

BOTANICAL DESCRIPTION

Family :Leguminoceae

sub-family :Papilionoideae

:Fabaceae

Common Name :Soyabean

Scientific Name : *Glycine max-Linn*

Origin:

- Domestication of soybean has been traced to the eastern half of North China in the eleventh century B.C. or perhaps a bit earlier soybean production was localized in China until after the Chinese-Japanese war of 1894-95.



Package of practices for Soyabean

- Globally legumes play vital role in human nutrition since they are rich source of protein, calories, certain minerals and vitamins. Among which soybean is probably the largest source of vegetable seed oil (20%) and protein (40%). Owing the nutritional and health benefits of soybean. It excited the growers in recent years. US, Argentina, Brazil and China claims as *the* biggest producers of this supercrop, the modern technologies and changes in their agronomic practices is worth to discuss on its possibility in Indian scenario.

SEASON AND CLIMATE

- Two cropping seasons of soybean kharif and spring.
- It is self pollinated crop.
- In case of kharif season most common time of sowing is onset of monsoon or last week of June to first week of July while spring sowing is done between 15th of February and 15th of March.
- Soybean has been adopted under wide range of climate and soil with better performance under Vertisols with good organic content.
- The crop requires about 60-65 cm annual rainfall drought at flowering or just before flowering results in flower and pod drops, while rains during maturity impairs the grain quality of soybean harmful.

CROP DESCRIPTION

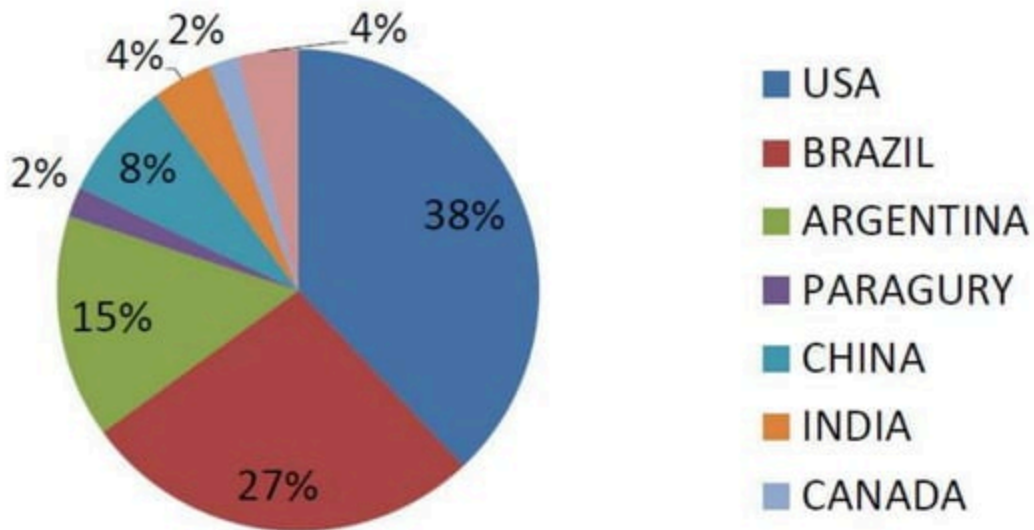
- Despite being rich source of protein, it is categorized as an oilseeds rather than a pulse crop.
- Oil contents varies from 15 to 21 % in soybean seeds.
- Crop generally reach a height of around 1 m (3.3 ft).
- Capable of transforming nearly 60-100 kg atmospheric nitrogen into 30-40 kg nitrogen in the soil.

GLOBAL SCENARIO OF SOYBEAN (2013-2016)

Country	Avg. Area (lakh ha)	Avg. Production (lakh tonnes)	Avg. Yield (Kg/ha)
USA	324.01	1010.74	3119
Brazil	310.22	918.00	2959
Argentina	194.30	558.35	2874
China	68.33	120.83	1768
India*	114.92	103.27	899
Paraguay	32.00	87.45	2733
Canada	20.87	58.29	2794
Ukraine	17.64	35.35	2004
Uruguay	11.77	28.30	2405
Russia	17.38	22.35	1286
Others	54.24	98.32	1813
World	1164.84	3030.62	2602

Source: FAO/USDA. *As per the estimates of DES, DAC&FW

Top Producer Of Soya Bean in the World

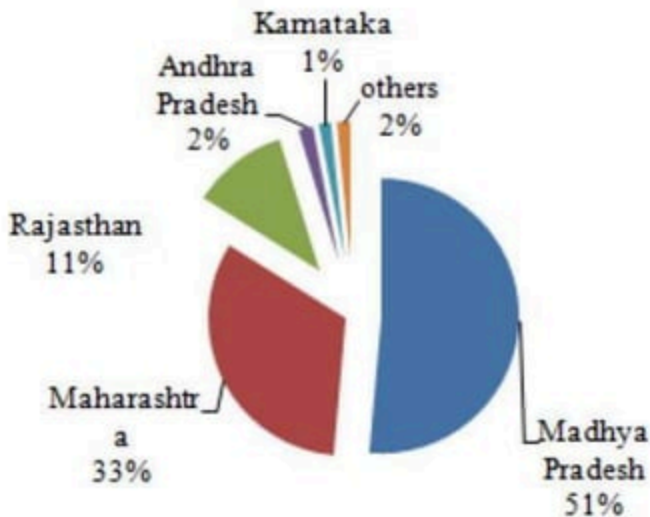


NATIONAL SOYBEAN SCENARIO (2013-16)

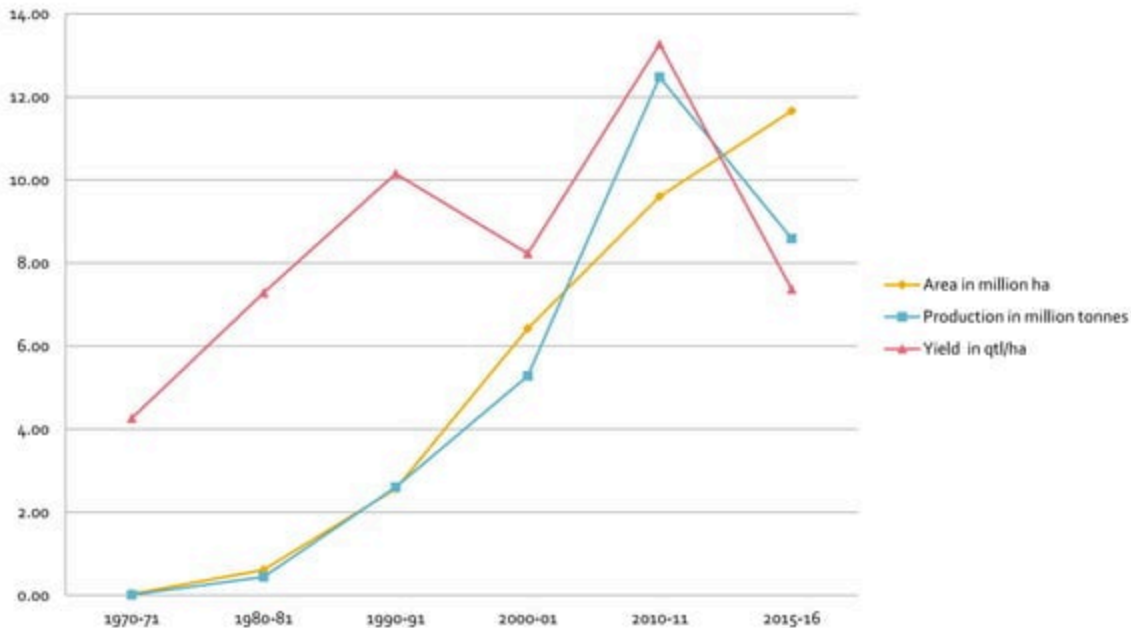
State	Avg. Area (lakh ha)	Avg. Production (lakh tonnes)	Avg. Yield (Kg/ha)
MP	59.32	54.99	927
Maharashtra	37.05	31.14	840
Rajasthan	11.02	9.76	886
Telangana	2.42	2.56	1058
Karnataka	2.41	2.12	880
Others	3.58	3.56	993
All India	114.92	103.27	899

Top Producer Of Soya Bean in the India

Major producing states



AREA, PRODUCTION AND YIELD TRENDS OF SOYBEAN IN INDIA



POTENTIAL DISTRICTS (60) OF SOYBEAN

State	Potential district (>50,000 ha area)
Madhya Pradesh (30)	Ujjain, Sehore, Dewas, Dhar, Shajapur, Sagar, Vidisha, Harda, Indore, Rajgarh, Chhindwara, Betul, Mandsaur, Hoshangabad, Guna, Ratlam, Raisen, Bhopal, Narsingpur, Shivpuri, Seoni, Neemuch, Khandwa, Ashoknagar, Damoh, Tikamgarh, Jhabua, Khargone, Satna, Chhatarpur
Maharashtra (20)	Amravati, Nagpur, Latur, Buldhana, Yavatmal, Nanded, Washim, Hingoli, Akola, Wardha, Kolhapur, Chandrapur, Sangli, Parbhani, Nasik, Satara, Ahemdnagar, Jalna, Beed, Osmanabad
Rajasthan (5)	Jhalawar, Baran, Pratapgadh, Kota, Bundi
Chhattisgarh (1)	Rajnandgaon
Karnataka(2)	Belgaum, Bidar
Telangana (2)	Adilabad, Nizamabad

Soil for soybean cultivation

- Well drained and fertile loam soils with a pH between 6.0 and 7.5 are most suitable for the cultivation of soybean.
- Sodic and saline soils inhibit germination of seeds.
- Water logging is also injurious to the crop.

Field Preparation

- Deep summer ploughing once in 2-3 years or one normal summer ploughing followed by 2-3 cross harrowing or cultivation for ideal seed bed of good tilth for soybean crop.

There should be optimum moisture in the field at the time of sowing.



Sowing of soyabean

- The sowing should be done in lines 45 to 60 cm apart with the help of seed drill or behind the plough.
- Plant to plant distance should be 4-5 cm. The depth of sowing should not be more than 3-4 cm under optimum moisture conditions.
- Seed rate of soybean depends upon germination percentage, seed size and sowing time.

POPULAR VARIETIES OF SOYBEAN

S.No.	State	Varieties
1	MP	JS-95-60, JS-97-52, JS-93-05, JS-335, MACS-1188, MACS-1281, NRC-7, , NRC-37, NRC-86
2	Maharashtra	MAUS-81, MAUS-61-2, MACS-450,MACS-1188, MACS-1281, JS-335, KDS-344, RKS-18
3	Rajasthan	RKS-45, JS-335, JS-93-05, JS-95-60
4	Karnataka	MAUS-2, RKS-18, DSb-1, DSb-21, JS-93-05, JS-335
5	Telangana	JS-335

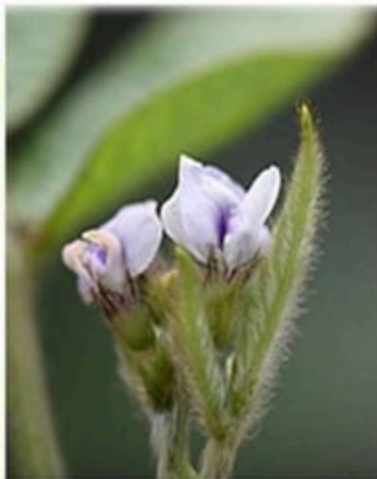
Seed and Sowing

S.No.	Input/practices	Central Zone
(i).	Seed Rate	Bold seeded-80-90Kg/ha Medium seeded-70-75kg/ha Small seeded-55-60 kg/ha
(ii).	Seed treatment	i) Fungicidal/Bio-agent: Thiram 75 WP + Cabendazim 50 WP (2:1) @ 3 g/kg seed or <i>Trichoderma viride</i> @ 4-5 gm/kg seed. ii) Microbial: About 500 g/75 kg seed <i>Bradyrhizobium japonicum</i> culture + PSB/PSM 500 g/ 75 Kg seed
(iii).	Sowing time	Middle of June to Middle of July
(iv).	Spacing (Depending on Sowing time)	30-45 x 5-8 cm
(v).	Depth of sowing	3 to 5 cm
(vi).	Plant population	0.4-0.6 million /ha
2	Storage	Store in moisture proof bags at seed moisture of about 9-10 %.

Growth Stages of Soyabean Crop



Erect



Flowering



Pod Formation

Fertilizer and Nutrient Management

- For obtaining good yields of soybean apply 15-20 tonnes of farm yard manure or compost per hectare.
- An application of 20 kg nitrogen per hectare as a starter dose will be sufficient to meet the nitrogen requirement of the crop in the initial stage in low fertility soils having poor organic matter.
- Soil test is the best guide for the application of potash in the soil. In the absence of soil test, 60 kg CO per hectare should be applied.
- N:P₂O₅: K₂O:S Kg/ha - 20:60: 20: 20

Water Management in soya crop

- The soybean crop generally does not require any irrigation during Kharif season.
- However, if there were a long spell of drought at the time of pod filling, one irrigation would be desirable.
- During excessive rains proper drainage is also equally important.
- Spring crop would require about five to six irrigation.

Weed Management

- Two hand weedings at 21 and 45 DAS or Fluchloralin or Trifluralin @ 1 kg a.i./ha as **pre-plant incorporation** or Alachlor @ 2 kg a.i./ha or Pendimethalin @ 1 kg a.i./ha or Metolachlor @ 1 kg a.i./ha or Clomazone @ 1 kg a.i./ha as **pre-emergence** or Imazethapyr @ 75 to 100 g a.i./ha or quizalofop ethyl @ 50 g a.i./ha as **post-emergence** (15 -20 DAS) in 750 to 800 liters water/ha.

No podding/ Bud proliferation syndrome

- Apply Phorate 10 G @ 10 Kg/ha as soil application followed by spray of either Triazophos 40 EC @ 0.8 l/ha or Ethion 50 EC @ 1.5 l/ha or Methomyl 12.5 L @ 2.0 l/ha or Quinalphos 25 EC @ 1.5 l/ha.

Disease Management

- **For foliar diseases** like Myrothecium, Cercospora leaf spot and Rhizoctonia aerea blight: Two spray of carbendazim 50 WP or thiophanatemethyl 70 WP @ 0.5 kg in 1000 l water/ha at 35 and 50 DAS.
- **For Bacterial pastule:** Spray of Copper oxychloride 2 Kg + Streptocycline 200 g /1000 l water at the appearance of the disease.
- **For the control of Yellow Mosaic :** Spray of thiomethoxam 25 WG @ 100 g/ha or methyl deinaton @ 0.8 l/ha.
- **For rust:** Two to three sprays of hexaconazole or propiconazole or triadimefon or ocycarboxin @ 0.1%. First spray at the time of appearance of rust followed by subsequent sprays at 15 days control. For hot spot areas one prophylectic spray of any of above fungicide at 35 to 40 days after sowing.

SOYBEAN MOSAIC VIRUS

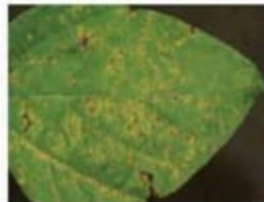


SOYBEAN RUST

CERCOSPORA LEAF SPOT (PURPLE STAIN)



Bacterial Pustule



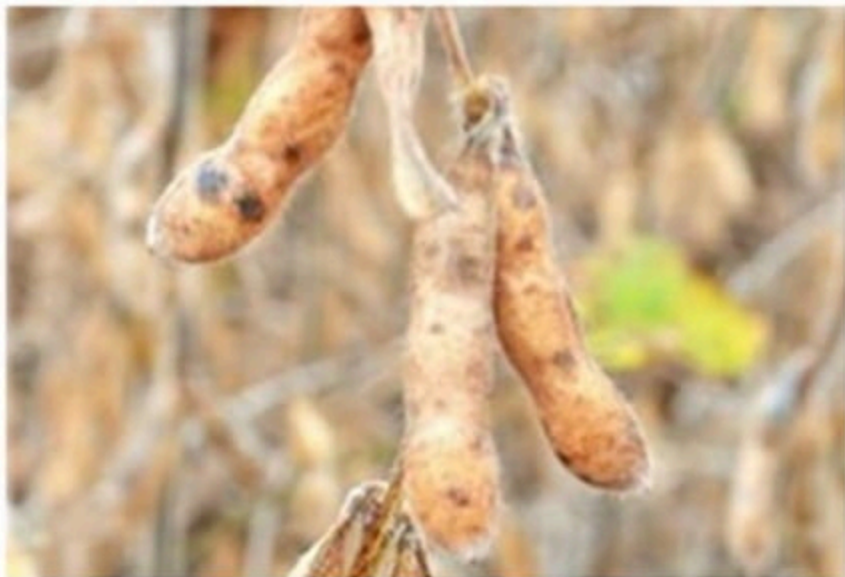
Insect Pest Management

- Furrow application of Phorate 10G @ 10 kg/ha, followed by 1 or 2 sprays of Quinalphos 25 EC (1.5 lit./ha) or Endosulfan 35 EC @ (1.5 lit./ha) or Monocrotophos 36 SC (0.8 lit./ha) or Triazophos 40 EC (0.8 lit./ha) or Methomil 40 SP (1 kg/ha) or Chlorpyrifos 20 EC (1.5 lit./ha) or Ethofenprox 10 EC (1 lit./ha), depending on the insect pest and intensity of damage.
- For one ha, the spray volume has to be 750 to 800 lit.

Harvesting

- The maturity period ranges from 50 to 140 days depending on the varieties.
- When the plants reach maturity, the leaves turn yellow and drop and soybean pods dry out quickly.
- There is a rapid loss of moisture from the seed. At harvest, the moisture content of the seeds should be 15 per cent.
- Harvesting can be done by hand. breaking the stalks on the ground level or with sickle.
- Threshing can be done either with the mechanical soybean thresher or some conventional methods.

Harvesting Stage



Harvesting stage

QUALITY SEED PRODUCTION IN SOYABEAN

CLASSES OF SEED

- **Breeder Seed**
Small pure seed quantity directly produced by the originating plant breeder or institution.
- **Basic (Foundation) Seed**
The progeny of breeder seed or pre-basic seed
- **Certified Seed**
Progeny of foundation seed

SITE SELECTION

- Choose areas:
 - ✓ With deep well drained fertile soils
 - ✓ That are fairly flat – with gentle slopes
 - ✓ That are easily accessible
 - ✓ That are well isolated from fields planted to same species - especially for cross pollinated crops
 - ✓ Where possible, that have easy access to water – that may be needed to spray pesticides.
- Avoid areas that have large shady trees, ant hills and termite colonies

Land requirement

- Land should be free of volunteer plants.
- The previous crop should not be the same variety or other varieties of the same crop
- It can be the same variety if it is certified as per the procedures of certification agency

- **Isolation**

For certified / quality seed production leave a distance of 3 m all around the field from the same and other varieties of the crop.

- **Harvest**

Seeds attained physiological maturity 27 –30 days after flowering
Harvest the pods as they turn yellow in colour

- **Threshing**

Thresh the pods either manually or mechanically using pliable bamboo stickse and other varieties of the crop.

- **Seed grading**

Grade the seeds using 14/64" (5.6mm) to 12/64" (4.8mm) round perforated metal sieve based on varieties.

- **Drying**

Dry the seeds to 7- 8% moisture content

- **Storage**

Store the seeds in gunny or cloth bags for short term storage (8-9 months) with seed moisture content of 10-12%

Store the seeds in polylined gunny bag for medium term storage (12- 15 months) with seed moisture content of 8 – 10%

Store the seeds in 700 gauge polythene bag for long term storage (more than 15 months) with seed moisture content of less than 7%

Seed Certification Standards

- Field Inspection
 - A minimum of two inspections shall be made, the first during flowering, and the second before harvesting after the leaves have shed
- Field Standards
 - A. General requirements
 - 1. Isolation

Contaminants	<i>Minimum distance (meters)</i>	
	<i>Foundation</i>	<i>Certified</i>
1	2	3
Fields of other varieties	3	3
Fields of the same variety not conforming to varietal purity requirements for certification	3	3

- B. Specific requirements

Factor	<i>Maximum permitted (%)*</i>	
	<i>Foundation</i>	<i>Certified</i>
Off-types	0.10	0.50

- *Maximum permitted at the final inspection

Seed Standards

Factor	<i>Standards for each class</i>	
	<i>Foundation</i>	<i>Certified</i>
Pure seed (minimum)	98.0%	98.0%
Inert matter (maximum)	2.0%	2.0%
Other crop seeds (maximum)	None	10/kg
Weed seeds (maximum)	5/kg	10/kg
Other distinguishable varieties (maximum)	10/kg	40/kg
Germination (minimum)	70%	70%
Moisture (maximum)	12.0%	12.0%
For vapour-proof containers (maximum)	7.0%	7.0%

Thanks



Introduction

- Chick peas are one of the oldest pulses known and cultivated from ancient times both in Asia and in Europe.
- It is assumed that gram is originated either from Himalayas or Mediterranean region.
- At present it is grown in Pakistan, India, Italy, Greece, Rumania, Russia, Egypt, North Africa and many other countries of world.
- Chickpea is valued for its nutritive seeds with high protein content, 25 – 28%.
- Chickpea seeds are eaten fresh as green vegetables, parched, fried, roasted, and boiled.

Origin

- Chickpea is the only domesticated species under the genus *Cicer*, which was originally classified in the tribe vicieae of the family Leguminosae and sub family, papilionoideae.
- Based on the pollen morphology and vascular anatomy, *Cicer* is now set aside from the members of Vicieae and is classified in its own monogeneric tribe, Cicereae Alef.
- The genus *Cicer* comprises 43 species and is divided into two subgenera.

Scientific Classification

- Kingdom: Plantae
- Division: Magnoliophyta
- Class: Magnoliopsida
- Order: Fabales
- Family: Fabaceae (Leguminosae)
- Subfamily: Faboideae (Papilionaceae)
- Genus: Cicer
- Species: *C. arietinum*

Health Benefits

- Chickpeas are a good source of fiber so helps in weight loss.
- Chickpeas are a good source of protein and energy.
- Chickpeas help in stabilizing sugar levels in blood.
- Chickpeas may help in reducing LDL cholesterol.
- Chickpeas may boost energy levels due to their iron content.
- Chickpeas have low glycemic index (GI) which is good for diabetic patients

Soil type

- The plant requires fertile soil with good drainage system.
- Chickpeas generally grow on heavy black or red soils.
- soil pH of 6.0 to 7.0.
- They prefer soil with good residual soil moisture content.
- This crop is grown on moderately heavy soils, black cotton soils, and sandy loam soils.

Climate & Temperature

- Chickpea crop grows well under good moisture conditions with ideal temperatures between 24°C and 30°C.
- Chickpeas are cultivated under both irrigated and rained condition. Basically this crop is winter season crop.
- Chickpea is a self-pollinated crop and usually grown as a rain-fed cool-weather crop or as a dry climate crop in semi-arid regions.
- The optimum daily temperature ranges from 18 to 29°C

Varieties

There are two different types of chickpea that are grown worldwide- Desi and Kabuli.

- Desi -Desi chickpeas have colored and thick seed coat. The seed colors of Desi chickpeas are brown, yellow, green or black.
- Kabuli --The Kabuli type chickpeas are characterized by white colored seed with ram-head to rounded shape. The seed coat is thin with smooth seed surface. The Kabuli type generally has large seed size and receive higher market price than Desi type.

Seed rate & Sowing

- Seed rate of 60kg/ha and plant density of 25 to 30 plants per square meter is ideal for chickpea farming. An average seed rate of 70-100kg/ha will ensure good growth of the crop.
- Chickpeas are propagated from seeds. Sowing is usually done on conserved soil moisture.
- A pre-sowing irrigation may be needed, if the available soil moisture is not adequate for germination. Drilling is the best sowing method for chickpeas.
- Row to Row spacing 25 – 40 cm and plant to plant spacing 10 cm at the depth of 2 – 12 cm with soil well pressed down.

Preparation of Field

- Chickpea is highly sensitive to soil aeration.
- This imposes a restriction for its cultivation on heavy soils and calls for special care in seedbed preparation.
- A rough seedbed is required for chick pea. In case the chickpea crop is taken after a kharif fellow.
- It would be desirable to go for a deep ploughing during the monsoon as the same would help in larger conservation of rain water in the soil profile for subsequent use by this crop. Very fine and compact seedbed is not good for chickpea but it requires a loose and well aerated seedbed.

Fertilizer Application

- It all depends on fertility of soil.
- In case of poor soils, this crop requires well rotten farm yard manure (F.M.Y) and in organic fertilizers like Urea (50kg/ha), Phosphorus (150kg/ha) MOP (70kg/ha).
- These manures and fertilizers should be applied before sowing the seeds.
- Apply these fertilizers using drillers with depth about 8cm in soil.

Irrigation

- Chick pea is mostly sown as a rainfed crop.
- However, where irrigation facilities are available, give a pre-sowing irrigation.
- It will ensure proper germination and smooth crop growth. If winter rains fail, give one irrigation at pre-flowering stage and one at pod development stage.
- In no case first irrigation should be given at flowering time of gram crop. A light irrigation should be given because heavy irrigation is always harmful to gram crop. Excess of irrigation enhances vegetative growth and depresses chick pea yield.

Weed control

- Chick pea being a stature crop suffers severely by infestation of weeds.
- One hand weeding or inter culture with hand hoe or wheel hoe after 25-30 days and second if needed after 60 days of sowing may take care of weeds.
- Fluchloralin (Basalin) 1 kg per hectare in 800-1000 liters of water as pre-planting spray may be used as an effective herbicide.
- It should be well incorporated in the soil before sowing

Pest & Diseases

- Diseases of Chickpea
- Wilt
- Blight
- Cercospora Leaf Spot
- Root and Stem Rot
- Anthracnose
- Pest of Chickpea
- Two main pest in chickpea cultivation.
- Cutworm.
- Pod Borer

Harvesting

- Chickpea crop will be ready for harvesting after leaves turn reddish-brown and start shedding from the plant.
- Using sickle or hand, plants should be plucked.
- Should allow the crop to dry in sun for about a week and threshing should be carried out by beating the plant with sticks.

Threshing

- Vines along with the pods are harvested from the field and dried in the threshing floor under sunshine.
- Threshing is done by beating with stick when sufficiently dry.
- Care should be taken during threshing so that the seed coats are not injured.

Drying

- Threshed seeds are cleaned by winnowing, dried to reduce seed moisture content to 12% for temporary storage.
- For longer storage pea seed should be stored in sealed containers at 10% moisture content and in air cooled rooms.

Storing

- Desi chickpeas will darken considerably and seed germination and vigour will decline in storage.
- The rate of quality decline is accelerated by high seed moisture content, high temperatures, high relative humidity, and condition of the seed at harvest.
- Seed subject to field weathering prior to harvest will deteriorate quicker in storage, even when stored under acceptable conditions of temperature and relative humidity.

INTRODUCTION

Botanical Name:

Cajanus cajan (L.)

Family:

Fabaceae (Leguminosae)

Chromosome Number:

$2n=2x=22$

Origin:

Hindustan.



Pigeon Pea

Pollination:

Often-cross pollinated

Common Name:

Pigeon Pea, Congo Pea,
Red Gram, Arhar, Tur

Distribution of pigeonpea

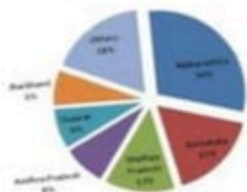


- ❑ Worldwide pigeonpea was grown in about 4.23 million hectares with a production and productivity of 4.68 million tons and 751 kg/ha, respectively (Pal *et al.*, 2016).
- ❑ India is the largest producer of pigeonpea accounting for 66 percent of total production. Other major pigeonpea producing countries are Myanmar (17.09%), Malawi (6.15%), Kenya (4.36%), and United Republic of Tanzania (5.29%).
- ❑ Pigeonpea ranks second after chickpea among all the pulses in the country and normally cultivated during *kharif* season. In India, it occupies an area of 3.81 million hectares with a production and a productivity of 3.07 million tons and 806 kg/ha, respectively (Pal *et al.*, 2016).
- ❑ In Gujarat, it occupies an area of 0.23 million hectares with a production and a productivity of 0.26 million tons and 1127 kg/ha, respectively (Anon., 2017).



■ Primary area ■ Secondary area

State-wise share (%)



IMPORTANCE

- An ideal plant for sustainable agriculture



Food crop (dried peas, flour, or green vegetable peas)



Green manure, providing up to 90 kg nitrogen per hectare and forage purpose



The woody stems of pigeon peas can also be used as firewood, fencing.



Why hybrid technology in pigeon pea?

- ✓ The national demand of pigeonpea in India always scores over the production, and in spite of decades of research and development programs, the mean productivity of the crop could not cross the barrier of 800 kg/ha.
- ✓ To break this yield plateau, SDAU and ICRISAT developed a hybrid breeding technology, globally the first in any food legume.
- ✓ This technology is based on cytoplasmic nuclear male sterility (CMS) and natural out-crossing.
- ✓ One commercial hybrid from CERP, SDAU, Sardarkrushinagar and three commercial hybrids from ICRISAT have been released and these hybrids demonstrated 30-50 per cent yield advantage over the most popular local cultivars in farmers' fields.
- ✓ To enhance the adoption of these hybrids, it is necessary that quality hybrid seed is produced in large quantities and made available to the farmers at reasonable cost.
- ✓ The hybrid seed technology is profitable and easy to adopt. However, for its sustainability and to understand the production constraints, it was found necessary to validate this technology in farmers' fields under diverse environments.

The commercial hybrids

GMS based hybrid released in India

Table 1: Genetic male sterility based pigeonpea hybrids released in India

Character	ICPH 8	PPH 4	CoH 1	CoH 2	AKPH 4104	AKPH 2022
Adaptability	Central Zone	Punjab	Tamil Nadu	Tamil Nadu	Central	Maharashtra
Year of release	1991	1994	1994	1997	1997	1998
Parentage	MS Prabhat DT x ICPL 161	MS Prabhat DT x AL 688	MS T21 x ICPL87109	MS CO5 x ICPL83027	NA	NA
Days to maturity	125 (CZ)	137 (NWPZ)	117 (SZ)	120-130 (SZ)	130-140	180-200
Yield (q/ha)	17.8	19.3	12.1	10.5	NA	NA
Superiority over check	30% over TAT 10, 41% over UPAS120	14% over UPAS 120, 14% over H82-1	22.3% over Vamban 1, 19.4% over ICPL87	35% over CO5	64% over UPAS120	34.9% over BDN2, 28.2% over C 11, 25% over ICPL 87119

ICPH 8

First commercial GMS based pigeonpea hybrid

High yield potential

Vigorous growth

Matures in 115-135 days

Wide adaptation

Drought tolerance

GMS based world first Pigeonpea hybrid ICPH-8



Table 2: Seed yields of pigeonpea hybrid ICPH 8 compared with those of the control cultivar UPAS 120, central zone, India, 1984-89.

Year	No. of trials	Seed yield (t/ha)	
		ICPH 8	UPAS 120
1984	7	2.58	1.93
1985	2	1.52	1.01
1986	3	1.09	0.79
1987	7	1.50	1.13
1988	10	1.48	1.15
1989	12	1.94	1.21
Weighted mean		1.78	1.26

CGMS based hybrid released in India

GTH-1 : CGMS BASED WORLD'S FIRST HYBRID

- World first CGMS based hybrid of pigeonpea developed by SDAU by utilizing the cytoplasm of wild species of *Cajanus* (*Cajanus scarabaeoides*)
- Released from SDAU in 2004 for cultivation in Gujarat state and central zone of India.

Important characteristics of GTH-1

- Parents : GT288 A (CMS line/cytoplasm of *Cajanus scarabaeoides*) and GTR-11 (restorer/male)
- Indeterminate Growth habit
- Early in maturity durations
- Very much stable fertility restoration
- Yellow color flower
- Green pod with streaks at base
- Bold and large white seed
- Batter dal recovery (87.2%) and grain yield 32 and 42% higher than GT 101 and AKP-4101
- Yield potential : 2827 kg/ha



Table 3: Performance of pigeonpea hybrid GTH-1 in comparison to check hybrid (AKPH 4101) and check variety (GT 101) in Gujarat state during *kharif* 2000 to 2003

Season & year of testing	Name of trial	Location of trial	Grain yield of hybrid/ varieties (kg/ha)			
			GTH 1	AKPH 4101 (Ch.)	GT-100 (Ch.)	GT-101 (Cv.)
<i>Kharif</i> 2000	PHT	S K nagar	2827	1224	1218	-
		Mean	2827	1224	1218	-
<i>Kharif</i> 2001	SSHT	S K nagar	1852	1279	1431	-
		Ladol	644	679	707	-
		Anand	450	825	770	-
		Mean	982	928	969	-
<i>Kharif</i> 2002	LSHT	S K nagar	2057	1543	-	1381
		Anand	2106	1759	-	1562
		Bharuch	1906	1662	-	1759
		Vadodara	849	548	-	540
		Derol	2547	1666	-	1782

Conti....

Season & year of testing	Name of trial	Location of trial	Grain yield of hybrid/ varieties (kg/ha)			
			GTH 1	AKPH 4101 (Ch.)	GT-100 (Ch.)	GT-101 (Cv.)
<i>Kharif</i> 2002	LSHT	Navsari	2346	1698	-	2022
		Mean	1969	1479	-	1508
<i>Kharif</i> 2003	LSHT	S K Nagar	2537	1444	-	1620
		Bharuch	1144	1130	-	1017
		Vadodara	1111	868	-	910
		Junagadh	2516	2161	-	2344
		Derol	938	608	-	573
		Navsari	1013	390	-	448
		Mean	1543	1100	-	1152
over all mean			1830	1183	1094	1330
Mean (2000-2001)			1905	-	1094	-
Mean (2002-2003)			1756	-	-	1330
% increase over			-	54.70(overall)	74(2000-01)	32 (2002-03)

ICPH 2671 (ICPA 2043 x ICPR 2671)

- The new hybrids developed on an improved A-line (ICPA 2043) showed promise with respect to yield, seed size and disease resistance.

Growth habit	Indeterminate and semi Spreading
Days to flowering	114-120 days
Days to 75% pod maturity	166-184 days
yield	2.5-3 tonne/ha
Flower color	Yellow with dense red streaks
Pod color	Dark purple
Seed color	Dark brown
Superiority over check	30-40%
Highly resistant to <i>Fusarium</i> wilt and sterility mosaic disease	



Field View of ICPH-2671

Table 4: Performance of hybrid ICPH 2671 in multi location trials

Year	Location	Fertility Restoration(%)	ICPH 2671(kg)	Maruti (control)	SEm	CV (%)	Heterosis %
2005	Medchal (JK Seeds)	100	2996	1041	± 331.6	21	188
	Coimbatore(TNAU)	98	4262	2538	± 252.7	17	71
	Patancheru (ICRISAT)	100	2671	1677	± 207.7	14	59
	Jalna (MAHYCO)	100	3416	2541	NR	07	34
2006	Parbhani (MAU)	98	4779	2648	± 173.4	0.6	80
	Jalna (Krishidhan)	100	1948	1092	± 91.8	10	78
	Coimbatore(TNAU)	100	1823	1100	± 324.7	28	66
	Phaltan (Nimbkar seeds)	-	3208	2243	± 147.3	20	43
	Patancheru (ICRISAT)	100	2660	1919	± 140.7	08	39
	Bangalore (UAS)	-	1603	1462	± 289.9	20	-

ICPH 2740 (ICPA 2047 × ICPL 87119)

Growth habit	Determinate
Days to flowering	125-130
Days to 75% pod maturity	176-189 days
Seed color	Brown
Yield	2.7-3 tonne/ha
Superiority over check	30-40%
Highly resistant to <i>Fusarium</i> wilt and sterility mosaic diseases	



ICPH 3762

Days to maturity	180 to 190 days
Yield	1.8 t/ha
Seed color	Brown
Seed size	Medium bold
Growth habit	Determinate
Superiority over check	40-50%
Highly resistant to <i>Fusarium</i> wilt and sterility mosaic disease	
Tolerant to terminal drought due to deep root system	



Table 5: Some promising medium duration pigeonpea hybrids developed at ICRISAT

Hybrid (ICPH)	Yield(kg/ha)	Standard heterosis (%)	100-seed weight (g)	* Wilt (%)	*Sterility mosaic (%)
3371	3013	62	11.50	0	0
3491	2919	57	13.40	0	0
3497	2686	44	10.90	0	15
2740	2900	57	12.30	0	0
3481	2637	41	11.60	0	0
3494	2586	39	12.40	0	9
2671	2509	37	12.20	0	0
3762	3000	62	11.90	0	0
Check	1864	-	11.10	0	0
SEm	±205.7	-	± 0.33	-	-
CV (%)	11.9	-	3.98	-	-

*Data from disease nursery

Major components of hybrid technology

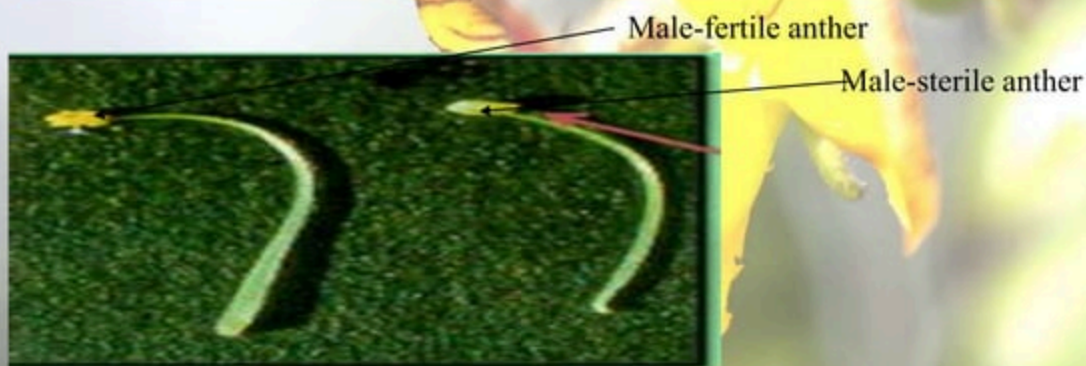


Male sterility

Male sterility is a situation where its male reproductive parts are either absent, aborted, or non-functional; and fail to reproduce through sexual means. This abnormality could be natural, induced by mutagens, or bred by crossing genetically diverse genotypes. This reproductive inefficiency has been exploited by plant breeders to produce hybrid seed at commercial level.

Male sterility systems in pigeonpea

- **Genetic male sterility**
- **Temperature sensitive male sterility**
- **Cytoplasmic nuclear male sterility**



Genetic male sterility

- In pigeonpea, two types of genetic Male sterility, each contribute by single recessive gene has been reported.
- Reddy *et al.*, (1978) identified a white translucent male sterile anther.
- Six male sterile plants were identified at ICRISAT in 1978, derived from totally two unrelated species.

Ms-3A	From ICP-1555
Ms-3B	
Ms-3C	
Ms- 3D	
Ms- 3E	From ICP-1596
Ms-4A	



Genetic male sterility

- Male sterility is governed by a single recessive gene. Maintenance of male sterility is done by sowing male sterile and fertile plants observed in the same population.
- The visible marker, i.e. white translucent anther provides an efficient way of recognizing these ms plants in the field.

Genetic male sterility system was not accepted by farmers due to

1. The economics of large scale seed production.
 2. The major drawback was roguing of fertile counterpart from the female plot, which was time and labor consuming.
- Cytoplasmic-genic male sterility system usually was a better option for large scale seed production
 - Pigeonpea (*cajanus cajan*) display considerable natural out crossing and now CMS lines are available with different cytoplasmic backgrounds.



Cytoplasmic genetic male sterility

- ❖ The first workable CMS system in pigeonpea was produced at GAU, Sardarkrushinagar by Tikak *et al.* (1997) from **wild cytoplasm *C. scarabaeoides***.
- ❖ The second breakthrough in this technology was achieved when a CMS system was developed by **crossing *C. cajanifolius* (a wild species) and a cultivated line ICP 28** (Saxena *et al.*, 2005).
- ❖ This CMS system stable across diverse environments and has an excellent fertility restoration system.
- ❖ After the development of a stable CMS system, several experimental hybrids were produced and evaluated.
- ❖ Kandalkar (2007) found that CMS-based hybrids recorded standard **heterosis up to 156% for grain yield**.
- ❖ Saxena (2007) reported **yield advantage of 50-100%** over the popular varieties/checks.

Table 6: List of CMS sources derived from different wild relatives of pigeonpea

Sr. No.	Cytoplasm	Donor	Characters
1	A1	<i>Cajanus sericeus</i>	Envt sensitive, stable in long photoperiod, low restores
2	A2	<i>Cajanus scarabaeoides</i>	Stable CMS, inconsistent fertility
3	A3	<i>Cajanus volubilis</i>	Fertility problem
4	A4	<i>Cajanus cajanifolious</i>	Best stable CMS, many fertility, good pod set and yield
5	A5	<i>Cajanus cajan</i>	Maintainer from wild
6	A6	<i>Cajanus lineatus</i>	Natural hybrid from wild
7	A7	<i>Cajanus platycarpus</i>	Tertiary gene pool, embryo rescue

ICRISAT

Saxena *et al.* (2010)



Cytoplasmic genetic male sterility



TGMS - Temperature – Sensitive Male Sterility

- Some environmental factors such as temperature and photo period are known to play a key role by inducing male sterility in pigeonpea.
- This approach popularly known as **two parent hybrid** breeding.
- In pigeonpea, TGMS material derived from an inter-specific cross involving *C. sericeus* (Benth, ex Bak.), a wild relative of pigeonpea and a cultivar **ICPA 85010**, a cultivated species *C. cajan*. This is the first report of Temperature–Sensitive Male Sterility system in pigeonpea

Table 7: Field observations recorded in three months on male sterility and fertility in four temperature sensitive selection (ICRISAT, Saxena, 2014)

Year	Selection	September		November		February	
		Sterile plants	Fertile plants	Sterile plants	Fertile plants	Sterile plants	Fertile plants
2007	Envs s-1	13	1	2	12	11	0
	Envs s-2	11	2	1	12	11	2
	Envs s-3	9	1	2	8	8	0
	Envs s-5	13	3	2	14	12	2
	Total	46	7 (13.2%)	7	46 (86.8%)	42	4 (8.7%)
2008	Envs s-1	22	0	1	21	22	0
	Envs s-2	8	0	1	7	8	0
	Envs s-3	10	0	0	10	7	0
	Envs s-5	18	0	3	15	16	0
	Total	58	0(0.0%)	5	53 (91.4%)	53	0 (0.0%)
2009	Envs s-1	37	0	0	37	37	0
	Envs s-2	32	0	0	32	32	0
	Envs s-3	27	0	0	27	25	0
	Envs s-5	23	0	0	22	21	0
	Total	119	0 (0.0%)	0	118 (100.0%)	115	0 (0.0%)

Fertility restoration

- ✓ **Perfect male fertility restoration** of hybrid plants is important to get good yields.
- ✓ According to Kaul (1988), once a fertility restorer (R-) line is crossed with male sterile (A-) plant, the dominant fertility restoring nuclear gene produces **certain proteins in F₁ plants** and thus, **repairs the defective mitochondrial genome** of the plant to produce **male fertile hybrid plants**.
- ✓ In pigeonpea two **dominant genes (*Rf₁* and *Rf₂*)** have been identified (Saxena *et al.*, 2011), which impart **fertility restoration** to the hybrid plants.
- ✓ In the primary gene pool the frequency of fertility restoring genes is fairly high and so far over **150 good restorers** have been identified in different maturity groups (Saxena *et al.*, 2014).

Table 8: Segregation for male-sterility and fertility in F_1 , F_2 and BC_1F_1 populations of crosses involving CMS line ICPA 2039 and five fertility restorers in pigeonpea

Cross	Number of plants								
	F_1 generation			F_2 generation					
	Total	Fertile	Sterile	Total	Fertile	Sterile	χ^2 (expected)	χ^2 (calculated)	P (0.01)
ICPA 2039 × ICP 12320	27	27	0	428	317	111	3:1	0.20	0.66
ICPA 2039× ICP 11376	30	30	0	430	312	118	3:1	1.37	0.24
ICPA 2039× HPL 24-63	25	25	0	471	373	98	3:1	4.42	0.04
Pooled	82	82	0	1329	1002	327	3:1	0.11	0.74
ICPA 2039 × ICP 10650	32	32	0	179	166	13	15:1	0.31	0.58
ICPA 2039 × ICP 13991	30	30	0	518	275	243	9:7	2.1	0.15

Table 8: Conti....

Cross	Number of plants					
	BC ₁ F ₁ generation					
	Total	Fertile	Sterile	χ^2 (expected)	χ^2 (calculated)	P (0.01)
ICPA 2039 × ICP 12320	103	42	61	1:1	3.50	0.06
ICPA 2039 × ICP 11376	158	68	90	1:1	3.06	0.08
ICPA 2039 × HPL 24-63	115	68	47	1:1	3.83	0.05
Pooled	376	178	198	1:1	1.06	0.30
ICPA 2039 × ICP 10650	108	78	30	3:1	0.44	0.50
ICPA 2039 × ICP 13991	112	37	75	1:3	3.86	0.04

Table 9: Fertility restoration of extra early maturing pigeonpea hybrids at four location during the rainy season

Hybrid	parentage	Fertility restoration				
		Gurdaspur	Faridkot	Patancheru	Ludhiana	Mean
PHP 32	ICPA 2089 × PHR21	37.5 (16)*	30.8 (13)	35.0 (20)	21.7 (23)	31.3 (72)
PHP 33	ICPA 2089 × PHR22	60.0 (10)	50.0 (12)	55.6 (18)	50.0 (26)	53.9 (66)
PHP 34	ICPA 2089 × PHR23	66.7 (15)	73.3 (15)	75.0 (20)	47.6 (21)	65.7 (71)
PHP 35	ICPA 2089 × PHR24	37.5 (8)	56.3 (16)	63.2 (19)	36.4 (22)	48.3 (65)
PHP 36	ICPA 2089 × PHR25	60.0 (10)	33.3 (6)	30.0 (20)	23.1 (26)	36.6 (62)
PHP 37	ICPA 2089 × PHR26	83.3 (6)	60.0 (15)	31.6 (19)	29.4 (17)	51.1 (57)
PHP 38	ICPA 2089 × PHR27	83.3 (6)	56.3 (16)	68.4 (19)	26.1 (23)	58.5 (64)
PHP 39	ICPA 2089 × PHR28	42.9 (7)	57.1 (14)	47.4 (19)	58.8 (17)	51.5 (57)
PHP 40	ICPA 2089 × PHR29	71.4 (7)	55.6 (9)	27.8 (18)	43.5 (23)	49.6 (57)
PHP 41	ICPA 2089 × PHR30	75.0 (4)	62.5 (16)	55.6 (18)	10.5 (19)	50.9 (57)
PHP 42	ICPA 2089 × PHR31	100.0 (11)	70.6 (17)	94.4 (18)	70.0 (20)	83.8 (66)
Location mean		65.2 (100)	55.1 (149)	53.1 (208)	37.9 (237)	52.8 (694)

Table 10: Segregation for male fertility and sterility in F_1 , F_2 , and BC_1F_1 generations and their chi-square tests.

Crosses	Generation	No. of plants					
		Total	Fertile	Sterile	Expected ratio	χ^2 calculated	Probability
Extra-early-maturing hybrid							
ICPA 2089 × PHR 31	F_1	18	17	01	1:0	-	-
	F_2	147	115	32	3:1	0.82	0.37
	BC_1F_1	187	107	80	1:1	3.90	0.05
Early-maturing hybrids							
ICPA 2039 × ICPR 2438	F_1	175	175	0	1:0	-	-
	F_2	225	212	13	15:1	0.09	0.77
ICPA 2039 × ICPR 2447	F_1	170	170	0	1:0	-	-
	F_2	222	210	12	15:1	0.27	0.60

Table 10: Conti...

Crosses	Generation	No. of plants					
		Total	Fertile	Sterile	Expectd ratio	χ^2 calculated	Probabi- lity
Late-maturing hybrids							
ICPA 2043 × ICPR 2671	F ₁	138	138	0	1:0	-	-
	F ₂	238	223	15	15:1	0.00	0.97
	BC ₁ F ₁	138	98	40	3:1	1.17	0.28
ICPA 2043 × ICPR 3467	F ₁	90	90	0	1:0	-	-
	F ₂	230	216	14	15:1	0.01	0.92
	BC ₁ F ₁	189	140	49	3:1	0.09	0.77

COST EFFECTIVE

Mass cross-pollination

- ✓ In most legumes, self-pollination is a common event due to their cleistogamous flower structure, but pigeonpea and a few other crops are an exception with partial natural out-crossing, often mediated by insects.
- ✓ Pathak (1970) identified *Megachile bicolor* and *Apis floreae* as pollinating insects in pigeonpea.
- ✓ Williams (1977) identified 48 insect species foraging on pigeonpea, but the common foraging insects were *Apis dorsata* and *Megachile spp.*

Table 11: Effect of spraying with bee-attractants on honeybee visitation

Treatments	Number of honeybees / 10 flowers /5 minutes			
	Bee attractants spray (10% flowering)			
	1 DAS	2 DAS	3 DAS	4 DAS
T ₁ – Bee-Q 10 g / l	3.66 c	4.06 c	4.00 c	3.26 c
T ₂ –Bee-Q 12.5 g/ l	5.26 a	5.53 b	5.20 b	4.86 b
T ₃ –Bee-Q 15 g/ l	4.73 b	3.93 c	3.86 c	4.40 c
T ₄ –Fruit boost 0.5 ml/ l	3.96 b	3.80 c	3.53 d	3.66 c
T₅–Fruit boost 0.75 ml/ l	5.93 a	6.46 a	6.13 a	5.80 a
T ₆ –Fruit boost 1 ml/ l	4.66 b	5.00 b	5.13 b	4.40 b
T ₇ –Open pollination (control)	2.93 c	2.86 d	2.86 d	2.93 d
F-Value	*	*	*	*
SEm	0.357	0.273	0.246	0.175
CD at 5%	1.032	0.789	0.711	0.506

* significant $p < 0.05$

Table 12: Effect of bee attractants on yield parameters

Treatments	Number of seeds/Pod		100 seed weight (g)		Seed Yield / plant (g)	
	Mean ±SE	% increase/Decrease over Op	Mean ±SE	% increase / Decrease over Op	Mean ±SE	% increase/Decrease over Op
T ₁ - Bee-Q 10g / l	5.00 b	7.29	13.50 b	3.44	135 c	13.44
T ₂ -Bee-Q 12.5 g/ l	5.33 a	14.37	13.80 c	5.74	146 a	22.68
T ₃ -Bee-Q 15 g/ l	5.00 b	7.29	13.45 b	3.06	130 b	9.24
T ₄ -Fruit boost 0.5ml/ l	5.00 b	7.29	13.55 a	3.83	138 b	15.96
T₅-Fruit boost 0.75ml/ l	5.33 a	14.37	13.95 a	6.89	150 a	26.05
T ₆ -Fruit boost 1ml/ l	5.00 b	7.29	13.25 b	1.53	140 b	17.64
T ₇ -Open pollination (control)	4.66 c	-	13.05 d	-	119 c	-
F-Value	*		*		*	
SEm±	0.561		0.881		1.174	
CD at 5%	1.654		2.598		3.462	

Table 13: Proportions of four important insect species recorded in pigeonpea fields and their activity on flowers

Pollinator insect species	Proportion of insects present (%)	Flowers visited/10 min	Stay on each flower (sec)
<i>Megachile</i> spp.	49.04	4.5	6.6
<i>Xylocopa</i> spp.	11.06	8.9	2.4
<i>Apinae</i> spp.	10.10	2.5	14.8
<i>Catopsilia</i> spp.	7.21	4.0	12.4
Others (15 spp.)	22.59	-	-

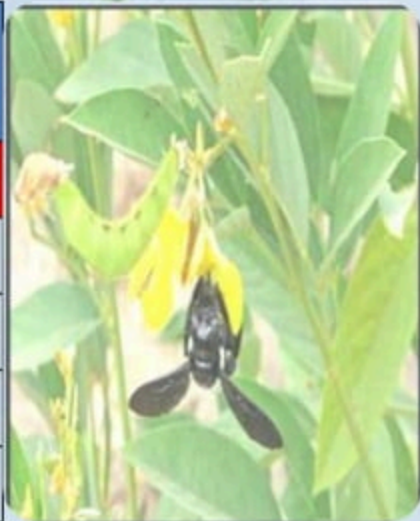


Table 14: Flower-visiting frequencies of insects on primary branches of A-line and R-line (times per 10 min)

Day	A-line						R-line					
	1	2	3	4	5	Mean	1	2	3	4	5	Mean
First day	3.8	2.0	5.2	3.6	1.2	3.2	10.2	4.4	4.8	3.6	4.4	5.5
Second day	2.8	1.4	3.6	3.2	1.0	2.4	6.4	6.6	4.4	3.8	2.8	4.8
Mean	3.3	1.7	4.4	3.4	1.1	2.8	8.3	5.5	4.6	3.7	3.6	5.2

Numbers 1 to 5 refer to the 5 plants of each line.

Hybrid seed technology

- The hybrid technology in pigeonpea is **new** and there are no recommended national seed standards for this product.
- In general, the production of hybrid seed in this crop is **complex** because cross-pollination is entirely dependent on certain insect species; and their population and the resultant degree of natural out-crossing are inconsistent across locations to locations.

Isolation requirements

Table 15: Natural out-crossing in pigeonpea reported from various locations/countries.

Country /place	% Out-crossing		Country /place	% Out-crossing	
	Mean	Range		Mean	Range
In India			In Kenya		
Pusa	-	1.6–12.0	Katumani	17.7	-
Nagpur	25.0	3.0–48.0	Kibos	12.6	-
Niphad	16.0	11.6–20.8	Makueni	21.0	-
West Bengal	30.0	-	Mtwapa	22.0	-
Ranchi	-	3.8–26.7	Kabete	45.9	23.3-45.9
Coimbatore	13.7	-	In other countries		
Varanasi	-	10.3–41.4	Hawaii	15.9	5.9-30.0
Badnapur	-	0.0–8.0	Puerto Rico	-	5.5-6.3
Coimbatore	-	10.0–70.0	Trinidad	26.4	-
Hyderabad	27.9	0.0–42.1	Australia	-	2.0-40.0
			China	24.6	15.0-30.0

Table 16: Isolation distance (meters) recommend for seed production of various seed classes of pigeonpea

Source	Seed Class			
	Breeder	Foundation	Certified	Truthfully labelled
FAO (Ariyanayagam, 1976)	-	-	180–360	-
Agrawal (1994)	-	400	200	-
Bhatia <i>et al.</i> (1981)	300	-	200	-
Tunwar and Singh (1988)	-	200	100	100
Sudewad <i>et al.</i> (2004)	200	200	100	-

Table 17A: Field Standards**A. General requirements**

1. Isolation

Pigeon pea seed fields shall be isolated from the contaminants shown in column 1 of the Table below by the distances specified in column 2 and 3 of the said Table:

Contaminants	Minimum distance (meters)	
	Foundation	Certified
Fields of other varieties	250	100
Fields of the same variety not conforming to varietal purity requirements for certification	250	100

B. Specific requirements

Factor	Maximum permitted (%)*	
	Foundation	Certified
Off-types	0.10	0.20

*Maximum permitted at and after flowering

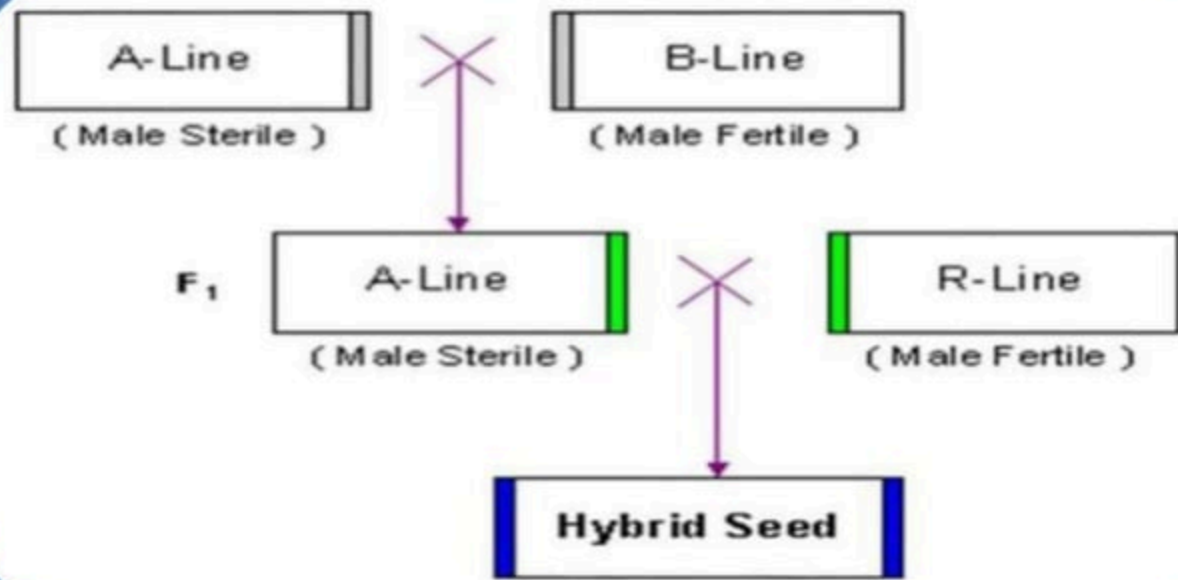
Table 17B: Seed Standards

Factor	Standards for each class	
	Foundation	Certified
Pure seed (minimum)	98.0%	98.0%
Inert matter (maximum)	2.0%	2.0%
Other crop seeds (maximum)	5/kg	10/kg
Weed seeds (maximum)	5/kg	10/kg
Other distinguishable varieties (maximum)	10/kg	20/kg
Germination including hard seeds (minimum)	75%	75%
Moisture (maximum)	9.0%	9.0%
For vapour-proof containers (maximum)	8.0%	8.0%

Field plot technique

- ✓ The critical point that should be given highest consideration in the field lay out is the availability of fresh pollen for a longer period. This will ensure more visits of the pollinating insects for extended periods to enhance pod setting on the male sterile plants.
- ✓ In general, a row ratio of **4 female: 1 male** is recommended, but it can be reduced to 3 female: 1 male, if the population of pollinating insects in the target areas is less.
- ✓ To ensure better pollen availability, the net seed production plot should be surrounded by a 2-3 meter belt of pollen parent; planted 2-3 weeks after the sowing of the net plot. This technique has worked well and in most places with small (< one acre) plots.
- ✓ In larger production plots, a slight modification in the design has given good results. For such locations, the entire isolation plot **is divided into 3-4 sub-plots**; and each sub plot is treated as one unit for seed production and planted with 4 female and 1 male rows and also surrounded by a belt of male parent. The sowing of each sub-plot should be **staggered by two weeks**. This treatment ensures extended pollen availability and good pod set.

Schematic production of hybrid seed production



A standard field layout plan for seed production of a CMS line

BBBBBBB	B	BB	B	BBBBBBB
BBBBBBB	B	BB	B	BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		BB		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		BB		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB		AA		BBBBBBB
BBBBBBB	B	BB	B	BBBBBBB
BBBBBBB	B	BB	B	BBBBBBB

2 meters

1 m

10 m

1 m

2 m

A hybrid seed production plot

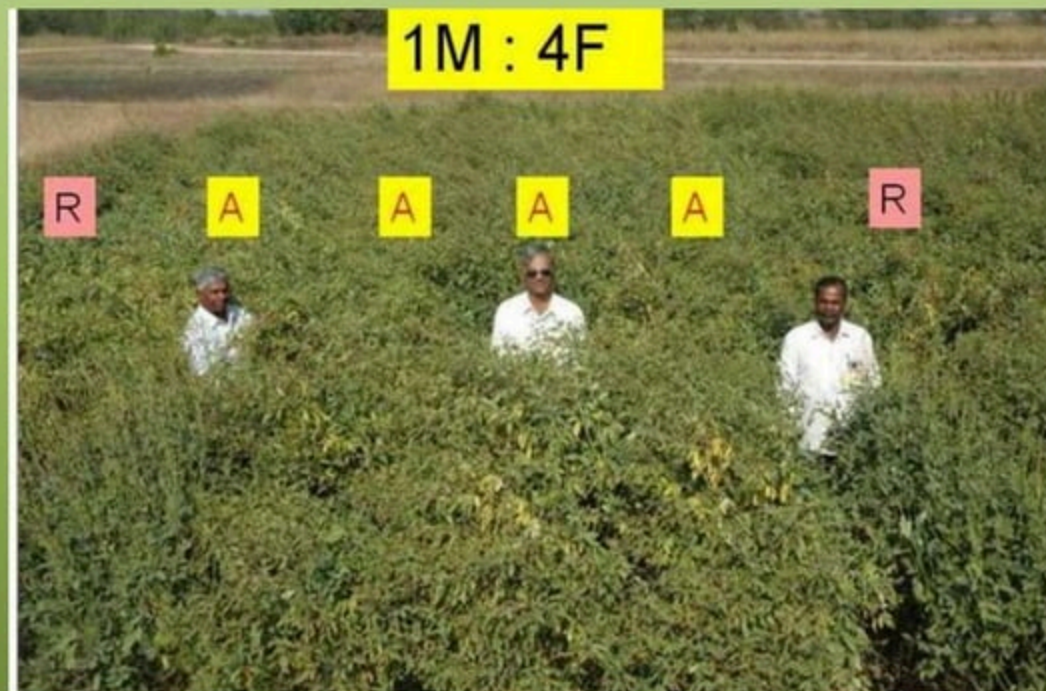


Table 18: Mean attributes of ICPA 2043 as influenced by the direct and interactive effects of row ratio, spacing and irrigation.

Traits	Year 1			Year 2		
	Factor	Treatment	Mean	Factor	Treatment	Mean
Yield/plant (g)	Irrigation effect	Every 21 days	117.91	Effect of row ratio	4:1	78.02
		Every 14 days	129.72		3:1	56.31
	Effect of spacing	150 x 50	149.07	Effect of spacing	150 x 50	98.61
		150 x 30	140.67		150 x 30	68.72
		75 x 50	101.43		75 x 50	59.23
		75 x 30	104.09		75 x 30	42.09
	Yield/ha (kg)	Effect of spacing	150 x 50	1432.10	Effect of row ratio	4:1
150 x 30			2278.90	3:1		934.33
75 x 50			1903.30			
75 x 30			3254.90			

Table 19: Effect of Different Planting Ratio's and Insect Attractant Spray on Seed Yield Parameters of Hybrid Pigeonpea Seed Production-ICPH-2671

Treatments	Seed Yield g/plant *A-line (ICPA- 2043)			Seed Yield kg/plot *A-line (ICPA-2043)			Seed Yield kg/ ha * A-line (ICPA- 2043)		
	T ₁	T ₂	Mean	T ₁	T ₂	Mean	T ₁	T ₂	Mean
P₁(3:1 Planting Ratio)	52.04	57.1	54.57	2.88	3.25	3.07q	1778	2006	1892
P ₂ (4:1 Planting Ratio)	52.96	59.2	56.08	4.04	4.64	4.34	1871	2148	2009
P ₃ (5:1 Planting Ratio)	54.16	63.86	59.01	5.15	6.15	5.65	1906	2278	2092
P ₄ (3:2 Planting Ratio)	53.11	61.45	57.28	2.99	3.52	3.26	1847	2175	2010
P ₅ (4:2 Planting Ratio)	57.36	66.25	61.81	4.44	5.19	4.81	2054	2402	2228
P₆(5:2 Planting Ratio)	59.21	68.24	63.73	5.7	6.62	6.16	2112	2452	2282
Mean	54.81	62.68	58.74	4.2	4.9	4.54	1928	2243	2085
For comparing means of	S.Em±	CD at 5%		S.E m±	CD at 5%		S.Em ±	CD at 5%	
Insect attractant (T)	1.16	3.4		0.04	0.12		26.27	77.05	
Planting ratio (P)	1.01	3.89		0.07	0.21		45.5	133.45	
P × T	1.84	3.33		0.1	0.3		64.35	188.73	

Note: * A-line (F₁ hybrid) = A(ICPA-2043) x R(ICPR-2671) line seed production. T₁: Without spray, T₂: Insect attractant spray (Bee-Q 12.1g/l).

Crop management

- ✓ **Field preparation** is an important activity to assure good crop.
- ✓ A basal dose of **100 kg/ha of di-ammonium phosphates** is recommended to provide 18 kg/ha N and 20 kg/ha P.
- ✓ Since genetic purity of the **seed** is of prime importance, the Breeder seed of highest quality should be obtained from a reliable **source**.
- ✓ The **sowing** should be undertaken at the time when the **soil moisture** is adequate for germination.
- ✓ The female parental **seed @ 4-5 kg/ha and that of male parent @ 1-2 kg/ha** should be used.

Crop management

- ✓ To manage the weeds a pre-emergence herbicide such as **Promytrine or Basaline** be sprayed. For controlling pod borers (*Helicoverpa armigera*) 2-3 spraying of **Dimethoate (30% EC @ 1.0 L /ha)** during reproductive stage gives good results. The most important consideration in spraying is that the insecticide should not kill the pollinating insects; and for this the spraying should be organized either before 9 AM or after 5 PM.
- ✓ Generally four rounds of rouging are recommended to **remove off-type** plants in hybrid seed production.
- ✓ Harvesting should be organized with utmost care. All the **male rows should be harvested first**, removed from field, and kept aside. This should follow the easy harvesting of female rows. Threshing, cleaning, drying, seed treatment, and storage should be done as per the local practices. At every stage enough care should be taken to maintain the purity of seed.

Seed Quality

- ✓ **Purity of seeds holds the key for the success of hybrids, because any level of genetic contamination will lead to the deterioration in its performance with respect to yield and resistance to various stresses.**
- ✓ **Traditionally, the commercial producers perform Grow-out Tests (GoT) on each seed lot to assess its genetic purity. In this test simply inherited dominant morphological trait present in the male parent is used, and tracked in the hybrid plants to ensure their hybridity.**

Quality control through molecular markers

Figure 1: The hybrid purity assessment of hybrid ICPH 2438 with the CCB4 marker

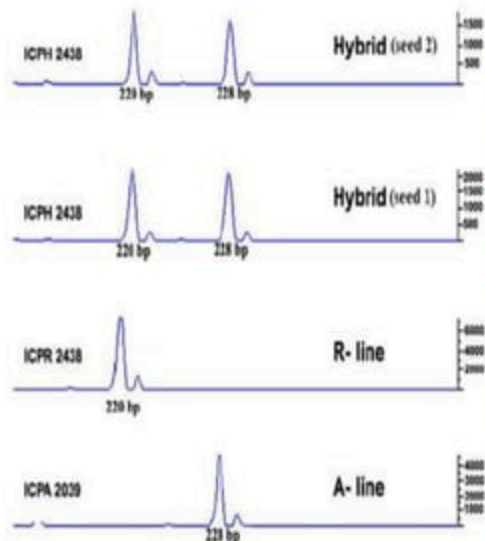


Table 20: A summary of purity assessment of ICPH 2438 hybrid seeds from two sources

Seed source /marker name	Allele size in (bp)			No. of hybrid plants	*Purity index (%)
	ICPA 2039	ICPB 2039	ICPR 2438		
ICRISAT					
CCB4	228	228	220	379	94.2
CCttc006	293	293	290	379	98.7
Mahabeej					
CCB4	228	228	220	91	95.6
CCttc006	293	293	290	91	97.8

* Purity index = [Number of true hybrids (containing alleles of both the parents) x 100]/Total number of hybrid seeds tested

Figure 2: SSR based molecular profiles of A-line (PA 163A) and R-line (AK 261322) and hybrid (IPH 09-5)

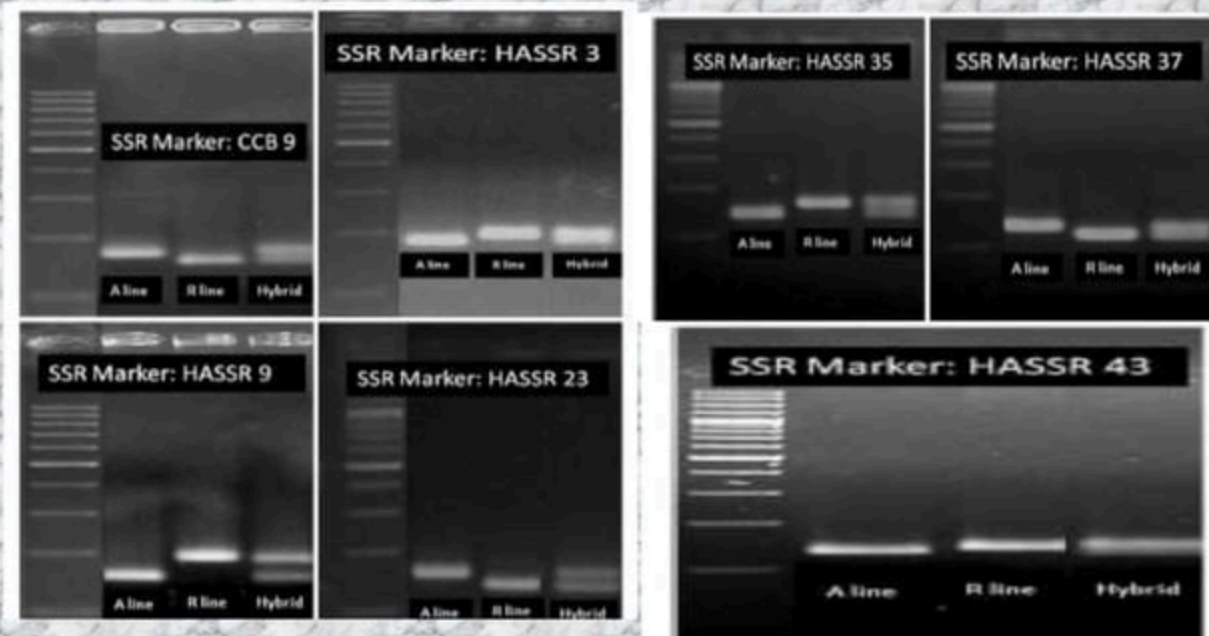


Figure 3. Validation of nad7 gene based marker nad7a_del in different A4 derived cytoplasmic male sterile (CMS) and its cognate maintainer lines.

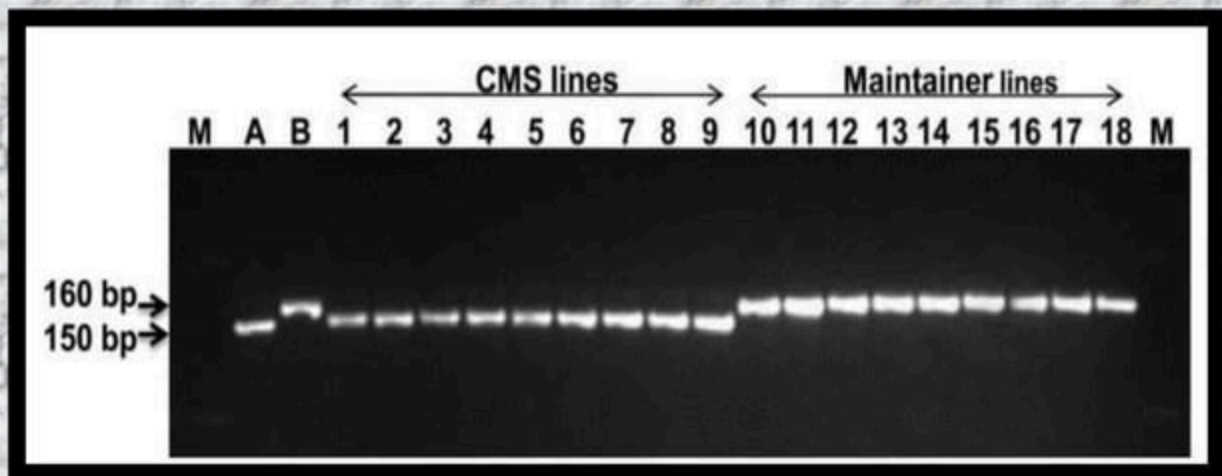


Table 21: GOT of GTH-1

Sr. No.	Characters	Hybrids / Parents			Maximum time / duration
		GTH-1 (SKNPCH-10)	GT-288-A (Female)	GTR-11 (Male)	
1.	Growth habit	Semi-erect	Erect	Bushy	80 days
2.	Growth type	NDT	NDT	DT	80 days
3.	Flower colour (standard)	Yellow with few red streaks	Yellow with few red streaks	Yellow	85 days
4.	Pod colour (pre-mature)	Green with black basal streaks	Green	Green with black streaks on entire pod	90 days

Table 22: Naked eye polymorphic (NEP) markers with potential to be used to track purity of pigeonpea hybrids and their corresponding parental lines; their expression time and inheritance

Trait	Phenotype	Genetic Control	Stage Of Expression	Heritability
Stem Color	Purple Vs. Green	Dominant, Single Gene	6–8 Wk After Sowing	Low
Leaf Shape	Obcordate Leaf Vs. Normal	Recessive, Single Gene	6 Wk After Sowing	High
Leaf Width	Narrow Leaf Vs. Broad Leaf	Recessive, Single Gene	4–5 Wk After Sowing	High
Growth Habit	Determinate Vs. Nondeterminate	Recessive, Single Gene	Flowering	High
Flower Colour	Yellow Vs. Red	Recessive, Oligo-genes	Flowering	Low–moderate
Pod Colour	Green Vs. Purple	Recessive, Oligo-genes	4–5 Wk After Sowing	Low–moderate
Seed Colour	White Vs. Brown	Recessive, Oligo-genes	Maturity	Moderate

Figure 1. Transition of obtuse to obcordate leaflets in ICP 5529. The arrow points to the terminal leaflet transitioning from **obtuse** (A) to **obovate** (B), **truncate** (C), and finally into **obcordate** (D); all of them are clearly different from normal lanceolate leaves.

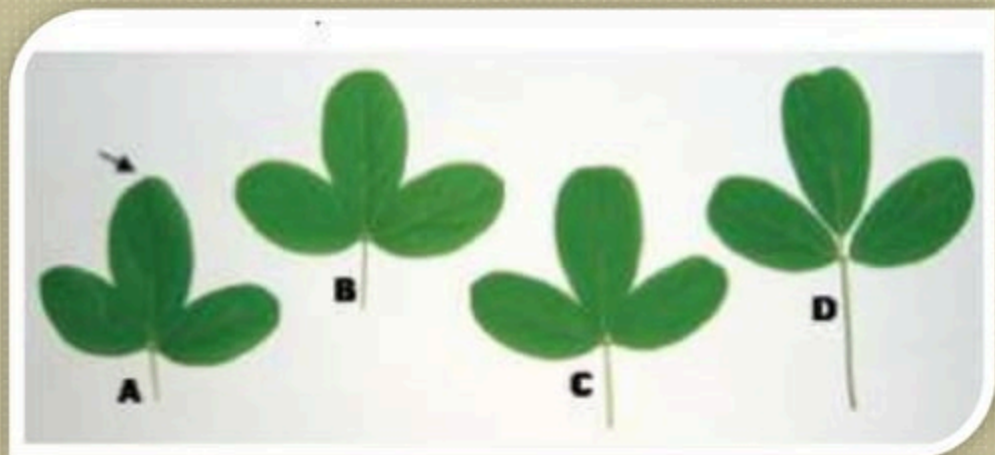


Figure 2. Breeding scheme to introgress the obcordate leaf trait from ICP 5529 to generate A lines (A4/rnrrn) with the obcordate leaves (set I)

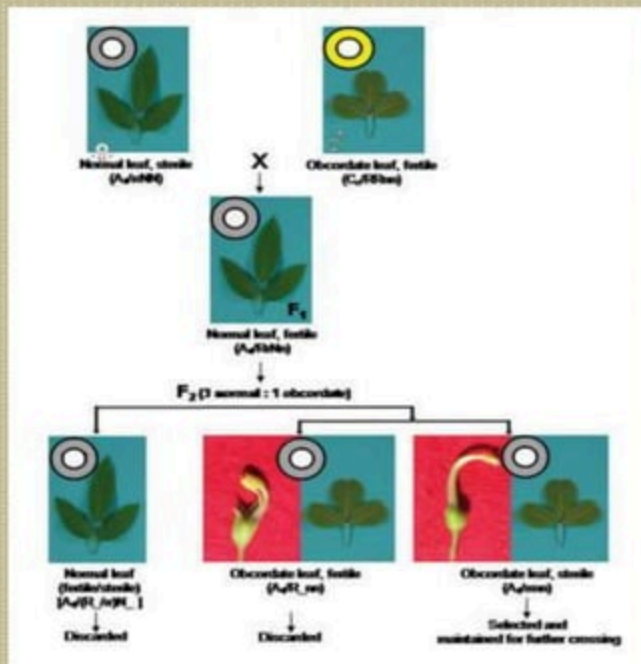


Figure 3. Breeding scheme to introgress the obcordate leaf trait from the ICP 5529 to generate B lines (C₄/rrnn) with the obcordate leaf trait (set II)

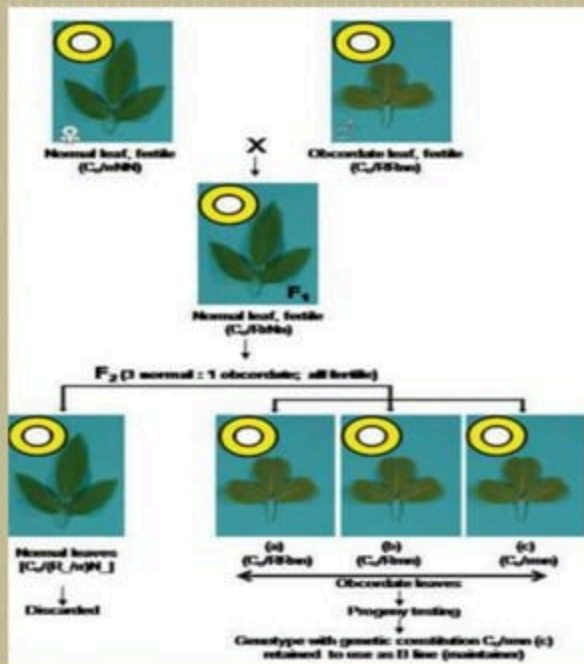


Table 23: Seed production of hybrid ICPH 2671 (A x R) in different locations 2007

State	Village	Area sown (ha)	Seed yield (kg)	Productivity (kg/ha)
Andhra Pradesh	Shadnagar	1.6	1400	875
	Gadivemula, Nandyal	1.6	1000	625
Andhra Pradesh	Alamur, Nandyal	1.6	10000	625
Andhra Pradesh	MK Puram, Nandyal	1.2	1000	833
Andhra Pradesh	Manapur, Ghanapur	1.2	1275	1063
Andhra Pradesh	Yallur	1.0	1000	1000
	Patancheru	0.4	500	1250
Andhra Pradesh	Medchal	0.4	500	1250
Andhra Pradesh	Eluru-1	1.2	750	625
Andhra Pradesh	Eluru-2	1.2	750	625
Andhra Pradesh	Eluru-3	1.6	1146	716

Table: 23 Conti...

State	Village	Area sown (ha)	Seed yield (kg)	Productivity (kg/ha)
Andhra Pradesh	Renjal	0.4	700	1750
Andhra Pradesh	Manoharabad	0.68	856	1258
Madhya Pradesh	Indore	0.15	340	2267
Gujarat	Ahmedabad	0.80	850	1063

Table 24: The pigeonpea ICPH 2671 hybrid (A×R) Seed production record in six Indian states

State	Locations	Highest yield (kg/ha)	Mean yield (kg/ha)
Andhra Pradesh	34 (6)	1750	998
Gujarat	4 (2)	1669	1179
Karnataka	2 (2)	1900	1138
Madhya Pradesh	9 (3)	3040	1674
Maharashtra	5 (2)	1017	603
Odisha	40 (1)	1040	523
Total/mean	94 (16)	3040	1019

Table 25: Some hot spots identified Hybrid seed production of ICPH 2671

Location	Area (ha)	Yield (kg/ha)
Madhya Pradesh		
Tikamgarh	5.0	3040
Seoni	1.0	2500
Indore	0.15	2267
Rewa	1.0	1740
Katni	3.0	1450
Jabalpur	1.5	1333
Andhra Pradesh		
Nizamabad	0.4	1750
Patancheru	0.4	1250
Medchal	1.4	1214
Warangal	1.2	1063
Nalgonda	2.0	1000

ECONOMICS OF HYBRID SEED PRODUCTION

Table 26: Profitability and cost of hybrid seed production of pigeonpea hybrid GTH 1

Sr. No	Particulars	Rates	Cost (Rs.)
1.	Seed cost	Female 18 kg @ Rs.50	900.00
		Male 3kg @ Rs.50	150.00
2.	Cultivation	3 hrs @ Rs.400	1200.00
3.	Sowing	2 hrs @ Rs.400	800.00
4.	Fertilizer	Dose 25:50:00 NPK kg/ha	1000.00
5.	Irrigation (Five)	5 @ Rs.600	3000.00
6.	Insecticides and Pesticides	As required	2000.00
7.	Rouging charges	3 @ Rs.400	1200.00
8.	Harvesting	12 labour @ Rs. 100	1200.00
9.	Thrashing	a. 2 labour @ Rs. 100	200.00
		b. 3 hrs thrasher @ Rs. 400	1200.00
10.	Grading	5 labour @ Rs. 100	500.00
11.	Packing charges	380 bag @Rs 10	3800.00
Total Expenditure per ha.			17150

Profit (Rs.) :

$$99085.00 - 17150.00 = 81935.00 \text{ or}$$

Seed cost of hybrid seed =

9.09 or Rs 9.00/kg

Profit /kg of seed = Rs 43.44 or 43.00




Particulars	Rates (Rs/kg)	Income (Rs.)
Hybrid seed production 1886 kg/ha	50	94300.00
Male seed production 319 kg/ha	15	4785.00
Total Income		99085.00

Table 27: Profitability and cost of hybrid seed production of pigeonpea hybrid ICPH 2671 at Indore during 2007

Item	Cost (Rs/ha)
Gross expenditure	
(a) Non-labors inputs	
Field preparation	2,000
Fertilizers & seed treatment	3205
Seed	900
Sub total (a)	6105
(b) Labor input @ Rs 93.50/day	
Sowing (40)	3,740
Weeding & Intercultur (58)	5,423
Roguing (20)	1,870
Spraying (22)	2057
Harvesting (45)	4,208
Threshing (32)	2992
Sub total (b)	20,290

Item	Cost (Rs/ha)
Cost of seed production	
Total expenditure (a+b) (Rs)	26,395
Hybrid yield harvested (kg)	1,400
Cost of producing one kg seed (Rs)	26,395 / 1,400 = 18.85
Gross returns (Rs/ha)	
Income from sale of 1400 kg hybrid seed @ Rs 60/kg	84,000
Income from sale of 800 kg R-line seed @ Rs 15/kg	12,000
Income from sale of total fuel wood	400
Total	96,400
Net Profit (Rs / ha)	96,400 - 26,395 = 70,005



Pigeonpea hybrid technology is now established with on-farm hybrid advantage of 30-50 per cent. The large-scale hybrid seed production is no more an issue. Since the cross-pollination primarily depends on insect pollinators, the selection of production sites helps in harbouring the hybrid yields of over 1500 kg/ha repeatedly harvested. Seed quality control is another key issue and this has been addressed by incorporating a naked eye polymorphic trait (obcordate leaf) in A- / B- lines. In the alternative approach, genomic science and GOT is being helped to determine the genetic purity of F₁ hybrids and their parents. Overall, the pigeonpea hybrid technology has reached a stage when it can be adopted easily. The statistics of hybrid pigeonpea with respect to on-farm heterosis, hybrid yields and profitability are comparable with other hybrid field crops.