Enhancing chickpea productivity and production in South Asia

Pooran M Gaur, Srinivasan Samineni, Shailesh Tripathi, Rajeev K Varshney, Laxmipathi Gowda CL, Hari C Sharma, Suresh Pande, Mamta Sharma, Vincent Vadez, Krishnamurthy L, Ranga Rao GV, Ma Cynhia S Bantilan, Parthasarathy Rao P, Kumara Charyulu D, Moses Shyam D, Nageswara Rao GD, Padmaja Ravula, Ganga Rao NVPR, Jayalakshmi V, Satish Y, Trivikrama Reddy A, Muniratnam P, Suhasini K, Vijaykumar AG, Salimath PM, Kulkarni, Kiresur VR, Mannur DM, Ranjan Deo R, Ramesh Nath Gupta, Ravi Gopal Singh, Dayanidhi Mishra and Jahangir Alam Md

Summary

The chickpea activities in the phase I were conducted in Andhra Pradesh (Kurnool and Prakasam districts) and Karnataka (Dharwad and Gulbarga districts) states of India. In the phase II, the project activities were extended to Bangladesh and two additional states (Bihar and Odisha) of India. The project partners included ICRISAT-Patancheru; Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad, Andhra Pradesh; University of Agricultural Sciences, Dharwad (UAS-D), Karnataka; University of Agricultural Sciences, Raichur (UAS-R), Karnataka; Bihar Agricultural University, Sabour, Bihar; Orissa University of Agriculture & Technology, Bhubaneswar, Odisha; Bangladesh Agricultural Research Institute (BARI), Bangladesh; National Seed Corporation (NSC), India; State Farms Corporation of India Limited (SFCI), Andhra Pradesh State Seed Development Corporation (APSSDC); and Karnataka State Seed Corporation (KSSC).

The status of adoption of improved varieties and traits preferred by the farmers were assessed at the beginning of the project. Considering the requirements of target regions, the chickpea improvement program focused on developing breeding lines with high yield potential, early maturity, drought and heat tolerance, resistance to major diseases (Fusarium wilt, Ascochyta blight and Botrytis grey mold), resistance to pod borer, suitability to machine harvesting, and market-preferred seed traits. ICRISAT supplied over 300 improved breeding lines to NARS partners in India and ESA. The research team engaged in chickpea improvement activities in TL II much similar to TL I project and thus there was a good integration of research inputs and outputs between these two projects.

A “QTL-hotspot” containing QTLs for several root and drought tolerance traits were transferred from the drought tolerant line ICC 4958 to three leading cultivars, including JG 11, through three cycles of marker-assisted backcrossing (MABC) under TL I project. Introgression lines of JG 11 were evaluated at three to four locations each across India and ESA during 2011–12 and 2012–13. Several lines giving at least 10% higher yield than the recurrent parent JG 11 were identified at each location and each growing condition (rainfed/irrigated). Several breeding lines with higher levels of heat tolerance as compared to the heat tolerant cultivar JG 14 were developed. Breeding lines with enhanced resistance to botrytis grey mold were developed for Bangladesh and with enhanced resistance to Ascochyta blight for ESA. Early generation breeding materials were developed for resistance to *Helicoverpa* pod borer through interspecific hybridization and promising lines were identified. Breeding lines with greater plant height and semi-erect growth habit were developed for making them amenable to machine harvesting.

The earlier studies indicated that the adoption of improved chickpea cultivars continued to remain low in TL II target countries. Lack of awareness among the farmers about the improved cultivars and/or their useful traits and inadequate availability of seed of improved cultivars were among the major factors for poor adoption. Farmer-participatory varietal selection (FPVS) trials were conducted for exposing farmers to improved cultivars and allowing them to select cultivars according to their preference. The most preferred cultivars identified were JG 11, JAKI 9218, JG 130 and KAK 2 in Andhra Pradesh; JG 11, BGD

103, JAKI 9218 and MNK 1 in Karnataka; JG 14, KAK 2 and Subhra in Bihar; JG 14, Vihar and JAKI 9218 in Odisha. The traits for which these cultivars were preferred included, profuse podding, high productivity, early maturity, resistance to Fusarium wilt, and market-preferred seed traits (eg, medium-sized seed in desi type and large-sized seed in kabuli type). The results of FPVS trials strengthened release proposals of varieties. Two varieties, BGD 103 (large seeded desi) and MNK 1 (extra-large seeded kabuli) were released in Karnataka and one variety Nandyal Shenaga 1 (heat and drought tolerant desi) was released in Andhra Pradesh.

Seed availability at local level was enhanced by strengthening the formal as well as informal seed production chain. During phase I, 1,207 tons breeder seed and 886 tons certified and truthfully-labelled seed (TLS) of farmer-preferred improved chickpea varieties were produced by the research partners in India. In phase II (2011 and 2012), 7,560 tons chickpea were produced by the research partners in India and 6.1 tons by the research partners in Bangladesh.

Close to 17,000 seed samples (4,979 in phase I and 12,016 in phase II) of 2 kg to 20 kg were distributed to farmers in India and 90 samples (in phase II) to farmers in Bangladesh for enhancing their awareness about the improved cultivars. Various awareness activities created high demand of seed for farmer-preferred cultivars. The public seed corporations (NSC, SFCI, APSSDC and KSSC) joined hands with the research partners and produced 74,531 tons seed in phase I and 76,215 tons in phase II in India. In Bangladesh, 181 tons of quality seed was produced in phase II. In Karnataka state of India, 48 small seed companies started chickpea seed production through the policy support by the state government and produced 12,752 tons foundation seeds and 91,707 tons certified seeds during 2013.

Under capacity building in phase I, training on various aspects of improved crop and seed production technologies of chickpea was provided to 12,000 (10,842 men + 1,158 women) farmers and 1,411 extension personnel (1,229 men + 182 women) in India. In phase II, training was provided to 3,381 farmers (2,973 men + 408 women) and 1,075 (878 men +197 women) extension personnel in India; and 410 farmers (355 men + 55 women) and 90 (78 men + 12 women) extension personnel in Bangladesh.

A total of 48 field days and 10 farmers' fairs were organized, with the participation of 27,000 farmers (24,290 men + 2,697 women). In phase II, 52 field days were organized in which 5,255 farmers (4,282 men + 973 women) participated, 4,288 in India and 967 in Bangladesh. Efforts were made to reach large number of farmers through electronic and print media to disseminate information on the improved cultivars and crop production technologies.

Efforts were also made to enhance capacity of NARS in chickpea improvement and seed production. Two one-month training courses on "Chickpea Breeding and Seed Production" and one two-week course on "Pre-breeding and crop improvement of grain legumes" were organized at ICRISAT-Patancheru in which 17 researchers (13 men + 4 women) from the NARS of Ethiopia, Tanzania, Kenya and Bangladesh participated. The infrastructure facilities for seed production, processing and storage were strengthened at the research stations. Four PhD students (all men) and three MSc students (one man + 2 women) from India (5), Ethiopia (1) and Kenya (1) were provided accommodation for their thesis research on chickpea at ICRISAT-Patancheru.

Chickpea (*Cicer arietinum* L.) also called Bengal gram or Garbanzo is an important source of protein for millions of people in the developing countries, particularly in South Asia (SA), who are largely vegetarians either by choice or because of economic reasons. Chickpea is grown in more than 50 countries, but developing countries account for over 95% of its production. Over 80% of the chickpea production comes from South Asia, wherein India is the largest chickpea producing country accounting for about 70% of the global chickpea production. In India, chickpea contributes to over 40% of total pulse production and is denoted as the most important pulse crop of the country. Chickpea meets 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 140 kg N ha^{-1} from air.

Because of its deep tap root system, chickpea can avoid drought conditions by extracting water from the deeper layers in the soil profile.

There has been a substantial increase in global area and production of chickpea during the past 10 years (2003–2012). Resultantly, chickpea has become the second largest grown and produced pulse crop of the world after dry beans. The global chickpea area, production and productivity have increased by 26% (9.6 million ha to 12.1 million ha), 26% (737 kg ha^{-1} to 931 kg ha^{-1}) and 59% (7.1 million tons to 11.3 million tons), respectively. Remarkable progress has been made in ESA, where the area increased by 35% (325,000 ha to 440,000 ha), productivity almost doubled (653 kg ha^{-1} to 1260 kg ha^{-1}) and production increased by 161% (212,000 tons to 554,000 tons). South Asia, which contributes to over 80% of the global chickpea production also showed good progress in chickpea production. The chickpea production increased by 59% (5.22 million tons to 8.32 million tons) due to an increase in its area by 32% (7.53 million ha to 9.96 million ha) and productivity by 21% (693 kg ha^{-1} to 836 kg ha^{-1}).

Drought and heat stresses at reproductive stage are the major abiotic stresses while Fusarium wilt, *Helicoverpa* pod borer, Ascochyta blight, Botrytis grey mold and Dry root rot are the major biotic stresses to chickpea production in SA. Though a wide range of improved chickpea cultivars are now available, many farmers continue to grow old varieties and landraces. The farmers are either not aware of the improved varieties or do not have access to seed of improved varieties. Thus, the achievements of chickpea improvement research have not been fully translated into increased productivity at the farm level. The productivity of chickpea can be substantially enhanced by the adoption of improved cultivars and associated improved production technologies. There is also scope for enhancing its area cover in the SA countries.

Intended targets to be achieved and major activities:

The project aims to increase the productivity and production of chickpea and the income of poor farmers in target regions by 15%, with improved varieties occupying 30% of the total area in the coming 10 years.

The major activities involved for achieving the different objectives are as follows:

Objective 1: To enhance the market opportunities, policies and partnerships along the legume value chain, to increase the income and nutritional security of smallholder farmers in the drought-prone areas of sub-Saharan Africa (SSA) and SA.

- Participatory monitoring and evaluation (M&E) of adoption and impact
- Targeting technologies and scaling-out innovations
- Assessment of market innovations, institutions and policy
- Capacity building

Objective 5: To enhance chickpea productivity and production in the drought-prone areas of SSA and SA.

- To identify and facilitate the adoption of farmer– and market–preferred chickpea varieties in the drought-prone areas.
- To develop improved chickpea germplasm to meet the requirement of farmers and consumers in the target environments.
- To enhance the capacity of NARS in chickpea improvement and empower the extension personnel and farmers with knowledge of chickpea production technology.

Objective 8.6: To develop sustainable seed production and delivery systems for the smallholder farmers in SA (India, Bangladesh)

- To provide support to the formal seed sector.
- To facilitate the promotion and economic analysis of alternate seed models.
- To enhance the local capacity to produce, deliver, store and market seeds
- To enhance the local–level awareness about the farmer-preferred varieties (Linked with Objectives 2, 5 and 6).
- To improve the availability of foundation seed by NARS and other public sector as well as private sector.
- To design and test the alternative seed production arrangements (tailored according to various clients needs)
- To design, test and implement diffusion, marketing and institutional arrangements to enhance the seed delivery (tailored according to various client needs).
- To enhance the local–level awareness about the released varieties (demand creation).

Locations and partners

In phase I, the target country was India, and the locations selected for chickpea activities included two districts (Kurnool and Prakasam) of Andhra Pradesh and two districts (Dharwad and Gulbarga) of Karnataka State in South India. During phase II, the project activities were extended to a new country Bangladesh and two other Indian states, Bihar and Odisha. The following were the key project partners:

- ICRISAT, Patancheru, Andhra Pradesh, India
- Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad, Andhra Pradesh, India
- University of Agricultural Sciences, Dharwad (UAS-D), Karnataka, India
- University of Agricultural Sciences, Raichur (UAS-R), Karnataka, India
- Bihar Agricultural University (BAU), Sabour, Bihar, India
- Orissa University of Agriculture & Technology, Bhubneswar, India
- National Seed Corporation (NSC), India
- State Farms Corporation of India Limited (SFCI), India
- Andhra Pradesh State Seed Development Corporation (APSSDC), India
- Karnataka State Seed Corporation (KSSC), India
- Pulses Research Center (PRC), Bangladesh Agricultural Research Institute (BARI), Ishurdi, Bangladesh

Situation and outlook

A number of biotic and abiotic factors limited the realization of yield potential, besides the lack of availability of improved seeds to farmers. The slow growth of chickpea yield in India can be attributed to: (i) the shift in crop area from favorable to marginal environments; (ii) the slow uptake of improved varieties and other production technologies; and (iii) its cultivation on poor soils under erratic rainfall conditions.

Trade in chickpea is relatively robust and has been growing over time. Close to 10% of the total chickpea produced during 2003–2005 entered the international market. The trade statistics indicated a demand-supply imbalance for pulses in Asia. While the quantum of chickpea exports from Asia doubled between 1981 and 2007, overall the region remains as a net importer. The increased import demand has induced countries such as Australia and Canada that traditionally did not grow chickpea to emerge as significant exporters now.

The scope of raising chickpea production in Asia through area expansion alone is extremely limited. Therefore, the main challenges for research and development are to bridge the gap between actual and attainable yield by: (a) enhancing the farmers' access to good quality inputs, improved technologies and information; (b) improving the competitiveness of pulse crops through domestic incentives related to production, marketing, processing prices in line with cereals and competing crops; and (c) achieving a technological breakthrough that not only overcomes yield barriers but also provides effective protection against insect pests and diseases, and tolerance to moisture stress.

Key achievements

Crop improvement

Development of cultivars

Considering the requirements of the target regions, the chickpea improvement program focused on developing breeding lines with high yield potential, early maturity, drought and heat tolerance, resistance to key diseases (Fusarium wilt, Ascochyta blight, Botrytis grey mold), resistance to pod borer, suitability to machine harvesting, and market-preferred seed traits.

Over 300 promising breeding lines were selected at ICRISAT–India and supplied to the project partners. Two international chickpea screening nurseries (ICSN–Desi and ICSN–Kabuli) were constituted each year and supplied to the project partners. Each ICSN consisted of 18 advanced breeding lines, one common check and one local check. The partners identified several promising breeding lines from these nurseries for further evaluation in station and multilocation trials. The promising lines identified included ICCV 09106, ICCV 09107, ICCV 09112, ICCV 09116, ICCV 09118, ICCV 07103, ICCV 07104 and ICCV 07110, ICCV 12101, ICCV 12110 and ICCV 12113 in desi type (>5–20% higher yield than the check JG 11/ICCC 37) and ICCV 06302, ICCV 12303, ICCV 12309 and ICCV 12313 in kabuli type (>5–10% higher yield than the check KAK 2). Considering the demand for extra-large seeded kabuli chickpeas, ICSN–Kabuli large seed was constituted and supplied to the project partners for evaluation during 2010 and 2012. Several lines (ICCV 10411, ICCV 10410, ICCV 10402 and ICCV 10404, ICCV 12402, ICCV 12403, ICCV 12405 and ICCV 12406) with larger seed and on par yields with check (KAK 2) were identified.

A "QTL–hotspot" containing QTLs for several root and drought tolerance traits was transferred from the drought tolerant line ICC 4958 to three cultivars (JG 11, KAK 2, Chefe) via three cycles of marker-assisted backcrossing (MABC) under the TL I project. A set of 20 BC_3F_4 introgression lines of JG 11 were evaluated at three locations in India (Patancheru, Nandyal, Gulbarga) and one each in Kenya (Koibatek) and Ethiopia (Debre Zeit) during 2011–2012. Another set of 20 BC_3F_4 introgression lines of JG 11 lines were evaluated at four locations in India (Patancheru, Nandyal, Gulbarga, Dharwad) during 2012–2013. Several lines giving at least 10% higher yield than the recurrent parent JG 11 were identified at each location and growing condition (rainfed or irrigated).

A set of 30 germplasm/breeding lines, including both desi and kabuli types, were evaluated during the normal-sown and late-sown conditions at three to four locations each during 2011–12 and 2012–13, with an aim to identify the stable heat tolerant genotypes. Based on the two years results, several promising heat tolerant genotypes (ICCV 07117, JG 11, JG 16, JG 130, JGK 2, JG 14, NBeG 3, ICC 8474, ICCV 07109, ICCV 06302, ICC 4958, ICCV 07102, and ICCV 07105) were identified. In addition, over 700 breeding lines were evaluated for heat tolerance at ICRISAT–Patancheru and several lines with higher levels of heat tolerance as compared to JG 14 were identified. Several tall and upright breeding lines suitable for machine harvesting were developed and evaluated at four locations (Patancheru, Nandyal, Dharwad, Gulbarga) in India. Promising lines identified included ICCV 13601, ICCV 13605, ICCV 13607, ICCV 05107, ICCL 85213, ICCV 04103 and ICCV 08108.

Breeding lines with enhanced resistance to botrytis grey mold were developed for Bangladesh and with enhanced resistance to Ascochyta blight for Ethiopia and Kenya. Pod borer (*Helicoverpa armigera*) is the most devastating insect-pest of chickpea. However, the levels of resistance available to Pod borer in the cultivated chickpea are very low. Interspecific crosses of *C. arietinum* (cultivated chickpea) x *C. reticulatum* (wild progenitor of chickpea) are being used to enhance the resistance to pod borer. Forty F_6 progenies derived from the cross between *Helicoverpa*-resistant *C. arietinum* accession ICC 506EB and the *C. reticulatum* accession IG 72953, along with parents and the susceptible checks (ICC 3137 and ICCC 37) were evaluated for resistance to pod borer using detached leaf assay in the laboratory and under no-choice cage conditions in the greenhouse. Some interspecific progenies with higher levels of resistance than either of the parents involved in the crosses were identified for further evaluation.

Identification of farmer- and market-preferred chickpea cultivars

The status of adoption of improved varieties and traits preferred by the farmers were assessed at the beginning of the project. Taking into account farmer- and market-preferred traits, in phase I, eight improved cultivars or breeding lines (4 desi + 4 kabuli) were selected for FPVS trials at each of the four project locations (Kurnool and Prakasam districts in Andhra Pradesh and Dharwad and Gulbarga districts in Karnataka). Twenty mother trials and 217 baby trials were conducted in 23 villages (5 to 8 villages in each district) during 2007–2008 to expose farmers to improved cultivars and allow them to select their preferred cultivars. The crop in Prakasam district of Andhra Pradesh was destroyed in the first year by heavy rains at maturity, so FPVS trials were repeated in the second year (2008–2009). About 1181 farmers (1052 men + 129 women) were involved in ranking of varieties in FPVS trials. The desi chickpea cultivars, JG 11 and JAKI 9218, were preferred in all four districts. In addition to these, desi chickpea cultivar JG 130 was preferred in both the districts of Andhra Pradesh while desi chickpea cultivar BGD 103 and kabuli variety MNK 1 were preferred in both the districts of Karnataka. Farmers in Prakasam district of Andhra Pradesh also preferred kabuli chickpea cultivar KAK 2. These cultivars were preferred due to traits like profuse podding, high productivity, early maturity, resistance to Fusarium wilt, and market–preferred seed traits (eg, medium seed size in desi type and large seed size in kabuli type).

During phase II (2011–12 and 2012–13), FPVS trials were conducted in new target regions of India (Bihar and Odisha states) and Bangladesh (Barind and Sylhet regions). Nineteen FPVS trials on six improved varieties were conducted in Bangladesh while 647 farmers participated in the selection process (608 men + 39 women), the most preferred cultivars identified were JG 14, BARI Chola 9 and BARI Chola 3. In India, 22 FPVS trials on six improved varieties were conducted in each of the new states (Bihar and Odisha). Hence, 1218 farmers (753 men + 465 women) ranked the varieties in Bihar and preferred one desi (JG 14) and two kabuli (KAK 2 and Subhra) varieties. Similarly in Odisha, 462 (386 men + 76 women) farmers participated in ranking of different chickpea varieties and the most preferred varieties identified were JG 14, Vihar and JAKI 9218. During Phase II, 17 demonstrations of BARI Chola 5 and BARI Chola 9 varieties were conducted in Bangladesh.

Release of cultivars

The results of FPVS trials strengthened the release proposals of varieties. A desi chickpea variety BGD 103 was released and notified for cultivation in Karnataka state of India in 2009. This was a high yielding, large–seeded variety with early maturity and resistance to Fusarium wilt. A kabuli chickpea variety MNK 1 was later released by the Central Variety Release Committee for South Zone of India. This variety had extra-large (52 g/100–seed) seed. One desi variety, Nandyala senaga 1 (NBeG 3), released in 2012 from the Regional Agricultural Research Station, Nandyal, Andhra Pradesh, India, was an early maturing, drought and heat tolerant, Fusarium wilt resistant and high yielding variety.

Seed systems

Seed systems and enhancing adoption of improved cultivars

The seed systems objective (Objective 8) was instrumental in catalyzing the scaling up of foundation and certified seeds (CS), seed delivery testing models, and raising farmer awareness about the improved cultivars. The economics of legumes seed production was not attractive enough for private seed sector, due to their large seed size resulting in high volume and consequently high costs incurred in transportation and storage. Thus, seed production was largely dependent on public seed sector and informal seed systems (seed production by individual farmers and farmers' groups/societies).

Breeder seed and other classes of seed produced by research partners

The project partners in the target locations of India and Bangladesh made excellent progress in chickpea seed production and distribution. Although the research partners were mainly engaged in production of breeder seed (BS) in phase I, they produced limited quantities of CS and TLS. They together produced 2,093 tons of seed, which included 1,207 tons BS, 205 tons CS and 681 tons TLS. The seed was produced both at the research stations and at the farmers' fields under direct supervision of scientists. The share of JG 11 was 84% in BS and 71% in CS and TLS. In phase II (2011 & 12), research partners in India (including new locations) and Bangladesh produced 7,560 tons and 6.1 tons quality seeds, respectively.

Foundation (FS) and certified seed (CS) produced by public seed corporations

A strong partnership between the research institutes and public seed corporations was established, where the research partners produced BS and the public seed corporations produced FS and CS. In phase I, the four seed corporations (NSC, SFCI, APSSDC and KSSC) together produced 74,531 tons of seed that included 3,924 tons FS and 70,607 tons CS. The JG 11 was the most popular variety with 85% share in CS. In phase II (2011 and 2012), the public seed sector partners in India (including new locations) and Bangladesh have produced 76,215 tons and 181 tons of quality seeds, respectively.

Foundation and certified seeds produced by private seed companies

During phase II, with the policy support from the state government of Karnataka, India, around 48 small private seed companies came forward to undertake the seed production of popular chickpea cultivars grown by the local farmers. These companies produced 12,752 tons FS and 91,707 tons CS during 2013.

Seed samples distributed to farmers

Seed sample packs of different sizes (2–20 kg) of farmer-preferred varieties were distributed to the farmers for enhancing their awareness about the improved varieties and ensuring the availability of initial quantity of high quality seed for further multiplication. In phase I4,979 seed samples were distributed in four target districts. The total quantity of seed distributed was 47.5 tons. In phase II (2011 and 2012), 76.2 tons of small chickpea seed samples (4–25 kg each) were distributed to 12,016 farmers in India and 90 farmers in Bangladesh.

Adoption and impacts

Key achievements and lessons learnt from Baseline survey and early adoption studies

Project progress during phase-I (2007-2010)

Under TL II, ICRISAT and its research partners tested promising chickpea varieties on farmers' fields at selected villages of Andhra Pradesh (AP) and Karnataka (KA) states during 2008–2009 through FPVS trials. Activities related to seed production and seed distribution of farmer–preferred varieties caused quick dissemination and improved the incomes of farmers within a short time period.

In Andhra Pradesh, which is a new area for chickpea, there has been a quick churning of varieties and cropping systems to hit on the optimum blend of soils, agronomy and varieties. Chickpea has taken deep roots as an alternative to tobacco, which is being discouraged by the governments and grown by farmers who grew other post-rainy season crops like sunflower, coriander etc. No varieties were entrenched as ruling varieties. The Regional Agricultural Research Stations (RARS), Lam and Nandyal of ANGRAU collaborated with ICRISAT and released few varieties like Sweta and Kranti in the early 1990s. Even Annigeri was tried as one of the alternatives in late 1990s. Farmers were quick in trying new varieties like KAK 2 and JG 11 which were released in 1999 by remaining in touch with the ICRISAT research stations and Krishi Vigyan Kendra's. The research stations were also in regular contact with the farmers in the selected villages to test their varieties and technologies. In case of Karnataka, chickpea is a traditional post-rainy crop but dominated by a single variety called Annigeri (A–1).

When TL II phase-I project was launched in 2007–08, some of these progressive villages were picked up as intervention and control villages. Due to this reason, farmers were already using the improved varieties in the baseline survey year of 2006–07. The same varieties were tried in the FPVS trials along with some other new varieties. JG 11 was preferred by the farmers in the FPVS trails conducted in both Kurnool and Prakasam districts of Andhra Pradesh. It showed better yields than the other desi and Kabuli varieties tested in the mother trials conducted in 2007–08 and 2008–09. The research system recommended the multiplication and supply of JG 11. Moreover, the public seed production units like the Andhra Pradesh State Seed Development Corporation (APSSDC), National Seed Corporation (NSC) and State Farms Corporation of India (SFCI) organized the seed production of JG 11 and put it in the seed supply chain. Farmers from both adopted and control villages of Kurnool district adopted it largely by 2009–2010, the years of early adoption survey. In the adopted and control villages of Prakasam district, the farmers used more of Kabuli varieties because of substantial difference in the market price over that of desi varieties. The marginal yield advantage in favour of desi varieties like JG 11 was swamped by the price difference of ₹500 ($7.57) to ₹600 ($9.09) per 100 kg in favour of the Kabuli varieties. KAK 2 remained as the most preferred variety in the adopted and control villages. The significant fact is that the farmers in the sample villages of both Kurnool and Prakasam district have completely adopted the improved varieties and other technologies. The impact of this technology adoption was seen in terms of improved yields and higher net returns (see Table 62 and 63).

Annigeri was a long entrenched variety in Karnataka region for nearly four decades. It evolved in Karnataka, earned quick popularity and remained as the most preferred variety of farmers even in 2006–07, when baseline survey was conducted. However, the FPVs trials conducted in 2007–08 in Dharwad and Gulbarga districts asserted the supremacy of new varieties like JG 11, BGD 103, JAKI 9218 among the desi varieties. KAK 2 and MNK 1 proved their superiority among the Kabuli varieties in Dharwad and Gulbarga districts, respectively. Farmers also selected JG 11 and BGD 103 as the top two varieties preferred for their agronomic and market characteristics. In TL II project, the researchers also supplied small quantities of the chickpea seeds of farmer-preferred varieties to the sample farmers in

Table 62. Performance of chickpea in the sample villages of Prakasam district of Andhra Pradesh.

	Varietal composition (%)		Yield (kg ha^{-1})	
Varieties	BL–2007	EA–2009	BL–2007	EA–2009
Annigeri	24.48	2.62	1,072	1,420
ICCV 2	9.87	0	1,200	-
KAK 2	26.37	78.5	1,317	1,912
JG 11*	39.28	18.88	1,241	1,877
JAKI 9218*	0	0	-	-
Overall	100	100	-	-

* introduced through the TL II project; BL: Baseline in 2007; EA: Early Adoption survey in 2009-10

Table 63. Performance of chickpea in the sample villages of Kurnool district of Andhra Pradesh.

	Varietal composition (%)		Yield (kg ha^{-1})	
Varieties	BL–2007	EA–2009	BL–2007	EA–2009
Annigeri	45.35	10.13	1,015	1,235
ICCV 2	0	0	-	-
KAK 2	1.43	0	1,112	-
JG 11*	53.22	89.45	1,356	1,869
JAKI 9218*	0	0.42	-	1,766
Overall	100	100	-	-

* introduced through the TL II project; BL: Baseline in 2007; EA: Early Adoption survey in 2009-10

adopted and control villages of Dharwad and Gulbarga districts. However, there was no large-scale effort to organize the seed production and distribution of preferred varieties by the State Seed Corporation in Karnataka. As a result, these varieties did not enter the seed supply chain in a big way (see Table 64 and 65).

Table 64. Performance of chickpea in the sample villages of Dharwad district of Karnataka.

	Varietal composition (%)		Yield (kg per ha)	
Varieties	BL–2007	EA–2009	BL–2007	EA–2009
Annigeri	91.5	41	1,023.8	1,030
Bhima	2.4	2	686.2	1,113
Kabuli (KAK 2)	4.9	2	992.9	1,019
Local or others	1.2	2	1,009.4	-
JG 11*	0	23	-	1,314
BGD 103*	0	18	-	1,374
JAKI 9218*	0	12	-	1,250
MNK 1*	0	0	-	889
Overall	100	100	-	-

* introduced through the TL II project; BL: Baseline in 2007; EA: Early Adoption survey in 2009-2010

Table 65. Performance of chickpea in the sample villages of Gulbarga district of Karnataka.

	Varietal composition (%)		Yield (kg per ha)	
Varieties	BL–2007	EA–2009	BL–2007	EA–2009
Annigeri	94.2	42	1,148.4	1,097
Bhima	0	0	-	-
Kabuli (KAK 2)	1.6	5	1,007.8	1,175
Local or others	4.2	3	955.1	748
JG 11*	0	22	-	1,398
BGD 103*	0	18	-	1,405
JAKI 9218*	0	0	-	1,333
MNK 1*	0	10	-	1,227
Overall	100	100	-	-

* introduced through the TL II project; BL: Baseline in 2007; EA: Early Adoption survey in 2009-2010

Project progress during phase II (from 2011 to date)

During the phase II of the TL II Project, two new locations (Bihar in India and Barind region in Bangladesh) were identified for targeting and introduction of new technologies. The baseline surveys in Bihar were completed in Bhagalpur and Banka districts with reference to 2010–11. Subsequently, FPVS trials were carried out during 2012–13. The mother trials conducted in different locations have concluded that JG 14, Shubhra and KAK 2 are the most preferred cultivars in Bihar. Deshla Plain and Deshla Roon were the preferred dominant local cultivars noticed during the baseline survey. The baseline report is still being finalized. Similarly, the chickpea baseline surveys were also implemented in Rajshahi and Chapai Nawabganj districts of Bangladesh in 2010–11. BARI Chola 5 and BARI Chola 9 are the most common cultivars (occupied nearly 85%) observed in the baseline sample households. Among the different BARI Chola varieties, BARI Chola 9 gave the highest productivity in the study locations. Mustard is the most competing crop with chickpea during the post-rainy season. The early adoption surveys are planned during the end of the third year of the project.

Two massive real-time tracking surveys covering 500 households each were initiated in the phase I locations ie, in Andhra Pradesh and Karnataka states respectively for a better understanding about the adoption of TL II project introduced improved cultivars in the targeted sites as well as their further diffusion across the seed sample beneficiaries from the project. Primary data collection, data entry and data validation have been completed under these surveys and data analysis and report writing are in progress. Based on the preliminary field insights, the adoption of chickpea improved cultivars in Prakasam and Kurnool districts of Andhra Pradesh has reached its peak (nearly 99%). In case of Karnataka, remarkable diffusion of JG 11 (nearly 60–70%) was observed in both Dharward and Gulbarga districts. The chickpea farmers were significantly benefited through the enhanced yields, improved soil fertility, increased household nutrition and fodder availability.

Capacity building

Knowledge empowerment of farmers, extension personnel and seed traders

Training farmers in chickpea crop and seed production technologies

The farmers' training in improved chickpea production technology, seed production and storage was given high priority. Over 150 training programs were organized by the NARS partners in the phase I with the participation of 12,000 (10,842 men + 1,158 women) farmers. In phase II (2011 and 2012), 75 training programs were conducted with the participation of 3,381 farmers from India (2,973 men + 408 women) and 410 farmers from Bangladesh (355 men + 55 women). These training programs covered various topics like FPVS trials, improved chickpea varieties, improved chickpea production technologies, integrated pest management; seed production, processing and storage; and post-harvest value addition.

Field days and farmers fairs

In phase I, 58 field days or farmers' fairs (also called Kisan Mela or Krishi Mela) were organized with the participation of about 26,987 farmers (24,290 men + 2,697 women). These events exposed farmers to improved cultivars and production technologies and gave them opportunities of interacting with researchers, extension personnel and developmental agencies. In phase II (2011 and 2012), 52 field days (41 in India and 11 in Bangladesh) were organized in which 5,255 farmers (4,282 men + 973 women) participated totally – in India, and in Bangladesh, 796 (726 men + 70 women).

Awareness activities through electronic and print media

Efforts were made to reach a large number of farmers through the electronic and print media to disseminate information on improved cultivars and chickpea crop production technologies. During phase I, the project partners organized 55 activities through the crop growth period to enhance farmers' awareness on integrated chickpea production practices. Similarly in phase II (2011 and 2012), 34 awareness activities were organized in India which was followed by two activities in Bangladesh. A chickpea seed production manual was published in English, Telugu (for Andhra Pradesh) and Kannada (for Karnataka) languages. The English version is available online (www.icrisat.org/tropicallegumesII/pdfs/ChickpeaManual_full.pdf).

Training of extension personnel

Training program on improved chickpea production technology was provided to the extension personnel from research organizations, Department of Agriculture (Agricultural Officers, Assistant Directors of Agriculture) and NGOs. In phase I, 1,411 (1,229 men + 182 women) extension personnel in India were given training at the district research stations. In phase II, 26 more training programs were organized with the participation of a total of 1,165 (956 men + 209 women) extension personnel 1075 from India, (878 men + 197 women) and 90 from Bangladesh (78 men + 12 women).

Training of seed traders

In addition to public seed sector, the local seed traders play an important role in making seed available to the farmers. This is particularly important when the private seed companies have little involvement in the legume seed production. Training programs were organized for improving the knowledge and skill of local seed traders in proper seed handling. In phase I, 130 seed traders were imparted training on seed processing and safe storage. Similarly, in phase II, 160 seed entrepreneurs from Andhra Pradesh and Karnataka states of India were given training on chickpea seed production technologies during 2011-12. There were no woman participants in these training programs because men dominate the local seed trading business.

Capacity building of NARS partners

Training of scientists and research technicians

In phase I, two one-month training courses on "Chickpea Breeding and Seed Production" were organized at ICRISAT-Patancheru. The first course was organized during January- February 2008 and the second course was organized during January-February 2009. Twelve researchers (9 men + 3 women) belonging to the NARS of Ethiopia, Tanzania and Kenya participated in these training courses. Various topics like conventional and biotechnological (genomic and transgenic) approaches of chickpea improvement and improved practices for chickpea cultivation and seed production were included. The participants also had an opportunity to visit other organizations in Hyderabad working on seed-related research, seed production and seed quality testing. In phase II, one two-weeks training program was organized on "Pre-breeding and crop improvement of grain legumes" in which four researchers from ESA (2 each from Tanzania and Kenya) and one researcher from Bangladesh participated. In 2012, one NARS scientist from Bihar Agricultural University received one-week training at ICRISAT, Patancheru on improved chickpea production technologies. Three scientists associated with TL II projects in India participated in multi-year training course on integrated breeding organized by GCP.

Development of infrastructure facilities

The research stations have responsibility of producing nucleus seed and breeder seed of the varieties developed by their institutes. Modest support was provided to strengthen the infrastructure facilities for seed production, processing and storage at the participating research stations. The following facilities were developed in phase I:

- RARS-Nandyal: Renovation of existing seed storage structures, motorbike, electronic weighing balance, digital seed counter, sump motor and multi-crop thresher.
- ARS-Darsi: Seed processing plant (capacity: 2 tons/hr), seed storage stands for the seed store and motorbike
- UAS-Dharwad: Mobile seed processing plant, seed storage bins, seed cabinets and motorbike
- ARS-Gulbarga: Sprayers, seed storage bins, motorbike, digital camera and computer.

Degree students

Seven students (5 men + 2 women), which included four PhD students (all men) and three MSc students (1 man + 2 women) were accommodated for their research work on chickpea at ICRISAT–Patancheru. Two PhD students (Tosh Garg and BS Patil from India) and one MSc student (Tadesse Safera from Ethiopia) completed their research work and were awarded degrees. Two PhD students (Pranab Paul and BP Mallikarjuna from India) are still conducting their experiments and two MSc students (Nancy Wathimu Njogu from Kenya and Prity Sundram from India) are writing their theses. Research work of four of these students has some components of the application of molecular markers (linked to TL I).

Lessons learned

The key lessons learned are as follows:

- Farmers' awareness about improved varieties and availability of the seeds of improved varieties are key factors in dissemination of improved chickpea cultivars.
- FPVS trials are very effective in enhancing the awareness of farmers about improved varieties and in dissemination of new varieties.

- In addition to yield, the maturity, resistance to diseases and seed traits preferred by market (seed size, color and shape) were given high weightage by the farmers in varietal selection.
- The farmers' preference for growing kabuli chickpea varieties largely depended on the price premium received over desi type.
- Lack of proper cleaning, grading and storage facilities hampers the seed production by individual farmers.
- The farmers were very keen to adopt the seed production of improved varieties, provided proper arrangement was made for seed procurement through national/state seed corporations or other agencies.
- Huge opportunities exist for the expansion of chickpea area in rice-fallows of Bangladesh, Bihar and Odisha.
- Dry root rot has emerged as a major disease of chickpea in southern India; however, tolerant varieties are not available.
- Varieties tolerant to herbicides and suitable for mechanical harvesting are needed in southern India.
- to be maintained among all the stakeholders for sustained pigeonpea productivity and trade.