Chapter 4

TECHNOLOGICAL INNOVATIONS IN PULSE PRODUCTION

B. Mishra

Not only do pulses contain higher protein in comparison to cereals, they also contribute to the sustainability of the environment through biological nitrogen fixation. For example, depending on the soil and agroecological environment, the chickpea plant fixes 23 kilograms to 97 kilograms (of nitrogen per hectare), pigeon pea fixes 4 kilograms to 200 kilograms, black gram fixes 119 kilograms to 140 kilograms, and green gram fixes 50 kilograms to 66 kilograms (Wani, Rupela, and Lee 1995). The biological nitrogen fixed by the preceding pulse crop saves a significant amount of synthetic nitrogen input that would otherwise be needed by the subsequent crop, carrying potential risks to the environment due to nitrogen runoff contaminating underground and surface water. This combination of high nutritional value and environmental benefit, together with their established place in traditional Indian diets, makes pulses an important target of long-standing and continuing agronomic research.

Background

Research on pulses in India started as early as 1905, with a modest beginning at the Imperial Agricultural Research Institute, now known as the Indian Agricultural Research Institute (IARI). Among pulses, chickpea and pigeon pea have a long history of research in the states of Madhya Pradesh, Maharashtra, and Uttar Pradesh. Research work on green gram and black matpe was initiated at Pusa in Bihar in 1925 with the collection of landraces (the varieties traditionally cultivated over a very long period) and selection based on various traits. However, systematic research on pulses commenced only with the establishment in 1967 of the All India Coordinated Pulses Improvement Project (AICPIP), which was later elevated to the Indian Institute of Pulses Research (IIPR). Table 4.1 presents the facts about All India Coordinated Research Project (AICRP) centers for different pulses in India. Assessed in terms of the number of centers, pigeon pea and chickpea

TABLE 4.1 All India Coordinated Research Project (AICRP) centers in India

Crop	Main center	Subcenter	Voluntary center	Total
Chickpea	9	15	34	58
Pigeon pea	9	17	11	37
Other	6	21	10	27

Source: AICRIP Annual Reports, various years

occupy the prominent position, with 75 percent of the centers focused on just these two pulse crops. The other pulses combined are covered by only 25 percent of the research centers. This chapter provides stylized facts about various technological innovations developed and adopted for pulse production in India over time.

Study Objectives and Data Sources

The objectives of the study presented this chapter are threefold: (1) to review the development of various technologies and innovations, including biotech innovations, in the production of the major pulses in India; (2) to look into the use of wild species as a source of gene pools, particularly for resistance to biotic and abiotic stresses; (3) to prepare an inventory of region-specific and environment-specific varieties of major pulses in India. The study is based on the secondary data collected from various publications, including the annual reports of the IIPR and the International Crop Research Institutes for the Semi-Arid Tropics (ICRISAT); the AICRP's reports on pigeon pea, chickpea, and other commodities; and several published research papers on the topic of technology development in pulses in India.

Development of Pulse Varieties

In India, pulse research has largely focused on five broad areas: (1) breaking the yield barrier; (2) developing resistance to pests and diseases; (3) breeding varieties for nontraditional and marginal areas; (4) reducing the length of the growing season by developing short-duration varieties; and (5) improving quality, especially in grain size. The early research efforts to break the yield barrier in pulses had limited success. Despite a growing demand-supply gap in pulses and modest progress on breaking the yield barrier compared to the achievements in rice and wheat, the number of full-time scientists engaged in

TABLE 4.2 Pulse cropwise varieties developed and released in India

	Number of varieties	
Pulse crop	Developed	Released (after 1990)
Chickpea	180	60
Pigeon pea	129	68
Green gram	130	45
Black matpe	90	34
Field pea	43	30
Lentil	45	26

Source: AICRIP Annual Reports, various years.

pulse research remains very low: at present, the ratio is only 2.5 full-time scientists per million hectares of pulse area (ASTI 2014–2015). In addition, there are scientists in the CGIAR centers, ICRISAT, and International Center for Agricultural Research in the Dry Area (ICARDA) who focus on pulses technology under agroclimatic conditions that are relevant to India.

Pulse research was unable to develop varieties to compete with the dwarf and high-yielding rice and wheat varieties that led to the Green Revolution. As described in detail in Chapter 3, since the 1970s pulses have in effect been largely thrown out of the Indo-Gangetic plains, supplanted by these high-yield cereals. Gradually but surely, pulses found new niches in the rainfed areas of the southern, western, and central parts of India. These nontraditional areas faced problems of drought, heat, pests, and diseases, so the challenge has been to fit pulses into new production systems under different agroecologies. Therefore, the varietal development programs in pulses have focused on selecting varieties for adaptation to the stresses of marginal environments rather than selecting for high-yield potential under unlimited conditions. The total number of varieties developed and released in the country for major pulses is quite large, as is evident in Table 4.2. Of course, development and release do not equate to adoption by farmers, an issue that is discussed in the next section.

Note that the social benefits of pulse R&D outweigh the private gains, because, except in the case of hybrids, private companies cannot fully appropriate the benefits of research into variety improvement, and the health and nutrition benefits of pulses are not likely to be fully reflected in market prices. Consequently, the private sector will likely underinvest in pulse varietal

improvement research, and this market failure will persist. Persistent market failures necessitate adequate public investment.

Chickpea (*Cicer arietinum* L.)

In India, more than 180 chickpea varieties have been developed by the national program either alone or in partnership with international institutions. Since the 1970s, the focus of development has varied through different phases of the program. During the 1970s most of the varieties were developed through selection from landraces, with a major emphasis on increasing yield potential. During the 1980s the emphasis was on breeding to develop disease resistance. During the 1990s the major thrust was to develop varieties for multiple-disease resistance, stress tolerance, and high input response.

Through all of this work, the most significant breakthrough in India has been the development of short-duration chickpea varieties. A large array of short-duration varieties have been developed to handle different types of stresses and situations. Because these improved varieties are tolerant to heat stress, they have found a niche in central and peninsular India, where their adoption has worked well in the hot and dry climates. During the 1990s, in addition to developing disease resistance, stress tolerance, and high input response, genetic sources were deployed to breed varieties tolerant to drought, cold weather, and salt. As a result of the decade's work, a number of varieties were released that are resistant to wilt, to root rot, ... and to Ascochyta blight (Singh and Sewak 2013) (Table 4.3).

Regional adaptation. Several varieties resistant or tolerant to *Fusarium* wilt were developed and released for cultivation in different regions and states (Table 4.4). These varieties were also high-yielding compared to the local landraces, and some were well suited to growing in nontraditional areas as well. Similarly, varieties tolerant to *Ascochyta* blight were developed for the country's Northwest Plain zone (especially Punjab, Haryana, northwestern Rajasthan, and western Uttar Pradesh). According to the Agriculture Science and Technology Indicators (ASTI) (https://www.asti.cgiar.org/trivsa), the rate of adoption of improved chickpea varieties in select Indian states in 2010 is as follows: Andhra Pradesh, 99 percent; Karnataka, 100 percent; Madhya Pradesh, 84 percent; Rajasthan, 68 percent; and Uttar Pradesh, 65 percent.

As these improved varieties expanded into new areas, they also replaced the traditional varieties. By 1995 about 52 percent of the existing chickpea area was allocated to improved varieties in Andhra Pradesh, Gujarat, and Madhya Pradesh (Joshi, Asokan, and Bantilan 1999). The result was substantial gains in both chickpea yields and farmers' incomes. The yield advantage was

TABLE 4.3 Environment-specific chickpea varieties at a glance

Environment	Varieties
Short-duration	ICCV2, JG74, Vijay, JG11, JG16, JAK1, 9218, KAK2
Salt-tolerance	CSG 8962 (Karnal Chana 1)
Drought-tolerance	ICCV10, Phule G5, RSG 888, Vijay
High-yielding kabuli chana varieties	KAK2, BG1003, BG1053, Phule G 95311, IPCK 2002–29

Source: AICRIP Annual Reports, various years.

reported to range from 28 percent in Andhra Pradesh to 67 percent in Gujarat. Moreover, the yield gains were much higher for high-yielding bold (*kabuli*) varieties, ranging from 108 percent in Andhra Pradesh to 123 percent in Madhya Pradesh (Joshi, Asokan, and Bantilan 1999). The farmers also benefited from the price premium they gained in the market due to the new varieties' size, color, and shape (Shiyani et al. 2002). The study reported that a silent "chickpea revolution" was witnessed in central and peninsular India, although it was combined with a gradual decline in chickpea area and production from northern and eastern India. Most notably, the production of chickpea in hot and dry climatic regions, which had contributed 40 percent of the country's total in the early 1980s, increased to account for 75 percent of total production in 1995 and 86 percent as of 2013–2014.

Adoption and yield. A recent study of the adoption of improved chickpea varieties in southern India's major chickpea-growing areas found that 97 percent of the farmers were adopting improved varieties, covering nearly 86 percent of the chickpea-growing area (Suhasini et al. 2012). A comprehensive 2014 study found that in Andhra Pradesh, as of 2011, nearly 90 percent of the area under chickpea production was planted in improved varieties (Bantilan et al. 2014). These findings testify to a high rate of seed replacement, with government figures showing that improved varieties expanded from a mere 3 percent in share in 2001 to 85 percent in 2011 (India, Ministry of Agriculture 2016). The comprehensive 2014 study estimated the direct welfare gains from investing in chickpea research and adopting the improved varieties to be on the order of US$358.9 million in Andhra Pradesh alone, before accounting for the general equilibrium effects, and particularly the price reduction, that would result from wider adoption of the improved variety across India.[1]

1 All dollar figures used in the chapter are US dollars.

A large share of the short-term gains (99 percent) accrued to the adopting farmers in Andhra Pradesh (Bantilan et al. 2014). Once general equilibrium effects were taken into account, the same study estimated the total net contribution of chickpea research investment at the all-India level to be $543.9 million (at constant prices), of which 85 percent ($450.2 million) would accrue to consumers (benefitting from price reduction), and 15 percent ($93.7 million) would accrue to adopting farmers across India. Nonadopting farmers would sustain a significant welfare loss. The overall internal rate of return on the investment in chickpea research was estimated at 28 percent.

New technologies. In addition to varietal improvement, new technologies introduced for chickpea production have included integrated pest management (IPM) and the development of farm machinery. IPM is discussed in greater detail later in this chapter. Concerning mechanization, the first machine-harvestable chickpea variety (NBeG 47) was recently released in Andhra Pradesh to overcome the problems of labor shortage and high wages (ICRISAT 2016). The machine can harvest 2.25 tons in 75 minutes, a boon for chickpea production in labor-scarce areas.[2]

Pigeon Pea (*Cajanus cajan* [L.] Millspaugh)

Pigeon pea is a long-duration and indeterminate crop that is prone to numerous diseases and insects and also suffers from low yield. The focus of research therefore has been fourfold: (1) to develop varieties of medium to short duration without compromising yield levels; (2) to develop resistance to pests and diseases; (3) to develop determinate varieties for uniform crop maturity; and (4) to increase yield levels. A number of varieties with different traits to handle a wide range of environments were developed, and a few promising ones are listed in Table 4.4.

Duration. Traditionally, the pigeon pea crop matured in 280 to 300 days, and in some cases ratooning was done for two to three years.[3] Therefore, developing short- and medium-duration varieties became a high research priority. During the 1980s and early 1990s, several medium- and short-duration varieties were developed, some of which found new niches and were adopted

2 All measurements in tons in this chapter are in metric tons.

3 Ratoon cropping is a multiple-harvest system in which regenerating stubbles of the established crop in the field are managed for subsequent production. The development of short-duration varieties of pulses has generated interest in ratooning. Instead of cutting whole plants, only the pods are picked from the ratoon crop and the plants are allowed to bear their next flush of pods. Irrigation after the main harvesting of the crop increases the yield from the ratoon crop (see Bantilan et al. 2014).

TABLE 4.4 Environment-specific varieties of pigeon pea at a glance

Environment type	Varieties
Wilt resistance	Maruthi, Asha, BDN2, BSMR 736, MA 6
SMD resistance	Bahar, BSMR 736, Asha, Sharad, Pusa 9
Wilt and SMD resistance	Asha, BSMR 736, BSMR 853
Hybrids	ICPH8, PPH4, COPH1, COPH2, AKPH410, AKPH2022

Source: AICRIP Annual Reports, various years.

in nontraditional areas. These varieties matured in 140 to 160 days without compromising the yield levels. Some of these varieties led to diversification in the rice-wheat production systems in northern India. Important among these varieties is the pea known as UPAS 120, which is the most popular. Its yield is in the range of 1.6 tons to 2.0 tons per hectare and it matures in just 120 days. It is most suitable for double cropping. Some estimates suggest that such short-duration varieties have expanded the pigeon pea area in northern and northwest India by roughly 200,000 hectares. The falling water table and remunerative pigeon pea prices are believed to be the leading factors motivating farmers to adopt these varieties.

A downside to the first available medium- and short-duration varieties is that they were susceptible to a few diseases (such as sterility mosaic, *fusarium* wilt, and *phytophthora* blight) and tended to prolong their maturity into the late monsoon rains. A breeding program, therefore, focused on developing varieties that would mature by early November to escape these diseases and fit well into the multicrop production system to ensure the timely sowing of wheat. Among other attributes, such as their determinate growth habit, short stature, and early maturity (120–130 days), several of the resulting new cultivars (like ICPL 87) proved to be suitable for both sole cropping and multiple harvesting.

The ICPL 87 variety was an especially successful example. It emerged from the National Pulse Development Program for Western Maharashtra, where sustainability of water and soil were adversely affected by the cultivation of sugarcane and banana. Designed to thrive in an irrigated environment in rotation with other crops, the variety also offered several other advantages, including enhancing income, improving soil health, and adapting to drought stress. By the mid-1990s it had been adopted across all districts with access to irrigation in Western Maharashtra (Bantilan and Parthasarathy 1999).

Disease resistance. Wilt is one of the major diseases that seriously harmed pigeon pea yield in earlier decades. Globally, estimates showed that

wilt reduced yields by up to 50 percent (Ryan 1981). Wilt-related production losses in 1977–1978 were estimated to be about $36.4 million in India and $5.2 million in Kenya, Malawi, and Tanzania (Ryan 1981). Research efforts yielded several wilt-resistant varieties for India and Africa. Among others, ICP 8863 was widely adopted in the semiarid tropics. Adoption studies in India revealed that this variety occupied almost 60 percent of the pigeon pea area in the wilt-affected districts of northern Karnataka and the bordering districts of Andhra Pradesh and Maharashtra. The potential benefits of adopting the wilt-resistance variety were estimated to be $79.8 million (Bantilan and Joshi 1996).

Adoption and yield. Adoption and impact assessment of pigeon pea varieties has not received due attention from professionals. However, one evaluation by ICRISAT has assessed the impact of improved pigeon pea varieties in rainfed areas of Odisha (Mula et al. 2014). The study found that the improved varieties had higher grain yields (70 percent) when compared with landraces. It also found significant increases in net income (which rose from 170 percent to 190 percent) and greater participation of women farmers (34 percent) in production. Unfortunately, the study did not trace the adoption of improved pigeon pea varieties in the study locations. According to an ASTI study in 2010 (https://www.asti.cgiar.org/trivsa), the rates of adoption of improved pigeon pea varieties in some Indian states is as follows: Andhra Pradesh, 70 percent; Maharashtra, 70 percent; Tamil Nadu, 70 percent; Madhya Pradesh, 65 percent; and Uttar Pradesh, 25 percent.

An additional program to break the yield barrier was an effort in India to develop a hybrid pigeon pea, which resulted in the world's first pigeon pea hybrid (ICPH 8), released in 1991. This hybrid was of short duration, offered a high-yield potential, and was drought-tolerant. Since then, the successful development of hybrids has opened up new avenues for enhancing the yield potential in pigeon pea (Saxena et al. 2005; Saxena 2009). Extensive testing of pigeon pea hybrids has shown yield advantages of 40 percent to 47 percent over the local varieties and even over other improved varieties in farmers' fields in India (Saxena and Nadarajan 2010).

In trials of hybrids conducted in five states, the mean yield (1,396 kilograms per hectare) was 47 percent higher than the yield of a popular variety (ICP 8863, 953 kilograms per hectare). The hybrids also exhibited high levels of resistance to the *Fusarium* wilt and sterility mosaic diseases (Saxena et al. 2013). Two of the recently released hybrids (ICPH 2740 and ICPH 14003) possess resistance to wilt and sterility mosaic diseases in Andhra Pradesh. These hybrids have a high-yield potential of 2.5 tons to 3.5 tons per hectare,

which is 25 percent to 40 percent higher than the local varieties. However, although several of these hybrids have been released for cultivation, they have not been particularly successful at getting adopted. Four major constraints to their adoption have been documented: (1) the high labor cost for seed production; (2) the high seed rate (amount of seed sown per hectare); (3) heavy damage from pod borers; and (4) lack of knowledge among farmers about seed production (Niranjan et al. 1998).

New developments. The next generation of breeding and agronomic efforts in pigeon pea will be focused on improving the plant type. Unfortunately, the genetic base of pigeon pea is quite narrow, with only 57 ancestors having been used for the development of 47 varieties through hybridization following selection. Only 32 wild species are known as valuable sources for resistance or tolerance to several biotic and abiotic stresses. But only 1 percent of the entire collection has actually been used to identify the sources of resistance to diseases, drought, and other abiotic stresses (Upadhyaya et al. 2009). Scientists are now using specific attributes, such as determinate growth habit, short stature, and early maturity (120–130 days), to develop varieties suitable for sole cropping and single or multiple harvesting. Research on developing transgenic varieties is now at an advanced stage, and pigeon pea is amenable to genetic transformation using recombinant DNA and tissue culture. Effective protocols are available to carry this regeneration out through organogenesis and somatic organogenesis in pigeon pea. Transgenic plants with the *Bt* gene have been tried for imparting resistance against *lepidopteron* insect pests that affect pigeon pea, but there is no product as yet, and we think that research on this needs to be systematized and intensified.

Green Gram (*Vigna radiata* L. Wilczek)

Green gram is mainly a rainy-season crop, although it is also grown during winter and summer. Its varietal development program has largely occurred in four phases with four areas of focus: (1) increasing yield potential; (2) reducing the duration; (3) developing resistance against diseases (especially powdery mildew and mosaic virus); and (4) breeding for large grain size.

Disease resistance. During the 1970s, research efforts mainly employed hybridization and mutation to breed high-yielding varieties. In the 1980s hybridization was used widely to combine agronomically useful traits and disease resistance. This led to the development and release of several varieties resistant or tolerant to powdery mildew and mung bean yellow mosaic virus (MYMV). During the 1990s, several sources of large grain size (> 6 grams per

100-seed weight) were introduced from the World Vegetable Center (formerly known as Asian Vegetable Research and Development Center, or AVRDC) and widely used in the Indian breeding program. According to the Asian Vegetable Research and Development Center (AVRDC 1998), MYMV is a virus with the potential to cause crop losses as high as 85 percent.[4]

By the mid-1990s, several large grain size varieties were developed and released, as were several multitrait varieties with desirable properties, including large grain size, short duration, photo-thermo insensitivity (resistant to heat and excessive sun), synchronous maturity, and resistance to major diseases. Recently, the incidence of MYMV disease has become a serious problem in the rice fallows of south India, so efforts have been diverted toward incorporating MYMV-resistant genes along with powdery mildew resistance. Some of the ruling varieties are listed in Table 4.5, along with their salient traits.

Broadening the genetic base. It is unfortunate that only a limited amount of the genetic variability in green gram has been exploited in varietal development programs. There is enormous potential to use known wild species and cultivate *Vigna* species to incorporate novel traits and broaden the genetic base. The gene introgression in green gram has already resulted in green gram derivatives that have shown potential for raising yields and building disease resistance. Moreover, these derivatives facilitate further genetic enhancement in green gram. The efforts made in this direction have led to the development of several improved cultivars of green gram, such as IPM 99-125, IPM 02-3, and IPM 02-14 (Singh, Dixit, and Katiyar 2010).

Current research. To further boost yield and find new niches, researchers are looking for ways to substantially change the plant's architecture. The available plant type in green gram is largely photo-thermo sensitive, with an indeterminate growth habit, low harvest index, and low grain yield. To remain a commercially competitive crop, green gram will have to fit into the production cycle of an intensive-input cereal-based cropping system. Therefore, the direction of future research is to develop a plant type that is determinate, photo-thermo insensitive, early maturing, high yielding (1.5–2.0 tons per hectare), with a high harvest index, and resistant to lodging and diseases. There is also a need to develop varieties of varying duration for India's different agroclimatic zones.

4 The AVRDC is now called the World Vegetable Center.

TABLE 4.5 Environment-specific varieties of green gram at a glance

Attributes	Varieties
Short-duration varieties for spring/summer	IPM 02–3, Meha, Samrat, TMB 37, HUM 16, HUM 1, PusaVishal, OUM 11–5, Pant M 5, SML 668
Powdery mildew–resistant varieties for *rabi* season	TARM 18, TM 96–2, Vamban 2, Vamban 4, TARM 2, TARM 1
Mung bean yellow mosaic virus–resistant varieties	Pant M 4, Pant M 6, KM 2241, Sattya, NDM 1, HUM 1, Ganga 8, Samrat, Meha, HUM 12, IPM 02–3
Large-seeded (5 grams/100 seeds)	Pant M 5, Pusa Vishal, SML 668, HUM 16, TMB 37, IPM 02–3

Source: AICRP Annual Reports (various years).

Black Matpe (*Vigna mungo* L. Hepper)

Black matpe is widely grown on the Indian subcontinent, where it originated and has been cultivated since ancient times. Early research on black matpe was started in the 1940s. The initial research phase focused on varietal development for improving locally adapted but genetically variable populations, mainly pure line and mass selections with a major emphasis on traits rather than yield. This resulted in the release of a large number of pure lines, some of which are still cultivated in certain parts of the country. Between 1943 and 1953 a large number of black matpe varieties (including T 27, T 77, and T 9) were developed that were adapted to the northern Indian environment. The variety T 9 is still a very popular variety, which is a striking fact considering how long ago it was developed.

Before 1970, several varieties of black matpe were developed from the locally adapted varieties. The most important lines preferred by farmers and most extensively used in the breeding programs were T 9, ADT 1, and CO 1. In the late 1970s, a hybridization program was started to develop short-duration and MYMV-resistant varieties. KM 1, which appeared in 1977, was the first variety developed through this hybridization. Later, a large number of varieties were developed for different ecosystems with varying traits using hybridization.

Disease resistance. In the 1980s the research priority for black matpe was to develop disease-resistant varieties. At that time, powdery mildew was the major disease of concern. The first variety resistant to powdery mildew was LBG 17, which was developed and released in 1983 for the rice fallow systems of coastal areas. It was so successful in its adoption that it revolutionized black matpe cultivation in the coastal regions of Andhra Pradesh. Later, more varieties of black matpe were developed and released, which led to an expansion

in their growing area in rice fallow land of the coastal peninsula. Since 1990, the major emphasis has been on breeding short-duration, photo- and thermo-insensitive varieties of black matpe along with resistance to biotic stresses (namely, yellow mosaic virus and powdery mildew). Some of the important black matpe varieties are given in Table 4.6.

Current research. As with other crops discussed previously, the varietal development program for black matpe has only exploited a limited amount of the plant's potential variability. The variety T 9 alone has contributed 75 percent to the development of new black matpe varieties. The genetic base of the available varieties is very narrow, but there is scope for utilizing the available gene pools from wild species to broaden the genetic base and borrow novel traits. Gene introgression in black matpe has already resulted in derivatives that have shown potential for yield-contributing traits and disease resistance. These derivatives have facilitated further genetic enhancement in black matpe, which has led to the development of improved cultivars like Mash 1008 and VBN 5 in black matpe (Singh, Dixit, and Katiyar 2010). These have facilitated the cultivation of black matpe in diverse agroecological regions.

Lentil (*Lens culimaris* Medic)

Lentil is gaining popularity due to its rich nutritional value; it is high in protein and iron and has no fat or cholesterol. In India today about 1.5 million hectares are planted in lentil. About 85 percent of lentil is produced in only three states—namely, Bihar, Madhya Pradesh, and Uttar Pradesh. The research efforts in lentil have been lackluster, particularly until the 1990s, and confined mainly to identifying landraces for better adaptability and yields. During the 1980s a few landraces were collected and used in recombination breeding through single crosses, followed in the 1990s by crosses involving more parents. The narrow genetic base has also been used to breed high-yielding, short-duration, and disease-resistant varieties, including many good varieties resistant against rust, *fusarium* wilt, and vascular wilt. Four high-yielding varieties resulted that have been commercialized—namely, Angoori, Noori, Priya, and Sheri. In the early 1990s, International Center for Agricultural Research in Dry Areas (ICARDA) introduced an early flowering line (Precoz: ILL 4605) that was used in hybridization with indigenous lines and has resulted in the selection of extra-early genotypes. ICARDA is providing India's national program with valuable nurseries, which are used for fixed and segregating populations for various desirable traits. Several varieties have been developed and released for cultivation using the source material received from ICARDA (Sarkar et al. 2007).

TABLE 4.6 Environment-specific varieties of black matpe at a glance

Attributes	Varieties
Short-duration varieties for spring/summer	WBU 109, Azad Urd 1, KU 300, Pant Urd 31, PDU 1, KU 92–1
Powdery mildew–resistance	LBG 625, LBG 685, LBG 623, LBG 20, WBG 26, LBG 709, LBG 645, VBN 4
Mung bean yellow mosaic virus–resistance	WBU 108, Pant U 30, Pant U 31, Pant U 40, Azad U 1, Azad U 2, Sekhar 2, Sekhar 3, IPU 02–43, Uttara, NDU 1, KU 96–3, Mash 1008, WBU 109
(Mung bean yellow mosaic virus + powdery mildew)-resistance	IPU 02–43, LBG 625, LBG 685

Source: AICRP Annual Reports (various years).

The improved varieties in lentil have made it possible to achieve wide adaptability in varying agroenvironments. The short-duration varieties that have been made available fit well into any production system where there is residual moisture. Over a period of four decades, the varietal development has been reflected in increased lentil production, which rose from 0.37 million tons in 1970–1971 to 1.13 million tons in 2012–2013. Both yield increase and area expansion contributed to this jump. National average yield increased over the same period from a mere 497 kilograms per hectare to around 800 kilograms per hectare, while in Bihar yield rose to more than 1,100 kilograms per hectare. Lentil area also doubled over the past four decades due to the availability of varieties that are disease-resistant and short-duration, expanding from 0.75 million hectares to 1.42 million hectares.

Transferring the Technology to Pulse Farmers

Pulses are seriously affected by a large number of insects and diseases. Important among these are the pod borer (*Helicovera armigera*) followed by the pod fly, wilt, and root rot. It is reported that *Bacillus thuringiensis* Berliner (Bt) var. *kurstaki* is effective in controlling pod borer; however, the successful release of Bt chickpea/pigeon pea varieties from either public or private research will take several more years. The other important pests affecting pulses are nematodes, among which root-knot nematodes are important due to the way they spread and damage crop yield. Among important diseases, wilt in chickpea, sterility mosaic virus (SMD) in pigeon pea, and yellow mosaic virus (MYMV) and powdery mildew (PM) in green gram and black matpe cause major damages to pulse crops.

Various combinations of the integrated pest management (IPM) approach have been developed, piloted, and disseminated for controlling pests and

diseases in pulses. The principle of IPM is to minimize the application of chemicals and manage pests and diseases through better crop management. Considerable efforts were made to promote IPM, although they have not succeeded as expected. The main constraint has been that IPM practices require collective action among farmers.

Production of Improved Varieties of Pulses

The availability of improved-quality seeds is one of the most important drivers for increasing pulse production, especially for resource-constrained farmers in rainfed areas. Unfortunately, the scarcity of breeder's seed and certified seed of improved varieties is constraining their adoption. There is a weak link between the research and development systems and the mass production and multiplication of breeder, foundation, and certified seeds. The link of the seed system with the market in terms of the desired varieties is also weak. The existing seed sector is fragile because of the low volume of business. However, the seed replacement rate of important pulses is increasing somewhat in recent times, although it is still quite low. For example, in chickpea the seed replacement rate is merely 14 percent (India, Ministry of Agriculture 2016). Gowda et al. (2013) point to several factors for low seed replacement rates such as low seed multiplication rate of legumes; reuse of grains from the previous harvest as seeds; and often demand for specific varieties adapted to more narrow agroecologies and consumers' needs.

Despite a long list of improved pulses varieties released for cultivation, their impact has not yet been fully realized by the resource-poor farmers in many states in India. The accessibility of smallholders to quality seed of improved pulses varieties is constrained by both inadequate demand creation and limited supply (Gowda et al. 2013). The policy support for the pulses seed system has been unfavorable and regulatory frameworks have been inadequate (Rubyogo, Sperling, and Assefa 2007).

Gowda et al. (2013) point out that legume seed business in general in India does not attract large seed companies since profit margins are low. In this context, Materne and Reddy (2007) point out that more than 95 percent of lentil seed in India (the world's largest producer of lentil) is sourced from the informal sector and this type of dominance of informal sector is quite generic for the pulses sector as a whole. The formal seed sector is still concentrated in areas with high population density and areas with better infrastructure. The small and medium seed companies that are emerging still have limited

capacities and apart from marketing problems lack a good supply of foundation seeds (Gowda et al. 2013).

Going forward, for the pulses seed sector, Singh and Saxena (2016) suggest several options to ensure quality pulses seed availability in the country. These are

- Adoption and promotion of new varieties by bringing them into the seed chain by the state departments.
- Production of Truthfully Level seed (TL seed) at research institutions and state agricultural universities (SAUs) as well as at Krishi Vigyan Kendra (KVK) or Agriculture Science Centers farms and their distribution to farmers.
- One cycle multiplication of certified seed at KVK farms before their demonstration/distribution to farmers.
- Continuation of subsidies for additional years for popular varieties that have large seed indent (requirement) but are going to be phased out of the seed chain due to completion of time period.[5]
- Strengthening infrastructures of research farms and KVKs for increasing seed multiplication ratios and developing/strengthening seed processing and storage facilities.

Singh and Saxena (2016) further argue that in the case of breeder seed production, some of the varieties are quite old and need to be gradually substituted by new varieties. Among the chickpea varieties—JG 11, JG 16, JG 322, and Vijay—there are more than 15 years of continuous subsidies among them. Similar is the case of pigeon pea and green gram. Singh and Saxena (2016) document that the average seed replacement rate (SRR) of pulses in India was about 25 percent at the end of 2011. The highest SRR was in the case of black matpe (34.41 percent), followed by green gram (30.29 percent), and pigeon pea (22.16 percent). Singh and Saxena (2016) like Gowda et al. (2013) point out that among major production constraints, availability of quality seed of

5 Indent is a seed requirement by different states given to the central government. Each state assesses its own seed requirement and gives indent to the central government. For just-released varieties, indent of breeder seed is given to Indian Council of Agricultural Research/SAUs and for old varieties indent for certified seed is given. There is a committee at the national level, which meets twice a year for this purpose for all crops.

improved varieties has been a major constraint in enhancing production and productivity of pulses in India.

This they relate primarily to lack of an organized seed production program for pulses where there still is a lack of proper medium-term (four to five years) seed rolling plan for the country's major pulse-producing states. The indent for breeder seed is quite low in many cases, including indent for old and obsolete varieties. Moreover, there is poor conversion of breeder seed to foundation and certified seed. To ensure timely availability of quality seed, capabilities of seed production must be enhanced with multiagency participation, such as seed societies, farmers, private sectors, and NGOs besides SAUs, Indian Institute of Pulses Research, and State Seed Corporations (Singh and Saxena 2016).

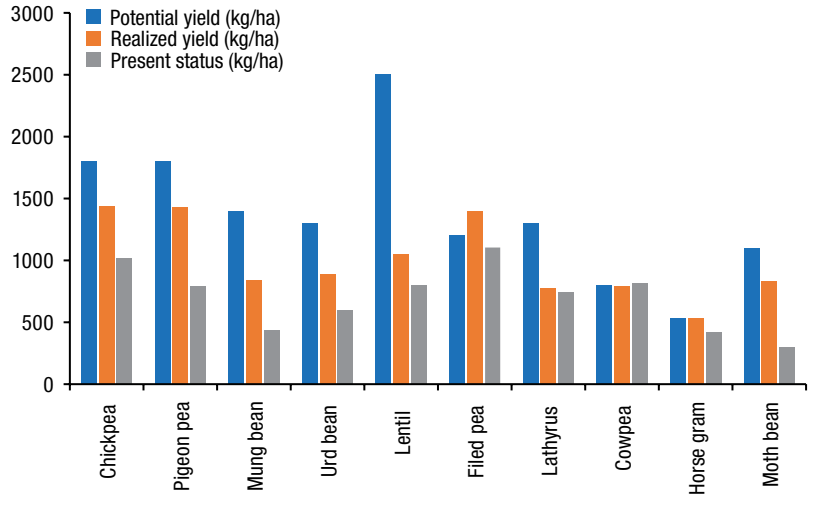
It is necessary to improve the seed system in providing quality seeds of the improved and preferred varieties in adequate quantities and at affordable prices, at the right place and the right time. There is also a need to find ways to link the formal and informal seed sectors to achieve sustainable seed delivery to farmers and to explore approaches to motivate small and medium-size seed companies and NGOs to enter the pulse seed production program. The public seed corporation should increase seed production to meet the future target of national demand.

Technology-Farmer Link

Currently, there is a significant unexploited potential of pulses in terms of yields. This is demonstrated in Figure 4.1, derived from Singh and Saxena (2016), which shows existing yields of different types of pulses in India alongside the yields achieved at experimental stations and in field trials. The yield gaps are quite significant, ranging from 75 percent in lentil to 224 percent in green gram. Singh and Saxena (2016) suggest that the underlying reasons for these gaps are mainly poor quality of seed and poor management practices.

To strengthen technology transfer to farmers and acquaint them with new varieties and management practices, in 1990–1991 the Indian Council of Agricultural Research inaugurated its Front Line Demonstrations (FLD). The FLDs are helpful to both researchers and producers of pulses, but their target groups are farmers and extension service delivery workers. The demonstrations are conducted with farmers under the close supervision of scientists on a block of 2 to 4 hectares, where the latest and most promising pulse varieties and management practices are exhibited. Participating farmers are trained in the complete package of practices necessary to attain the potential yields. The approach also allows for farmers and extension workers to provide feedback,

FIGURE 4.1 Actual and potential yields in different pulses (kilograms per hectare)



Source: Singh and Saxena (2016).

and it generates evidence that researchers can use to identify what factors are contributing to higher crop yields and what the constraints are under different farming situations.

The crops covered under the scheme are chickpea, pigeon pea, green gram, black matpe, field pea, lentil, kidney bean, lathyrus, and arid legumes (cowpea, guar, moth bean, and horse gram). The scheme over time has been transformed into a new mission mode program, Integrated Scheme on Oilseeds, Pulses, Oil Palm, and Maize (ISOPOM), with the following objectives:

- To demonstrate newly released crop varieties, their production and protection technologies, and their management practices at farmers' fields under different farming situations.
- To study the factors contributing to higher crop production.
- To generate production data and feedback information.

From 1996 to 2001 the field demonstrations showed the efficiency of improved technologies in enhancing the productivity of green gram, black matpe, lentil, field pea, kidney bean, and lathyrus. A total of 324 on-farm demonstrations were organized by various centers to test different technology components, including varieties. They found that pulse productivity could be

increased by 50 percent to 100 percent (FLDs [1996–2001], AICRP 2013). From 2002 to 2007, 1,252 FLDs were conducted on chickpea in the major chickpea-growing states under the AICRP. The yield gains from improved varieties, measured in comparison with the yields of local varieties, ranged from 8.7 percent in Karnataka to 29.7 percent in Madhya Pradesh, with an average increase for all demonstrations of about 20.3 percent. From 2007 to 2013 the number of FLDs in chickpea and pigeon pea in different states was increased to 2,891 and the overall increase in yield due to improved varieties over local ones was 18.6 percent. The highest increase in yield was recorded in the state of Chhattisgarh (45.7 percent), followed by Uttar Pradesh (36.4 percent), Madhya Pradesh (25.5 percent), Maharashtra (22.3 percent), Gujarat (21.3 percent), Rajasthan (15.5 percent), Karnataka (10.9 percent), and Andhra Pradesh (9.9 percent).

From 2012 to 2013 the FLDs revealed that even higher average increases in yield (over time) were possible with farmers' adoption of a complete package of improved technologies, including an increase of 26.5 percent in chickpea and 30.4 percent in pigeon pea. Similarly, for other pulses, a higher grain yield was achieved through the adoption of a package of improved technologies, with increases of 22.9 percent in *kharif* green gram, 32.0 percent in *rabi* green gram, 29.5 percent in *kharif* black matpe, 29.4 percent in *rabi* black matpe, 21.0 percent in lentil, and 15.0 percent in field pea (AICRP 2013). One should note that the results from experimental plots of the kind promoted by the initiatives reported above are potentially biased upward in terms of yield improvement because they do not incorporate farmers' real-world constraints related to labor, credit, and so on. It is also not known what the impacts of the initiatives were, in terms of increased adoption in the neighboring areas.

Potential and Niche Areas for Pulses

Pulses are finding new niches as a result of the availability of improved varieties suited to new geographic areas. Table 4.7 shows that a minimum of 3.35 million hectares in India can potentially be used for cultivation of pulses (more recent estimates of rice fallow lands based on India, Ministry of Agriculture [2016] They are show the area of rice fallow lands equal to 4 million hectares). The discussion here highlights that the extent of technological progress in pulses has largely been a function of the ability to use fallow lands. According to NAAS (2013), rice fallows are found in the states of Andhra Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, West Bengal, and Uttar

TABLE 4.7 Potential niches for pulses

Cropping system	Potential niches	Potential area (in millions of hectares)	Suitable varieties of pulse crops
Pigeon pea–wheat	Haryana, Punjab, northwest Uttar Pradesh, and north Rajasthan	1	UPAS 120, Manak, Pusa 33, AL 15, AL 201
Maize–*rabi* pigeon pea	Central and eastern Uttar Pradesh, north Bihar, West Bengal, Assam	0.3	Pusa 9, Sharad
Maize–potato/ mustard + green gram/black matpe	Punjab, Haryana, and west Uttar Pradesh	1	Green gram: Pant Mung 2, PDM 11, HUM 2, SML 668, Pusa Vishal; black matpe: PDU 1, Narendra Urd 1, Uttara
Spring Sugarcane + green gram/black matpe	East Uttar Pradesh, Bihar, West Bengal	0.15	Green gram: Pant Mung 2, PDM 11, Narendra mung 1; black matpe: PDU 1, Pant U 19, TARM 1, Pusa 9072
Rice–green gram	Odisha, parts of Karnataka, Tamil Nadu, Andhra Pradesh	0.35	TARM 1, Pusa 9072
Rice–black matpe	Coastal areas of Andhra Pradesh, Karnataka, Tamil Nadu	0.35	LBG 17, LBG 402
Rice–wheat–green gram	Western Uttar Pradesh, Haryana, Punjab	0.1	Pant Mung 2, Narendra, Mung 1, PDM 139, HUM 2
Maize–kidney bean–green gram	Central and eastern Uttar Pradesh, north Bihar	0.07	Green gram: Pant Mung 2, PDM 11, HUM 2; kidney bean: HUR 137, HUR 15, PDR 14, Amber
Kidney bean–Potato	Eastern and central Uttar Pradesh	0.03	PDR 14, Amber

Source: Ali (2004).

Pradesh. In these areas, after the harvest of *kharif* rice, climatic conditions of rice fallow lands are suitable for growing cool and warm season pulses by using the residual moisture. The pulses that can fit into these rice fallow systems are lentil, green gram, black matpe, lathyrus, and peas.

Pulses are finding new niches as a result of the availability of improved varieties suited to new geographic areas. Broadly, this process includes: (1) horizontal expansion into the rice fallow system in the coastal regions of Andhra Pradesh, Karnataka, Odisha, and Tamil Nadu; and (2) diversification within the rice-wheat system through the planting of short-duration green gram varieties and intercropping in sugarcane, pigeon pea, and cereals.

Naturally, such an expansion into a rice fallow system works best if the rice variety itself is of short duration and vacates the field early. Since lentil is more suitable and assured than chickpea in lowland areas with excessive soil moisture, lentil could be popularized in the lowlands of eastern Uttar Pradesh, Bihar, Jharkhand, and West Bengal (NAAS 2013). As explained in Chapter 3, Bihar, Jharkhand, and Odisha are also states where pulse cultivation has lost ground to other crops, so better utilization of rice fallow systems could help recover much of what was lost in these states. It is a fortunate coincidence that the scope for expansion in these states is comparatively large. Data shows that in the coastal areas of Odisha and Andhra Pradesh, as technologies were developed for rice fallow systems, an expansion in pulse cultivation occurred. Further use of rice fallow systems for pulse expansion in noncoastal areas, backed by the development of improved varieties of pulses and other technologies and by extension services, needs to be explored and prioritized. Indeed, a case may be made that expanding pulses into rice fallow systems should be tried first before attempting to extend the growth of pulses in new areas at the cost of competing crops like cereals or oilseeds.

The Way Forward

Pulse research needs to place a stronger emphasis on developing improved varieties that can break the existing low-yield barrier. Given the dynamics of supply in pulses in India, there is a need for horizontal expansion to new niches (such as the rice fallows in coastal regions of Andhra Pradesh, Karnataka, Odisha, and Tamil Nadu). Diversification in India's rice–wheat system has to be extended through short–duration green gram varieties and intercropping in sugarcane, pigeon pea, and cereals. Of high potential is the popularization of hybrid pigeon pea developed at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Also, the progress made in using wild species for the introgression of valuable genes for their agronomic traits in different pulse crops—an approach that has largely been underutilized due to crossability barriers—can be scaled up. The following areas need greater attention in pulses research for technology development to meet the future demand.

Breaking the yield plateau and enhancing productivity. Three areas stand out as needing attention. First, the potential of biotechnology needs to be harnessed, including gene characterization for yield-determining traits using biparental populations, MAGIC (Multi-Parent Advanced Generation

Inter-Cross) populations, association mapping, and the development of functional markers for the genes. These research methods can be used without wading into the deeply divisive issue around commercializing genetically modified (GM) crops in India because these methods are not associated with the commercialization of GM crops. New tools of bioinformatics and statistical genetics should be used extensively, because this enables new genetic information to be generated very fast.[6] Second, the genetic base/gene pool needs to be widened. This includes prebreeding with wild pulse relatives. Third, hybrid technology needs to be developed with a suitable level of heterosis.

Developing crops resilient to climatic adversities. Resilient/smart pulse varieties and technologies need to be developed. Better monitoring of disease and pest dynamics in relation to climate change is needed as well.

Developing quality pulses. Due consideration must be paid to the quality traits when pulse varieties are identified for release.

Producing quality seed. Quality seed needs to be produced in sufficient quantity, effectively using the chain from breeder seeds to foundation and certified seeds.

Resource management. Ways to increase the input-use efficiency of nutrients and water need to be developed, with consideration for the differing macro and micro nutrients needed by different pulses and across environments. The efficiency of symbiotic processes for enhanced nitrogen fixation by Rhizobia needs to be improved. Finally, research is needed on microorganisms, like phosphate-solubilizing bacteria/fungi and biofertilizers such as vesicular arbuscular mycorrhiza (VAM), which are capable of solubilizing nonavailable phosphate into an available form and helping in phosphate uptake by pulse crops.

Conclusion

India has a long history of programs relating to technology development in pulses. Since pulses' preferences vary across regions, research has had to cover several varieties. The developments in pulse farming have faced several

6 The main objective of developing MAGIC populations is to promote intercrossing and shuffling of the genome. The advantages of using multiparent populations are that (1) more targeted traits from each of the parents can be analyzed based on the selection of parents used to make the multiparent crosses; and (2) increased precision and resolution can be detected due to the increased level of recombination (Cavanagh et al. 2008). Multiparent populations are now attractive for researchers due to the development of high-throughput genotyping platforms and advances in statistical methods to analyze data from these populations (see Bandillo et al. 2013).

dynamics that have had a significant bearing on technology development. First, pulses have moved significantly across regions. Technology has had to keep pace with these movements while adjusting to help the expansion across different regions (with different agroclimatic conditions) be successful. Efforts should be made to identify and map genes of economic importance from a large array of wild species and develop a molecular linkage map. Molecular markers linked to traits of agronomic importance in pigeon pea are limited. Microsatellite markers are being developed and mapped to overcome the relatively low amount of information that can be derived from the widely used dominant markers in pigeon pea.

Second, when the Green Revolution happened in cereals, it affected the prospects for pulses. Technology development had to focus not only on improving pulse yields but also on fitting pulse farming into the cropping complex that includes cereals. Hence, many short-duration and very-short-duration varieties had to be developed to meet the need to fit into rice-wheat cropping cycles. The increased focus on cereals meant that pulses have been increasingly pushed to marginal environments, creating a set of challenges to which technology development has had to adjust. Much of the technology development has focused on disease and pest resistance. Recent research that indicates the possible effectiveness of Bt-based technology in controlling pulses pests suggests directions for future research. The recent development of biopesticides could also be valuable in reducing the harmful residues of chemicals used in controlling pests. Also, given that several types of pests are involved in infestations, policy should be directed toward developing multiple-resistant pulse varieties that simultaneously control many pests.

As discussed, the availability of improved-quality seeds is one of the most important drivers for increasing pulse production. However, it is not only the development of technology but the delivery systems that have been an issue in the case of pulse technology. One way forward may be to link the formal and informal seed sectors for sustainable seed delivery to farmers, which would also motivate small and medium-size seed companies to enter into pulse seed production. Importantly, the private sector has been missing from the research and development in pulses, which is mainly driven by the public sector, including the government and such international organizations as ICRISAT and ICARDA. This is in sharp contrast with crops like maize and pearl millet.

To change this situation, best practices should be drawn from cases where the private sector has delivered in terms of seed development and then applied to pulses. The positive impact of seed policy reforms on private investment in agriculture has been studied and summarized in Kolady, Spielman, and

Cavalieri (2012), who document that although public research organizations and state seed corporations still play an important role in India, the private-sector seed companies have become important. State seed companies are now confined to distributing certified seeds in pulses and other low-value crops such as wheat and rice, while the private sector has made sizable inroads in the higher-value segment of the seed market, which includes hybrids of crops like maize and pearl millet (Pray, Ramaswami, and Kelley 2001).

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Appendix

TABLE 4A.1 Promising varieties of chickpea, by state

State	Variety
Andhra Pradesh	JG 11, KAK 2, JAKI 9218, MNK–1, ICCV 37
Bihar	Gujarat Gram 4, Pant G 186, HK 05–169, Pusa 372
Chhattisgarh	Digvijay, JG 6, JAKI 9218, JG 14, JG 63, IPCK 2002–29, Vaibhav
Gujarat	JG 16. Gujarat Gram 1, Gujarat Junagadh Gram 3, JSC 55 (Raj Vijay Gram 202), JSC 56 (Raj Vijay Gram 203)
Haryana	Haryana Chana–3, Haryana Chana–5, HK–1
Jharkhand	KPG 59, BG 1003, Pant G 114, KWR 108, Pusa 372, HK 05–169
Karnataka	ICCV 37, JAKI 9218, JG 11, MNK–1, Phule G 0517
Madhya Pradesh	JG 130, JG 322, JG 63, JG 16, JG 14, JAKI 9218, JGK 2, JG 315, JGK–1, Vijay, JSC 55 (Raj Vijay Gram 202), JSC 56 (Raj Vijay Gram 203), Raj Vijay Kabuli 101, Raj Vijay 201, Phule G 0517, PKV Kabuli 4
Maharashtra	Vijay, Digvijay, JAKI 9218, Vishal, Virat, KAK 2, Phule G 0517, JSC 55 (Raj Vijay Gram 202), JSC 56 (Raj Vijay Gram 203), PKV Kabuli 4
Punjab	GPF 2, L 551
Rajasthan	GNG 1581, RSG 888, Pratap Chana–1, GNG 1488, GNG 1499, GNG 663, GNG 469, RSG 973, RSG 963, CSJD 884
Tamil Nadu	JG 11, Co4
Uttar Pradesh	KPG 59, KGD 1168, KWR 108, HK 05–169, Pusa 372
Uttarakhand	Pant G 186, Pant G 114, DCP 92–3, Pant Kabuli 1
West Bengal	Anuradha, Mahamaya–1, Mahamaya–2

Source: AICRIP Annual Reports (various years).

TABLE 4A.2 Promising varieties of pigeon pea, by state

State	Variety or hybrid
Andhra Pradesh	ICPL 151, IT 6, Maruthi, ICPL 87, ICP 332, Asha, Sarita, Durga (ICPL 84031), Laxmi (ICPL 85063), WRG 27, WRG 53, LRG 30, LRG 38, Lam 41
Bihar	Bahar, Pusa 9, NDA 1, DA 11 (Sharad), UP AS 120, BirsaArhar 1
Gujarat	BDN 2, C 11, TT6, TIS-IS, ICPL 87, GT 100, Asha» GAUT 001E(Banas)GTH 1, IT 40I,TJT 501,BSMR 853, GT 101
Haryana	Manak, Pusa 84, Pus a 33, Pusa 855, Paras, Pus a 992, PAU 881
Karnataka	ICPL 151, TT6, ICPL 87, TTB 7, Maruthi, Asha, BRG 1, BRG 2, Hy3C, TS 3R,WRP 1
Madhya Pradesh	C 11, TT 6, ICPL 87, JA 4, Asha, JKM 7, MA 3, IT 401, TJT 501, JKM 189
Maharashtra	BDN 2, C 11, TT6, TAT 10, ICPL 87, BSMR 175, Asha, BSMR 736, JKM 7, AKT 8811, TJT 501, IT 401,Vipu1a, BSMR 853, BDN 708
Odisha	UPAS 120, Asha
Punjab	UPAS 120, AL 5 Manak, Pusa 84, Pus a 33, Jagriti (ICPL 151) , Pusa 855,AI 201,Pusa 992, PAU88I, PA 291
Rajasthan	Pus a 992, UPAS 120, Pusa 855, VLA 1
Tamil Nadu	ICPL 151, IT6, ICPL 87, Co 5, Vamban 1, Asha, Co6, CORG 9701, Vamban 2
Uttar Pradesh	UPAS 120, Bahar, NDA 1, NDA 2, Amar, Azad, MA 6,MAL 13, Pusa 9, NDA 3
West Bengal	Bahar, WB 20,Pusa 9, NDA 2, NDA 3

Source: AICRIP Annual Reports (various years).

TABLE 4A.3 Promising varieties of green gram for different growing seasons, by state

State	Growing season	Variety
Andhra Pradesh	Kharif	PKV AKM 4, IPM 02–14, COGG 912, OUM 11–5, Warangal–2, LGG 407, LGG 450, Madhira 295
	Rabi	Pusa 9072, LGG 460, TM 96–2, WGG–2
Assam	Kharif	SG 1 (Pratap), Pant moong 2, Pant Moong 4, Narendra moong 1, IPM 2–3
	Spring/ summer	PDM 139, Pusha Vishal, Meha, Pant moong 5, TMB 37, HUM–16, HUM 12
Bihar and Jharkhand	Kharif	Pant moong 2, Pant Moong 4, Narendra moong 1, Sunaina, PD-M139,MH2–15, HUM–1, IPM 2–3
	Spring/ summer	PDM 139, Pusha Vishal, Meha, Pant moong 5, TMB 37, HUM–16, HUM 12
Delhi	Kharif	IPM 2–3, Pant Moong 3, ML 337, MUM 2, Ganga 8, MH 02–15
Gujarat	Kharif	PKV AKM 4, BM 4, Gujarat Moong 3, Pant moong 2, PIMS 4 (Sabar-mati), GujratMoong 2, GujratMoong 4
	Spring/ summer	Gujarat moong 2, PDM 139
Haryana	Kharif	MUM 2, Pusa Vishal, Ganga 8, MH 2–15, IPM 2–3, Muskan
	Spring/ summer	Pusa Vishal, SML 668, Pant Mung–5
Himachal Pradesh and Jammu and Kashmir	Kharif	Pant Moong 2, Pant Moong 6, KM 2241, Shalimar moong 1, Pusa 0672
Karnataka	Kharif	IPM 02–14, PKV AKM 4, COGG 912, HUM 1, China Moong, KKM 3
Madhya Pradesh and Chhattisgarh	Kharif	Pant Moong 3, ML 337, BM 4, JM 721, Jawahar 45, HUM–1, Meha, TJM 3
	Spring/ summer	HUM 1, Pusa 9531, PDM 139, Meha
Maharashtra	Kharif	PKV AKM 4, Kopergaon, ML 131, BM 4, Phule M 2, TARM 1, TARM 18, TARM 2, BM 200–1, HUM 1
Odisha	Kharif	OUM 11–5, COGG 912, PKV AKM 4, TARM 1, PDM 139
	Rabi	Pusa 9072, Sujata (Hyb 2–4), TARM–1, OBGG–52, LGG–460, PDM 139
Punjab	Kharif	MUM 2, ML 613, Ganga 8, MH 2–15, IPM 2–3
	Spring/ summer	Pusha Vishal, Pant moong 2, SML 668, Pant Mung–5
Rajasthan	Kharif	Ganga 8, RMG 268, MUM 2, SML 668, RM 492, IPM 2–3, MH 2–15
	Spring/ summer	RMG 268, SML 668, PDM–139, Meha
Tamil Nadu	Kharif	Paiyur 1, Vamban 1, ADT 3, CO 5, TM 96–2, COGG 912, OUM 11–5
	Rabi	Pusa 9072, Sujata (Hyb 12–4), ADT–3
Uttar Pradesh and Uttrakhand	Kharif	Pant Moong 2, Pant Moong 3, Narendra Moong 1, Pant Moong 4, Pant Moong 5
	Spring/ summer	PDM 139, Pusha Vishal, Meha, Pant moong 5, TMB 37, HUM–16, HUM 12
West Bengal	Kharif	Narendra Moong 1, Pant Moong 4, Pant Moong 5, MH 2–15, Sreku-mar
	Spring/ summer	PDM 139, Pusha Vishal, Meha, Pant moong 5, TMB 37, HUM–16

Source: AICRIP Annual Reports (various years).

TABLE 4A.4 Promising varieties of black matpe for different growing seasons, by state

State	Growing season	Variety
Andhra Pradesh	Kharif	WBG 26, KU 301 (Shekhar –1), WBU 108, LBG 648, Pant U 31, IPU 2–43, LBG 685, LBG 625, LBG 752, IPU 07–3, VBG 04–008, LU 391
	Rabi	TU 94–2, LBG 611, LBG 20, LBG 402, LBG 623, LBG–709, WBG–26
Assam	Kharif	Pant U 30, WBU 108, IPU 94–1 (Uttara), WBU 108
Bihar and Jharkhand	Kharif	IPU 94–1 (Uttara), BirsaUrd 1, Pant U 30, Pant U 31, WBU 108
	Spring	KU 92–1 (Azad Urd 1), WBU–109, Pant U 31
Gujarat	Kharif	KU 96–3, TPU 4, AKU 4, WBU 108, GU 1
Haryana	Kharif	Mash 338, Pant U 19, KU 300 (Shekhar 2), WBU 108, IPU 94–1 (Uttara)
Himachal Pradesh	Kharif	Pant U 19, Pant U 31, Pant U 40
Karnataka	Kharif	KU 301, WBG 26, WBU 108, LBG 402, LBG Manikya, 1, TU 94–2, LU 391, IPU 07–3, VBG 04–008, IPU 2–43
Madhya Pradesh and Chhattisgarh	Kharif	KU 96–3, TPU 4, JawaharUrd 2, JawaharUrd 3, Khargone 3, Pant U 30
	Spring	Pant U 31
Maharashtra	Kharif	TPU 4, Pant U 30, TAU 1, TAU 2, AKU 4 (Melghat), AKU 15, KU 96–3
Odisha	Kharif	KU 301, WBG 26, WBU 108, Sarla, IPU 2–43
	Spring	TU 94–2, LBG 402, OBG 17, B–3–8–8, Mash 338
Punjab	Kharif	IPU 94–1 (Uttara), WBU 108, Krishna, Mash 414
	Spring	KU 300 (Shekhar – 2), KUG 479
Rajasthan	Kharif	IPU 94–1 (Uttara), WBU 108, Pant U 31, KU 300
	Spring	KU 300, KUG 479
Uttar Pradesh and Uttrakhand	Kharif	IPU 94–1 (Uttara), WBU 108, Narendra Urd 1, Pant U 35, Pant U 31, Pant U 40
	Spring	KU 92–2 (Azad Urd 1), KU 300 (Shekhar 2), Narendra Urd 1, WBU 109, KUG 479
Tamil Nadu	Kharif	ADT 3, ADT 5, Vamban 2, WBU–108, KU 301 (Shekhar 1), Vamban–3, ADT 4,Vamban–4, ADT 5, IPU 07–3, IPU 2–43, VBG 04–008 WBG–26, Vamban–3, TU 94–2, VBN–5, IPU 2–43. KBU 512, Vamban 2
West Bengal	Kharif	IPU 94–1 (Uttara), WBU 108, Pant U 31
	Spring	KU 92–1 (Azad urd 1), WBU 109, Pant U 31

Source: IIPR Annual Reports (various years).

TABLE 4A.5 Promising varieties of lentil, by state or region

State or region	Variety
Assam	HUL 57, WBL 77, KLS 218, Asha (B 77)
Bihar	HUL 57, WBL 77, Arun (PL 77–12)
Delhi	DPL 62 (Sheri), LH 84–8
Gujarat	IPL 81, JL 3
Haryana	DPL 62 (Sheri), IPL 406
Himachal Pradesh	HUL 57, VL 507
Jammu and Kashmir	HUL 57, VL 507, Shalimar Masoor 1
Madhya Pradesh	IPL 81 (Noori), JL 3, IPL 406
Maharashtra	IPL 81 (Noori), JL 3
Northeast Hill Region	HUL 57, DPL 62
Odisha	HUL 57, WBL 77, B 77 (Asha)
Punjab	DPL 62 (Sheri), Pant L 4, LH 84–8, LL 147
Uttar Pradesh	HUL 57, DPL 62 (Sheri), IPL 81 (Noori), Narendra Masoor 1, IPL 406
West Bengal	HUL 57, WBL 77 KLS 218, Ranjan (B 256), Asha (B 77)

Source: IIPR Annual Reports (various years).