanya; Blantyre	210	187	260	8.4	69.7	5.9	Brown
13424	Southern Africa		Zomba	210	180	253	8.7	85.7	5.4	Brown
13438	Southern Africa			230	194	260	8.6	69.3	5.5	Brown
13440	Southern Africa			260	187	260	11.1	37.3	5.4	Brown
13459	Southern Africa			235	159	253	7.4	56.7	5.8	Brown
13468	Southern Africa			230	159	237	8.4	59	5.4	Brown

Continued

Annexure II *continued*

ICP No.	Region	Province	Location	Plant height (cm)	Days to flowering	Days to maturity	Pod length (cm)	Pod number	Seeds per pod	Seed eye color
13482	Southern Africa			190	177	253	10.7	129	5.4	Brown
13516	Southern Africa			230	152	226	8.5	33.3	5.5	Purple
13645	Southern Africa	Transvall	Duivelskloof 12N	250	187	260	8.5	73.3	5.5	Brown
14270	Southern Africa			185	134	182	10.1	98.3	5.4	Brown
15553	Southern Africa			210	168	220	9	148.7	5.4	Brown
9120	West Africa			170	142	194	8.1	152.7	5.5	Brown
13633	West Africa			250	156	218	7	125.7	5.4	Brown
15333	West Africa	Kaduna	Kagoro; Lere; Zonkwa	190	156	201	8.2	77.3	5.4	Brown
15339	West Africa	Kaduna	Kpak; Kagoro	210	156	201	8	140.7	5.4	Brown
15386	West Africa	Enugu		190	149	195	7	245.7	5.4	Brown
15416	West Africa	Kaduna		210	147	201	8.3	131.3	5.4	Brown
15417	West Africa	Kaduna		230	152	201	8	95	5.6	Brown
15423	West Africa	Niger		190	147	198	8.5	76	5.4	Brown
15428	West Africa	Kogi		200	152	204	8.5	67	5.6	Brown
15431	West Africa	Kogi		180	149	201	8.5	232.3	5.5	Brown
15449	West Africa		North bank; Makundi; Benue	170	156	210	6.4	140.3	5.4	Brown
15452	West Africa		Taratu; Alaide; Benue	200	152	201	8.3	137	5.5	Brown
15460	West Africa		Iduje; Okehi; Kogi	200	149	198	10	140.7	5.4	Brown

About ICRISAT

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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