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Pigeon pea (*Cajanus cajan*) an important food legume in Indian scenario – A review

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ABSTRACT

According to Indian Institute of Pulses Research Vision document, India's population is expected to touch 1.68 billion by 2030 and the pulse requirement for the year 2030 is projected at 32 million tonnes with anticipated required annual growth rate of 4.2%. Pigeon pea is an important legume crop cultivated across several countries throughout the tropics and subtropics. They are cultivated in India, Malaysia, Indonesia, the Philippines, Caribbean, East and West Africa. Commonly known as 'Arhar' in Northern India, this protein rich pulse crop has growing demand in Asia. Among the pulses pigeon pea is the second most important kharif grain legume after chickpea in India and grown predominantly under rainfed conditions. The kernels are nutritionally rich containing 20-22% protein. Its cultivation would be able to provide 40-60 kg N/ha to the subsequently grown crop. The leaves and immature stems can be used as a green manure. Fallen leaves can also be used as mulch and thus help to enhance the water holding capacity of soil. Its beneficial effect as an intercrop has also been reported. Sometimes ground dry peas are mixed with wheat flour just to improve the flour quality and its protein content. Additionally, pigeon pea shares a vital part in India's pulse import and export. Keeping all these in view the present review depicts the various aspects of pigeon pea cultivation and its status in Indian trade on pulse.

Key words: Cultivation, Intercropping, Medicinal use, Pigeonpea, Trade.

Pigeon pea [*Cajanus cajan* (L) Millsp] (In Sanskrit: Adhaki, Hindi: Arhar, English: Pigeon pea, Bengali: Tur) is a perennial member of the family Fabaceae. It is also known as red gram, congo pea, gungo pea, and no-eye pea (Wu, 2009). Pigeon pea is a tropical and subtropical species particularly suited for rainfed agriculture in semi-arid areas due to its deep taproot, heat tolerance and fast growing habit (Mallikarjuna *et al*., 2011). It is the sixth most important grain legume crop grown in the semi-arid tropics of Asia, Africa and the Caribbean under a wide variety of cropping systems (Mula and Saxena, 2010). Pigeon pea is a legume reported to contain 20-22% protein, 1.2 % fat, 65% carbohydrate and 3.8% ash (FAO 1982). Its demand in India is significant because it can provide high quality protein in diet, especially to the vegetarian population (Bhattacharjee *et al*., 2013). It is a fast growing, hardy, widely adaptable and drought resistant (Bekele-Tessema, 2007). It is very heat-tolerant and grows better in places where temperatures range from 20° to 40°C and which are deprived of frost (FAO, 2016). Being environmental friendly by fixing nitrogen, flexibility for mixed cropping or inter crop, due to this it has significant position in dry land farming systems especially adopted by small and marginal farmers in many parts of world (Pandit *et al*., 2015). In addition to being efficient in fixing nitrogen in field conditions, pigeon pea rhizobia also present other biotechnological applications, such as biopolymer production and enzymatic activity (Fernandes *et al*., 2012; Junior *et al*., 2011). Its deep taproot is able to extract nutrients (like P) from the low layers lower layers of soil, and bring them to upper layers where they can benefit to other crops (Valenzuela, 2011). Thanks to drought resistance as it can be considered of utmost importance for food security in regions where rain failures are prone to occur (Crop Trust, 2014).

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Origin

The centre of origin of pigeon pea is probably peninsular India, where the closest wild relatives (*Cajanus cajanifolia*) occur in tropical deciduous woodlands (Van der Maeson., 1995). But, some other opinions state that the origin of *Cajanus cajan* was either from Northeastern Africa or India (Ecocrop, 2016; van der Maesen, 1989). Archaeo logical finds of pigeon pea dating to about 3400 years ago (14th century BC) have been found at Neolithic sites in Karnataka (Sanganakallu) and its border areas(Tuljapur Garhi in Maharashtra and Gopalpur in Orissa) and also the south Indian states such as Kerala, where it is called Tomara Payaru (Fuller, and Harvey, 2006). From India it traveled to East Africa and West Africa. There, it was first encountered by Europeans, so it obtained the name Congo Pea. By means of the slave trade, it came to the American continent, probably in the 17th century (Carney and Rosomoff, 2009). According to Van der Maesen, 1980, India is the native of pigeon pea because of its natural genetic variability available in the local germplasm and the presence of its wild relatives in the country.

Area and production

World production of pigeon peas is estimated at 4.49 million tons. About 63% of this production comes from India. Africa is the secondary centre of diversity and at present it contributes about 21% of global production with 1.05 million tons. Malawi, Tanzania, Kenya, Mozambique and Uganda are the major producers in Africa. The total number of hectares grown to pigeon pea is estimated at 5.4 million. India accounts for 72% of area grown to pigeon pea or 3.9 million hectares (FAO, 2018). India is a principal pigeon pea growing country accounting for approximately 90% of the total world production (Singh and Vaishampayan, 2017; Bhattacharjee and Sharma, 2015). In India, it is the second most cultivatable pulse crop after chickpea which cultivated on about 3.62 million ha (Singh *et al*., 2015). Although Uttar Pradesh is the biggest producer of pigeon pea in India but its average yield is lower in comparison to adjoining states *viz*., Jharkhand and Bihar (Ahlawat *et al*., 2005; Prasad *et al*., 2017).

Table 1a: Area, production and yield of pigeon pea in India.

Year	Area (Million Hectares)	Production (Million Tonnes)	Yield (Kg/ Hectare)
2007-2008	3.73	3.08	826
2008-2009	3.38	2.27	671
2009-2010	3.47	2.46	711
2010-2011	4.37	2.86	654
2011-2012	4.01	2.65	661
2012-2013	3.89	3.02	776
2013-2014	3.90	3.17	813
2014-2015	3.85	2.81	729
2015-2016	3.75	2.46	656

Source: Directorate of Economics & Statistics, DAC&FW.
*4th Advance Estimates.

Botany

Pigeon pea plants are a perennial legume which can reach a height upto 3 feet to 12 feet. The compound leaves of this plant consist of three green leaflets which have a pubescence and darker color on the upper side and a gray-green color on the underside. The flowers are yellow with red lines or completely red on the exterior (Jonael Bosques). The flowers are bisexual, zygomorphic and predominantly yellow (Sundaraj and Thulasidas, 1980). The inflorescence is raceme which contain up to ten flowers per panicle and usually two flowers open at a time on a single inflorescence (Sharma and Green, 1980). The androecium has 10 stamens bunched into two groups (diadelphous) of 9 and a single free stamen that is attached at the base of androecium. The fruit of pigeon pea is a flat, straight, pubescent, 5-9 cm long x 12-13 mm wide pod. It contains 2-9 seeds that are brown, red or black in colour, small and sometimes hard coated (FAO, 2016; Bekele-Tessema, 2007). The 100 seed weight of short duration cultivated varieties are low (generally 6-8 grams) as compared to long duration varieties (9-13 g). Root of pigeon pea is well developed in upper 60 cm soil profile (Natarajan and Willey, 1980). The root system consists of fine lateral roots as well as a large taproot. This root provides the capacity to overcome moderate drought

Table 1b: Pigeon pea: Area, production and yield during 2014-15 and 2015-16 in major producing states along with coverage.

State	2014-15					2015-16*				
	Area (M. ha)	% to all India	Production (M. tons)	% to all India	Yield (Kg/ha)	Area (M. ha)	% to all India	Production (M.tons)	% to all India	Yield (M. ha)
Madhya Pradesh	0.52	13.53	0.51	18.20	981	0.58	15.44	0.62	25.40	1079
Maharastra	1.21	31.43	0.73	25.86	600	1.04	27.71	0.47	19.01	450
Karnataka	0.73	18.91	0.47	16.89	651	0.65	17.28	0.26	10.69	406
Gujrat	0.21	5.56	0.24	8.37	1098	0.23	6.05	0.24	9.63	1044
Uttar Pradesh	0.29	7.45	0.17	6.20	606	0.27	7.07	0.18	7.44	691
Jharkhand	0.20	5.09	0.20	7.11	1018	0.19	5.16	0.17	7.06	896
Andhra Pradesh	0.15	3.92	0.08	2.71	503	0.22	5.87	0.13	5.24	586
Odisha	0.14	3.58	0.12	4.41	898	0.14	3.69	0.12	4.98	886
Telengana	0.22	5.71	0.11	3.88	495	0.25	6.61	0.10	4.23	419
Tamil Nadu	0.07	1.88	0.08	2.74	1064	0.06	1.60	0.06	2.34	957
Bihar	0.02	0.52	0.03	1.02	1438	0.02	0.57	0.03	1.31	1511

Source: Directorate of Economics & Statistics, DAC&FW.
*4th Advance Estimates.

periods (Jonael Bosques). The vegetative growth of the pigeon pea starts slowly, but accelerates when the plant reaches 2 to 3 months.

Medicinal uses

Pigeon pea possesses various medicinal uses. Most of the citations are dealing with pigeon pea leaves, which are mainly anti-inflammatory, anti-bacterial and abirritative properties (Fu *et al*., 2007). Leaves can be used to treat traumatism, burnt infection, bedsore, cough and diarrhoea (Sun *et al*., 1995). Amongst its many medicinal uses, pigeon pea is indicated in the relief of pain in traditional Chinese medicine and as a sedative (Ahsan *et al*., 2009). The wide ranging biological activities and medicinal properties of diverse chemical compounds obtained from pigeon pea were reviewed recently by Pal *et al*. (2011). Cajanol an isoflovanone found in the roots having anticancer activity were also demonstrated in vitro against human breast cancer cells by Luo *et al*. (2010). Genistein and apigenin is a pair of isomeric compounds found as the main constituents present in pigeon pea roots and possess a wide spectrum of pharmacological activities. Genistein (40,5,7-trihydroxyisoflavone) is a principal isoflavone and a kind of plant estrogen with anti-oxidant, anti-inflammatory (Kang *et al*., 2003; Saxena *et al*., 2010a), anticancer (Sonn *et al*., 2005; Wu *et al*., 2008) and protein kinase inhibitory activities (Kang *et al*., 2001). It has low toxicity and is commonly used as a dietary supplement (Weiss and Landauer, 2003). Apigenin (40,5,7-trihydroxyflavone) is a potent flavone, which shows an extraordinary anti-inflammatory, anticancer, antiviral, anti-oxidant and free radical scavenging activities (Wang and Huang, 2004). It has been used widely for many years for treating diabetes, sores, skin irritations, hepatitis, measles, jaundice, dysentery and many other illnesses; for expelling bladder stones and stabilizing menstrual period (Yuan-gang *et al*., 2010; Oke, 2014). In some parts of Tamil Nadu, India, leaves, seeds and young stems are used to cure gingivitis, stomatitis and as a toothbrush (Ganeshan, 2008).

Insect-pests and control

Pigeon pea are damaged by a large number of insect pests, of which pod borer (*Helicoverpa armigera*), legume pod borer (*Maruca vitrata*), spiny pod borer (*Etiella zinckenella*), pod fly (*Melanagromyza obtuse*), leaf miner (*Liriomyza cicerina*), stem fly (*Ophiomyia phaseoli*), pea and bean weevil, aphids (*Aphis craccivora*, *Aphis fabae* and *Acyrthosiphon pisum*), white fly (*Bemisia tabaci*), defoliators (*Spodoptera litura*, *S. exigua*, and *Amsacta spp*.), leaf hoppers (*Empoasca spp*.), thrips (*Megaleurothrips dorsalis* and *Caliothrips indicus*), blister beetles (*Mylabris spp*.) and the bruchids (*Callasobruchus chinensis* and *Bruchus pisorumcause*) cause extensive losses worldwide (Sharma *et al*., 2005). This crop is attacked by more than 250 insect pests but the damage caused by *Helicoverpa armigera, Melanagromyza obtusa, Maruca vitrata* and *Clavigralla gibbosa* results in major reduction to grain yield. However, improved cultivation practices along with location specific Integrated Insect Pest Management approach results in enhancement of yield (Srivastava and Joshi, 2011). Particularly *Helicoverpa armigera* caused pod damage of 20-57 per cent in both early and late maturing varieties, ensuring the losses in seed yield up to 28 per cent (Sahoo and Senapati, 2000). The grain yield losses due to *M. obtusa* have been reported in the range of 60-80 per cent (Durairaj, 1995) and from *M. vitrata* has been reported ranging between 50-68 per cent in pigeon pea (Sharma and Franzemann 2000). Saindane *et al*., (2016) showed that spraying of quinalphos 25 EC (350 g a.i./ha) at fortnightly interval was found to be the most effective in controlling pod borers on pigeon pea. Among microbials tested, *Nomuraea rileyi* 1.15 WP (5 g/lit) and *Metarrhizium anisopliae* 1.15 WP (5 g/lit) at fortnightly interval found effective at 7 DAS and onwards to control pod borers and resulted in appreciable yield over untreated control. Sharma *et al*. (2014) suggested that chlorpyriphos 20 EC would to be the best treatment to control *Helicoverpa armigera*. They recommended the use of combination of insecticide with neem formulations. The use of insecticide in half the quantity with half quantity of neem products will be very effective if compared with chemical insecticide alone to control pod borer *Helicoverpa armigera,* the key pest of pigeon pea. Among various treatments tested, chlorpyriphos 0.05% was found superior with 2.6% infestation authenticated by Gandhi *et al.* (2013). Singh and Nath, (2011) reported that Tur pod bug *Clavigralla gibbosa* (Spinola), a potential pest and occasionally cause significant grain yield losses in long duration pigeon pea. The damage in grain yield due to pod bug generally ranges between 25 to 40 per cent (Gopali *et al*., 2013). In an experiment by Srujana and Ram Keval (2014), application of Imidacloprid 17.8 SL @ 20 g a.i. /ha gave the best result in which the percentage grain damage of 2.9% was found followed by thiamethoxam 25 WG @ 75 a.i /ha (3.1%) and then acetamiprid 20 SP @ 20g a.i. /ha (3.4%). Meena *et al.* (2010) reported that tur pod fly, *Mealanagromyza obtusa* is the major insect pest of long duration pigeon pea, especially in north and central India. The concealed mode of life of pod fly within the pod (Subharani and Singh, 2010) makes it difficult to control, with chemical insecticides. Therefore, host-plant resistance is an important tool for management of this pest (Jaisal *et al*. 2010). Bruchids (*Callosobruchus chinensis*) is a major storage pest of pigeon pea and several other grain legumes known to cause substantial economic losses. Seed treated with castor oil provided the best protection from the insect infestation as compared to all other seed treatments. Vinod kumar *et al.* (2014) reported that test weight decreased gradually as insect infestation increased at the end of 12^{th} month of storage period. Castor oil treated seeds maintained the highest test weight (10.22 g) among the botanicals followed by sweet flag rhizome powder (10.09 g) and these botanicals were found to be on par with chemically treated seeds. Polythene bags act as better storage container as compared to the cloth bag.

Weed management

Slow growth habit of pigeon pea at initial stages encourages rapid growth of weeds and leads to severe crop weed competition, which eventually reduces the crop yield (Channappagoudar and Biradar, 2007). Moasunep *et al.* (2014) noted lowest dry weight of weeds (15 g m^{-2} and 32.00 g m^{-2}) at 60 and 90 DAS with the application of Imazethapyr @75 g a.i./ha + Quizalofop ethyl @ 50 g a.i./ha on 15 DAS+ one hand weeding on 50 DAS/ Intercultivation. Hand weeding twice (20 and 40 DAS) produced better plant growth and seed yield. Highest net return and B:C ratio were noticed when weeds were removed by hand weeding at 20 and 40 DAS. It has been observed that pre emergence application of pendimethalin at 1 kg a.i/ha on three DAS with one hand weeding on 30 DAS was found to be most effective and economical weed management practice in rainfed pigeonpea for getting higher net returns and B:C ratio (Chakravarthy and Manoharan, 2016). Channabasavanna *et al*. (2017) studied the performance of post emergence herbicides on the control of grassy weeds in pigeon pea and its residual effect on the following pigeon pea. Application of Imazethapyr @ 0.075 kg/ha and hand weeding twice at 20 and 40 DAS recorded the highest grain yield of 1683 kg/ha and 1521 kg/ha, respectively and was followed by propaquizafop @ 0.062 kg/ha (1372 kg/ha). The weed control efficiency was highest in hand weeding (100%) closely followed by phenoxaprop-p-ethyl (99.7%) and imazethapyr (99.2%). Herbicides had no residual effect on the following pigeon pea.

Diseases and management

Though several factors are known to affect pigeon pea cultivation, the most important being the diseases. Wilt, stem rot, canker, sterility mosaic are the important diseases that threaten pigeon pea production in several pigeon pea growing regions. Among the diseases, *Fusarium* wilt caused by *F. udum* is the most important soil borne disease. The disease appears on young seedlings but the highest mortality occurs during flowering and podding stage (Patil *et al.,* 2005). It is economically important disease in India due to differential host range of *F.udum* on pigeon pea (Rangaswamy *et al.,* 2012). Sunil Kumar *et al.* (2014) noticed that as the sowing was delayed, disease incidence gradually declined indicating negative relationship between sowing dates and disease incidence. Maximum disease incidence of 88.5% was recorded on earliest date of sowing *i.e.,* 1st July sown crop followed by 16th July (87.1%) which were on par whereas 16th August sown crop had recorded least disease incidence (74.3%) and on par with 1st August sown crop. Singh and Singh (2010) reported significant influence of sowing dates on myrothecium leaf spot disease intensity and yield of pigeon pea caused by *Myrothecium roridum*. The minimum disease intensity (28.6%-26.3%) was observed when the crop was sown early in the season (16th June), whereas maximum disease intensity 43.3%-41.5% was observed when the crop was sown late (16th July). The disease intensity was also high when the crop was further delayed in sowing (23rd July), but its declination percentage was at gradual level. Hence, for the optimum yield the crop could be grown in between 16th to 23rd June. Shakywar *et al.,* (2013) reported that systemic fungicide (ridomil MZ 72 WP @ 2.0 g/kg seed), contact fungicide (indofil M-45 @ 2.5 g/ kg) and *T. viride* 10g/kg seed were the effective treatments and can be recommended at a large scale for management of *Alternaria* blight of pigeon pea.

Intercropping

The initial slow growth rate and deep root system of pigeon pea offers a good scope for intercropping with fast growing early maturing and shallow rooted crops (Nandhini *et al*., 2015). Selection of an appropriate component crop could enhance the total productivity of the system by virtue of best use of available resources and inputs (Praharaj *et al*., 2015). Pigeonpea is suitable for inter- cropping with different crops like cotton, sorghum, pearlmillet, mungbean, urdbean, maize, soybean and groundnut for increasing the system productivity and improving the soil health. Growing of blackgram or sorghum as intercrop helps to sustain the productivity and the system would prove to be a viable intercropping system (Pal *et al*., 2016). It has also been identified as a highly popular legume suitable for intercropping with maize due to its high social acceptance and ease of adoptability (Bezner-Kerr *et al*., 2007; Mhango *et al*., 2012). Intercropping system suppress the attack of pest and diseases as compared to monocropping. Equal or more yield of musli under intercropping with pigeon pea indicate that these crops do not compete with musli for underground resources such as nutrients and moisture and a certain degree of shade (30-40%) is helpful for the growth and root production of musli (Singh *et al*., 2010). Lad *et al*., (2016) found a significant effect of different row proportions of Safed musli + Pigeon pea on incidence and intensity of foliar diseases of Safed musli caused by*Alternaria alternata* and *Phoma* spp. Intercropping had significant difference in reduction of pod damage, grain damage (in number and by weight basis) as compared to pigeonpea monocrop. The intercrops pigeon pea + rice, pigeonpea + sorghum and two sprays of NSKE 5% were found most effective combination for the management of pod, grain and grain weight loss by pod bug, *Clavigralla. gibbosa* (Singh and Nath, 2011). Pal *et al*. (2016) reported highest grain yield and stalk yield of pigeonpea in pigeon pea + urdbean and lowest in pigeonpea + sorghum system. Being excellent cover crops, it also plays a greater role in control of soil erosion through protecting soil from direct rains (Mula and Saxena, 2010). Srichandan *et al*., (2015) found that maximum seed yield of pigeonpea was recorded in pigeon pea + rice intercropping system than rest of cropping systems. Rai *et al*. (2015) showed that pigeonpea + greengram system fetched maximum gross returns, net returns and B: C ratio followed by pigeonpea + blackgram and lowest was in sole pigeonpea. Nagar *et al*. (2016) reported significantly highest soil microbial biomass carbon (SMBC) and microbial population (fungal, bacterial and actinomycetes); and lower bulk density, pH and EC, higher OC and available N, P, K under pigeonpea + blackgram and pigeonpea + greengram intercropping over sole pigeonpea. Ray *et al*. (2016) observed that pigeonpea

+ black gram (1:1) performs better in terms of net return and PEY (Pigeonpea Equivalent Yield) over all other combinations followed by pigeonpea + green gram (1:1). Kathmale *et al*., (2014) reported that among pigeonpea based intercropping systems, pigeonpea + groundnut (1:3) recorded maximum PEY (1425 kg/ha) followed by pigeonpea + soybean (1:3), whereas, maximum LER was in pigeonpea + soybean (1:3) intercropping system.

Genetic resources

Plant breeders have created varieties adapted to drier conditions, more resistant to diseases and suited to different production systems and cropping cycles (Valenzuela, 2011). To investigate the host plant resistance to pod bug, *Clavigralla gibbosa* screening is an appropriate method to identify resistant genotypes. Its incidence increases with the advancement of crop age and actual damage to the economic produce also takes place after flowering in case of pulses. Among the twenty nine genotypes screened, IVT-520, IVT-509 and AVT-603 were found to be the most resistant against pod bug damage and hence should be promoted (Singh *et al*., 2017). Twenty two pigeon pea genotypes were screened on the basis of physiological parameters at eight day old seedling stage with 20, 30, 40, and 50mM NaCl concentrations. Screening was carried out for the following physiological parameters *viz.,* per cent of germination, RL/SL (root length/ shoot length), RFW/SFW (root fresh weight / shoot fresh weight), RDW/SDW (root dry weight / shoot dry weight) and SVI (seed vigour index). Moreover STI (Salt tolerant index) and SSI (Stress susceptibility index) were also investigated for all genotypes to determine the tolerance and sensitivity, respectively. Genotypes differed significantly at higher NaCl concentration (40 and 50mM NaCl) for RL, SL and SVI due to increased ion toxicity. On the basis of calculated STI and SSI for vigour index, genotype AL 1816 was found to be tolerant and AL 1881 sensitive, at 40 and 50mM NaCl concentration, respectively (Johal *et al*., 2016). The most important yield constraint on pigeon pea is the lepidopteron pest, *Helicoverpa armigera*. Efforts were made to develop transgenic plants independent to tissue culture method with high efficiency and expression ofcry1 Aa3 gene for resistance against legume pod borer *H. armigera*. Therefore, a protocol of *Agrobacterium* mediated genetic transformation of pigeon pea genotype GT-102 was developed by using *Agro- bacterium* strain LBA 4404 harboring a modified binary vector pBIN1*Aa3* carrying the marker gene *neomycin phosphotransferase II* (*npt II*) and a synthetic *cry1 Aa3* gene under a constitutive 35S promoter. The protocol for pigeon pea transformation reported here is highly efficient and genotype independent as well. (Parekh *et al*., 2014). Ten promising varieties of pigeon pea were raised to assess the processing quality and protein, methionine and tryptophan contents. Husk varied from 13.99-17.68% and dahl from 58.20 to 67.95%. Maximum dahl recovery was observed in Amar variety (67.95%) followed by KA-09-0-01, T-21, Mal-13, Azad, Shekhar-3, Bahar and UPAS-120. Broken dahl recovery ranged between 6.84 to 14.29%, lowest being in Amar and highest in KA-26-4. T-21 showed highest protein content both in grain and dahl, the values being 22.92 and 26.44%, respectively. Azad and Shekhar-3 had maximum methionine content (1.033 mg per 16 g N) while KA-09-0-01 variety showed highest tryptophan content of 0.80 mg per 16 g N in dahl (Babu *et al*., 2014). Genetic amelioration for disease resistance considered to be the most effective and economical method of protecting the crops to ensure their productivity. Kumar and Rani (2010) have evaluated ninety six germplasm collections comprising of local collections, released varieties, advanced lines selected from previous year and germplasm accessions received from ICRISAT and IARI Pusa were screened for resistance to *Alternaria* blight. Three entries *viz,* RAUP-32, RAUP-34 and Pusa-(B)-35 were found to be resistant (1-10% intensity) in reaction. Genotypes RAUP-32, RAUP-34, Pusa-(B)-35 may be utilized as donor for resistance in breeding against *Alternaria* blight.

Pollination

Pigeon pea is partially cross pollinated crop with diploid chromosome number 2n=2x=22 and genome size 1C= 858 Mbp. Like soybean and other pulses, pigeon pea is self-pollinated crop but yield increases by bee pollination (Abrol and Shankar, 2015). Singh *et al.* (2017b) studied on pollinator complex and revealed that, *C. cajan* flowers attracted 15 species of insects belonging to five families, 7 genera and three orders. The Hymenoptera insect were most abundant. Of all the bees, megachilid bees were most abundant and compared more than 50 % of the total flower visiting insects followed by honeybees 39.4% and anthophorid bees 6.6%. Bee pollination was superior to all other treatments in improving qualitative and quantitative parameters of *C. cajan* crops in the order: bee pollination > open pollination > hand pollination > selfpollination > Carbaryl 50 WP 0.1% + Open pollination > Imidacloprid 17.8 SL 0.05% + Open pollination. More *et al*., (2015) showed that 4-framed *Api indica* was superior for number of pods per plant and weight of 1000 seeds, whereas 6-framed *Apis mellifera* was superior for number of seeds per plant, yield in kg per ha and per cent seed setting and a colony of *Apis florea* was superior for per cent crinkled seeds while per cent of germination was high under open pollination. Rajkhowa and Deka (2016) reported highest pod set in Bee pollination @ 5 hives/ha (78.5%). There was 138.3% yield increase of pigeon pea with bee pollination @ 5 hives/ha treatment over without bee pollination (WBP).

Fertilizer application

Integration of inorganic, organic and biofertilizers are essential in realizing the higher yield and reducing cost of cultivation of pigeon pea. Goud and Kale (2010) reported that the uptake of NPK and S by pigeon pea increased significantly due to the application of 18:46:20:20 kg N:P:K:S/ha compared with its reduced levels. Higher protein and grain yield of pigeon pea fertilized with 25:50:25 NPK kg/ha along with foliar spray of 1% 19:19:19 NPK grade was reported by Mallesha *et al*. (2014). Balpande *et al*., (2016) observed higher N and P uptake due to the application of 30 kg K and 20 kg S/ha. The highest K uptake was noticed with the application of 45 kg K and 20 kg S/ha in combination. The recovery of NPK was higher in 30 kg potassium per hectare. Highest uptake of calcium was observed in the application of 30 kg K and 20 kg S / ha. Application of FYM @ 5.0 t/ha or vermicompost @ 2.5 t/ha with 100% RDF proved equally effective for enhancing the grain yield of pigeon pea and both produced significantly higher grain yield than RDF alone (Pandey *et al*., 2013). Ray *et al*. (2015) recommended 150 kg/ha lime with 4g/kg of molybdenum and 75% of recommended dose (@ 20:60:40 of NPK for nutrient management practice of pigeon pea under rainfed conditions in Alfisols. Aher *et al*., (2015) reported that quality protein content (20.52 %) was improved significantly by the application of higher levels of phosphorus @ 100 kg P_2O_5/ ha. $ZnSO_4$ @ 15 kg/ha along with RDF exhibited higher yield attributes and grain yield of pigeon pea however, it was statistically similar with RDF+$ZnSO_4$ 25 kg/ha (Rathod *et al*., 2016). Higher yield attributes, grain and stover yield were produced with the application of 200% RDF (30:60:30:30 kg NPKS/ha) but it was statistically similar to 150% RDF (Singh *et al*., 2016a). Sahay *et al*., (2015) showed improvement in N, P, K content in grain and stalk of pigeon pea with the fertilization of 100% RDF + 5 t FYM + Rhizobium + PSB.

Irrigation

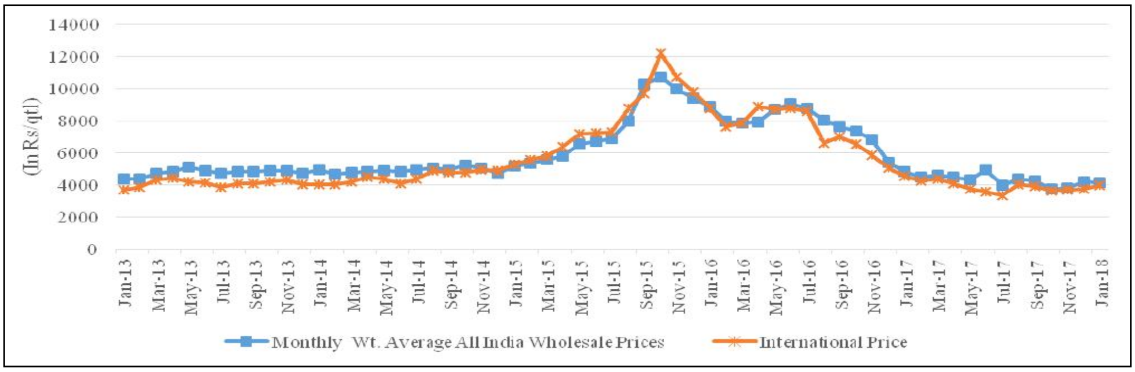
In addition to nutritional content of pigeon pea, there are many reasons that support numerous unique characteristics suitable for dry land agriculture such as resource conserving nature, capability to produce higher economic yield levels due to deep root system even under limited moisture conditions (Pandit *et al,* 2015). Pigeon pea is one of the most drought tolerant legume crops, with a wide rainfall tolerance. In dry areas with less than 400 mm annual rainfall, water can be supplemented by irrigation for the first two growing months and during flowering to harvesting the irrigation should be ceased to reduce damage by pests and diseases (Department of Agriculture, Forestry and Fisheries, Republic of South Africa, 2009). The low yield of pigeon pea is not only due to unavailability of good quality seeds but due to faulty agro techniques, where soil moisture plays a very critical role for flowering and pod development which leads to reduction in grain yield (Sharma *et al*., 2012). Saritha *et al*., 2012 suggested two irrigations one at flower initiation and another at early pod formation stage significantly increased yields of pigeon pea as compared to control and one irrigation at early pod formation stage.

Commercial hybrids

To increase the national pigeon pea production, now efforts are being made to introduce hybrid cultivation. The first hybrid ICPH 2671 was produced by crossing ICPA 2043 with ICPR 2671. It was released in 2010. The ICPH 2671 performed well in Maharashtra, Andhra Pradesh, Madhya Pradesh and Jharkhand; and on an average, the hybrid recorded 51% superiority over the respective controls (Saxena *et al.,* 2013). After the success of ICPH 2671, two more hybrids were released in India. These were ICPH 3762 in Odisha in 2014 (Saxena *et al.,* 2014) and ICPH 2740 in Telangana (Saxena *et al.,* 2015). Introduction of hybrid cultivation is a key to enhance the productivity of pigeon pea and thus the persistent yield plateau can be ruined.

Over all scenario of pigeon pea in India

India accounts for more than 90 per cent of the world's pigeon pea produc- tion and area (Mathukia *et al.,* 2016). Total production, import and export of pulse in India was 22.95, 6.61 and 0.14 million tonnes, respectively in 2016-17 and expected to be 22.90, 5.10 and 0.09 million tonnes, respec- tively in 2017-18 (Source: Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Department of Commerce). Pigeon pea contributed 15.65% share to total pulse production during 2016-17 and expecting 20.82% share in 2017-18. In 2015-16 the production of pigeon pea was 2560 Thousand Tonnes and the same is expected to be 4780 thousand tonnes in 2017-18. The average domestic price was moderately high compared to the international price (Fig 1). In 2017-18 its export is expected to be 8.45 thousand tonnes compared to 12.30 thousand tonnes in 2016-17 having 9.62 and 8.96% share in total pulses export, respectively. It is exported mainly to



Source: Department of Agriculture & Cooperation (DAC), Agmarknet and Agriwatch.

Fig 1: Price Trend of Pigeon pea.

USA (40.79%) followed by U Arab EMTS (18.28%). The other countries where it is exported are Canada (11.28%), UK (10.75%), Singapore (5.11%). Myanmar (46.35%) is the major import source followed by Tanzania (18.71%), Mozambique (15.36%), Malawi (12.56%) and Sudan (3.36%). India imported about 703.54 thousand tonnes of pigeon pea, comprising 10.64 % share in total pulses import during 2016-17. During 2017-18, the import amount is expected to be as 309.35 thousand tones registering 6.60% share in India's import basket of pulses (Source: Directorate of Economics and Statistics, Source: Department of Commerce).

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