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Seed Systems for Rainfed Agriculture:

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International Crops Research Institute
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Seed Systems for Rainfed Agriculture:
Village Based Seed Enterprise for Seed Production and Dissemination of Improved Varieties of Chickpea and Pigeonpea in India

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1. Preamble

The crops grown under rainfed agriculture are described as farming practices that rely on rainfall for crop production and their seed systems describe, how farmers in these regions are sourcing seeds for cultivating these crops. The objective of this publication is to share information and experiences of some success stories of seed value chain models developed for production and supply of improved varieties of seed of rainfed crops to resource poor farmers in the semi-arid tropical regions to enhance productivity. Majority of legume crop varieties grown under rainfed agriculture system are open pollinated varieties or self-pollinated crops especially, cereals and legumes grown in semi-arid tropics of the globe. The importance of rainfed agriculture varies regionally but produces high percentage of food for poor communities in the developing countries. In sub-Saharan Africa more than 95% of the farmed land is rainfed, while the corresponding figure for Latin America is almost 90%, for South Asia it is about 60%, 65% for East Asia and 75% for the Near East and North Africa (FAO STAT, 2005).

The problems in semi-arid tropics are exacerbated by adverse biophysical growing conditions and the poor socioeconomic infrastructure. The uncertain climatic conditions or otherwise known as climate change/variability effects makes SAT farmers more vulnerable. The most essential input for crop production is seed and is the cheapest of all inputs in rainfed agriculture. A good quality and improved variety seed can enhance the productivity up to 20% and with improved crop production practices can increase the yield by 35-40%. The major types of seed constraints in rainfed agriculture are 1) Seed insecurity due to frequent droughts, and natural disaster 2) Poverty and food insecurity 3) Demand for quality seed and new varieties and 4) Development of appropriate seed systems.

Availability and accessibility to improved varieties of seed in these areas is a big task. During drought years and natural calamities government subsidized seed or international relief programs meet the requirement of seed supply which nullifies farmers' preference and forces them to adopt the variety available. But it's a temporary relief for farmers and the problem of seed in security continues. The semi-arid tropics home to 38% of the poor in developing countries, 75% of whom live in rural areas. Over 45% of the world's hungry and more than 70% of its malnourished children live in the semi-arid tropics. The institutional mechanisms to multiply the farmer preferred varieties of crops grown in rainfed agriculture is poorly developed and private seed sector does not seem to show any interest insuch crops because of economic reasons. Although the public sector research and development organizations do focus on spreading improved developed varieties to enhance production and productivity in these regions, the public sector extension mechanisms are unable to disseminate the technologies to farmers to meet their requirements completely in India (Macklin Michael, 1992).

Despite a wide range of reform initiatives in agricultural extension in India in the past decades, the coverage of, access to, and quality of information provided to marginalized and poor farmers is uneven (Glendenning, Babu, and Asenso-Okyere, 2010; Ferroni and Zhou, 2011).

2. Cultivation of chickpea and pigeonpea

India is the largest producer and consumer of pulses in the world. Major pulses grown in India include chickpea or Bengal gram (*Cicer arietinum*), pigeonpea or red gram (*Cajanus cajan*), lentil (Lens culinaris), urdbean or black gram (*Vigna mungo*), mungbean or green gram (*Vigna radiata*), lablab bean (*Lablab purpureus*), moth bean (*Vigna aconitifolia*), horse gram (*Dolichos uniflorus*), pea (*Pisum sativum* var. *arvense*), grass pea or khesari (*Lathyrus sativus*), cowpea (*Vigna unguiculata*), and broad bean or faba bean (*Vicia faba*). Most popular among these are chickpea, pigeonpea, mungbean, urdbean, and lentil (Gowda *et al.* 2013). Among the various pulse crops, chickpea dominates with over 40 percent share of total pulse production followed by pigeonpea (18-20%), mungbean (11%), urdbean (10-12%), lentil (8-9%) and other legumes (20%) (IIPR Vision 2011). Nevertheless, India increased imports of pulses from 350,000 t in 2001 to 2.7 million t in 2008 (FAO-STAT). Reddy (2004; 2009) and Reddy *et al*. (2010) forecasted that India's domestic supply will be insufficient to meet demand ranging from 9% to 26%. Concerns about demand continuing to outstrip supply has prompted Indian government to take aggressive steps to foster increased grain legume production, such as raising minimum support prices and launching the Accelerated Pulses Production Program (A3P).

Pigeonpea (*Cajanus cajan* (L.) Millsp.) Globally pigeonpea is cultivated in 4.3m ha with a production of 3.5m tons annually. Pigeonpea is a staple grain legume in South Asian diets and is also widely grown and consumed in African households – and rapidly expanding as an export crop from eastern and southern Africa to South Asia. Household production is not well documented in the FAO database. India is by far the largest producer with 3.6 m ha but this is insufficient to meet its domestic needs; thus it imports from Myanmar (0.5m tons) and other countries in the eastern/southern Africa region. Pigeonpea is also important in some Caribbean islands and some areas of South America where populations of Asian and African heritage have settled. Traditional long-duration pigeonpea expresses a perennial tall bush-like growth habit that conveys exceptional soil protection, nitrogen fixation, and deep-rooted nutrient recycling ability. Pigeonpea is generally relay or intercropped with sorghum, cotton, maize, and groundnut, delivering important sustainability benefits to these farming systems. The world's first F1 CGMS hybrid of any grain legume crop was recently developed by ICRISAT and partners, that produces 30 to 40% higher yields.

Chickpea (*Cicer arietinum* L.) (6.7 million tons on 9.2 million ha) is the world's second-largest smallholder-cultivated food legume with over 95% of its production and consumption in developing countries. Chickpea is an excellent source of high-quality protein, with a wide range of essential amino acids. Chickpea also fixes relatively large amounts of atmospheric nitrogen. India, a major chickpea consuming nation, does not produce enough to meet its needs, creating export opportunities for East African and other countries (Australia, Canada) to enter into this large market. Consequently the chickpea area in eastern and southern Africa has doubled over the past 30 years with exports accounting for about 30% of total production, indicating that farmers are using chickpea for both food and to earn extra income. The area under chickpea in West Asia has also increased dramatically in the past 30 years (from 378,000 ha to 1,526,000 ha) leading to the export of chickpea from countries such as Turkey, Syria, and Iran. Drought stress commonly affects chickpea because it is largely grown under rainfed conditions during the post-rainy season on residual soil moisture.

Productivity constraints include biotic (insect pests, disease, weeds), abiotic (drought, heat), and other factors (waterlogging, soil fertility). Technology and use barriers comprise of three contextual factors affecting: production availability/ access to seed or technology, difficulty in harvesting and mechanizability and legumes being "pushed out" of farming systems because of policy support or productivity gains of other crops.

General constraints of production

Conclusions drawn from research over the past three decades on chickpea and pigeonpea are summarized below, according to the key constraints in production: diseases, insect pests, drought, high and low temperatures, edaphic problems, salinity and aluminum toxicity, nitrogen fixation, phenology and weeds.

Diseases

- Chickpea suffers from Fusarium wilt. Ascochyta blight and botrytis gray mold are other important diseases in the northern part of India.
- Fusarium wilt and sterility mosaic disease (SMD) are the major pigeonpea diseases. Sources with individual and combined resistance to Fusarium wilt and SMD have been identified, and used for developing as well as deploying resistant cultivars. Phytophthora blight is also emerging as a major threat to pigeonpea production.

Insects

- All legumes suffer significant losses due to insect pests, especially chickpea and pigeonpea. *Helicoverpa armigera* is a serious pest on chickpea and pigeonpea, and *Maruca vitrata* and pod fly *Melanagromyza obtusa* are other pests on pigeonpea. Integrated Pest Management (IPM) systems, including host-plant resistance where available, have been the focus of research while devising control methods. Moderate levels of resistance to *Helicoverpa* have been identified in chickpea and pigeonpea, leading to the release of tolerant cultivars.
- IPM becomes necessary because of the ineffectiveness of individual control methods and the lack of high levels of resistance to the pests.

Drought

- Drought is one of the most important constraints to crop production especially as it can occur at any stage of crop development. Short-duration cultivars in chickpea and pigeonpea have been developed in legumes to overcome end-of-season drought. In pigeonpea terminal drought plays an important role in crop failure. Short to medium duration (130-150 days) pigeonpea varieties are now available to the farmers for cultivation and needs popularization. Early maturity of crops is one of the essential requirement of the farmers around the world to avoid end-of-season drought, beside exploitation of short season niches, and in multiple cropping systems.

High and low temperatures

- Research by The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) has shown that high temperature stress (above 300C) will occur with increasing frequencies in the near future in the important legumes growing areas like East and Southern Africa, India, South East Asia, and Northern Latin America. Heat stress even for a few days during flowering and pod filling stages drastically reduces seed yield. Chilling temperatures during the early reproductive growth cause yield losses in chickpea in many parts of Asia whereas low temperatures result in poor germination, poor crop stand, and reduced yield.

Edaphic problems

- Soil constraints, especially low soil fertility, limit legume yields across the tropics in smallholder agriculture. Root traits for efficient acquisition of nutrients (e.g., phosphorous) could contribute to improved efficiency in fertilizer use in legumes. Pigeonpea has the capacity to cope with low soil phosphorus as its roots secrete pissidic acid which solubilises phosphorus from the soil.

- The use of phosphate solubilizing bacteria, especially from *Pseudomonas*, *Bacillus,* and *Rhizobium,* has been used as inoculants to increase phosphorus uptake by the plant and increase crop yields. Phosphate solubilizing bacteria and plant growth promoting rhizobacteria together could reduce phosphorus fertilizer application by up to 50% without any significant reduction in the crop yield.

Nitrogen fixation

- Legumes fix atmospheric nitrogen (symbiotic nitrogen fixation or SNF), and also increase access to nutrients such as phosphorus. Sufficient numbers of compatible *Rhizobia* do not often occur naturally in most of the soils where grain legumes are cultivated but there is need for *Rhizobia* application to seeds. Production of efficient inoculants and distribution to smallholder farmers is a limitation, and needs to be addressed.

3. Interventions for enhancing production

One of the reasons for the low performance of many development projects and programmes is that they are often designed to address problems of target groups as perceived by government officials and other outsiders rather than as perceived by the people themselves. The danger with this approach is that in many cases, considerable amount of resources are expended on trivial problems while high priority issues of people are left unattended. The result is often that as soon as external funding and assistance are withdrawn, the initiated development activities which are supposed to be continued by the people are not carried beyond the life of the project period (Cromwell, Wiggins, and Wentzel 1993).

To enhance the on-farm productivity and to develop a sustainable integrated seed value chain, ICRISAT partnered with government, public and other institutions. The project partners are: Professor Jayashankar Telangana state Agricultural University (PJTSAU), Directorate of Agriculture (DoA), Regional Agricultural Research stations (RARS), Krishi Vignana Kendras (KVKs), and Farmers Associations (FAs), with the aim of convergence of individual resources and knowledge to increase crop productivity and farmers' incomes by reducing the gap between on-station yields of pigeonpea (1.0-1.5 t ha^{-1}) and farmers yields (0.3-0.5 t ha^{-1}) and providing market linkages.

The Morocco-India Food Legumes Initiative (MIFLI), an OCP Foundation funded project on "Increasing food legumes production by small farmers to strengthen food and nutrition security through adoption of improved technologies and governance within South-South cooperation" was launched by ICRISAT in India on 3 April 2013. ICRISAT is the Project Executing Agency (PEA) with principal partners from PJTSAU, Hyderabad, Telangana, DoA and University of Agricultural Sciences, Raichur (UASR) Karnataka.

Project locations: The partners identified two clusters in Telangana (Kodangal, and Ramapuram in Mahbubnagar district), Similarly partners in Karnataka have identified two clusters i.e., Raichur and Gulbarga districts covering a total of 12,000 farmers in 5 years period for both the crops, chickpea and pigeonpea.

The following improved crop production technologies were demonstrated across all villages and clusters of the project areas.

1. Improved varieties of pigeonpea such as PRG 176, (early duration) PRG 158 (Medium duration), and hybrid ICPH 2740 for assured irrigation areas were targeted. The varieties were recommended based on soil type and availability of irrigation sources.

2. Plant population geometry and spacing: Dibbling method of sowing to maintain plant population ranging from 15,000 to 20,000 plants ha^{-1} is optimum depending on receding soil moisture. Soil types play an important role in deciding the plant population. Wider row spacing of 150cm × 45cm and 10-12 cm depth of sowing must be adopted for better crop yields; a seed rate of 750 gram to 900 grams ha^{-1} depending upon variety or Hybrid is recommended for optimum plant population. A seed drill was developed for wider row spacing and deep placement of seed and fertilizer should be used for sowing under rainfed cultivation of pegionpea.

3. Seed treatment and fertilizer management: Seed treatment with *Rhizobium* for atmospheric nitrogen fixation and *Trichoderma* is a must to manage fusarium wilt disease. Application of fertilizer dose (before sowing) was recommended based on soil analysis reports. Emphasis was laid on application of micronutrients Zn, B, and S as foliar spray during vegetative phase or soil application once in three years is recommended based on soil analysis report.

With these interventions farmers were convinced and are showing more inclination for growing improved varieties. To mitigate the deficiency of seed production and supply, an innovative seed system model "Village-based Seed Enterprise" (Fig 1) was developed. A 'Farmers' cooperative society' was formed during 2013 for its implementation and monitoring and it involved farmers as the stakeholders of the enterprise with detailed roles and responsibilities in production and distribution of seed.

4. Mapping existing seed systems of chickpea and pigeonpea in the project area

The baseline survey findings (Kadiri Mohan *et al.* 2013) reveled that, inadequate seed production systems and the lack of access to seed by distant smallholder producers are particular bottlenecks to the adoption of improved varieties. Despite needs, the private-sector seed industry has been reluctant to invest in grain legumes due to the lower seed sale volumes, a larger number of site-specific varieties, and economic viability of private seed sector. Institutional and technical innovations to overcome these obstacles are showing promise and will be further developed.

Table 1. Sources of seed for pigeonpea and chickpea in the project area.

	Percentage of farmers procuring seed from various sources	
Seed source	**Pigeonpea**	**Chickpea**
Seed from previous crop (Farmers own saved seed)	53	69
Purchased from relatives	9	3
Government supplied seed	2.5	5
Private seed company	4	0
Village local markets	5	0
Inputs dealers shop	2	3
Other farmers in the village	16	20
KVK/ Agricultural University	8.5	0

Source: Baseline survey report 2013.

Note. KVK*:* Krishi Vigyan Kendras.

The survey data revealed that farmers are sourcing pigeonpea and chickpea seeds in the Telangana districts (project area), mostly by own saved seed accounting for 53% and 69% respectively, followed by purchased seed from other farmers or relatives in the village accounting for 16% and 20% respectively. In both crops the other sources of seed (Krishi Vigyan Kendras, universities, Govt. supplies, Department of Agriculture, and input dealers) constitute less than 10% (Table 1).

It is understood from the findings that the majority of farmers in the study area were accustomed to saving the cultivated variety seed for next cropping season and very few farmers sold the entire produce and procured seed from neighbouring farmers, because of debt recovery by the private money lenders. There was no significant role of private seed companies in selling pigeonpea and chickpea seed (Fig. 1). In this scenario, farmers are required to be trained in proper selection and storing of seed material, good seed treatment practices and chemicals for controlling seed borne pest and disease.

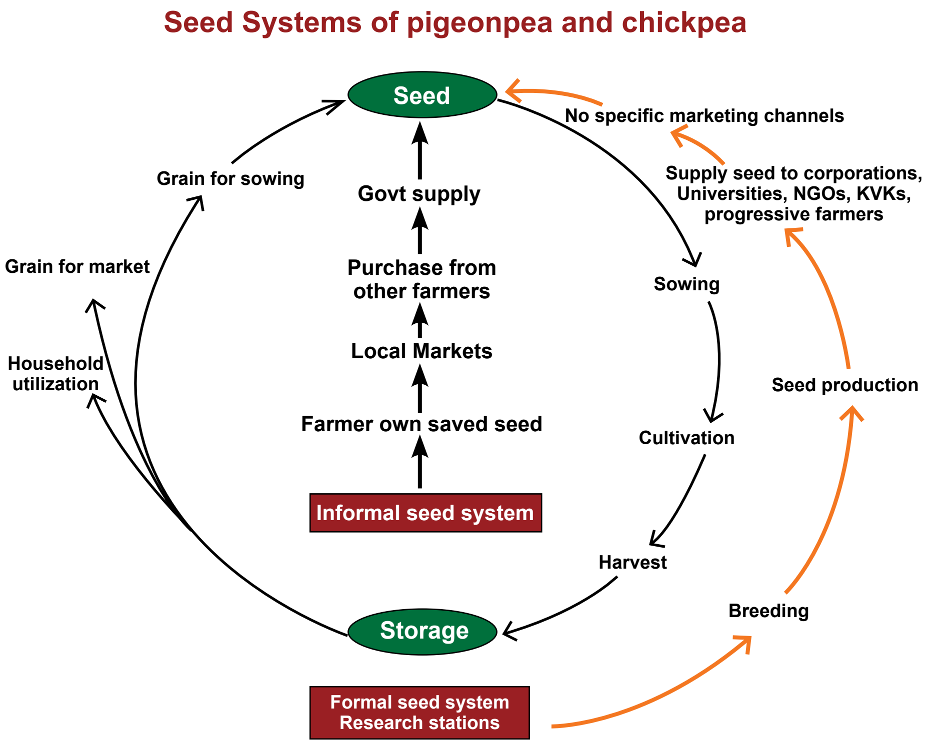

Fig. 1: Flow of genetic material from formal and informal systems in pigeonpea and chickpea crops in the Telangana state.

Reasons for high and low yields of pigeonpea and chickpea in the project area

During interactions pigeonpea farmers responses were sought on major identified reasons for high and low yield and farmers were also asked to rank them based on the importance of the reason in influencing the crop yields.

Table 2: Major reasons as perceived by the farmers for getting high yields of pigeonpea and chickpea (n=300) (Garrets scores)			
	Farmer's response (%)		
Reason for high yield	**Yes**	**No**	**Rank**
Good variety and quality seed used	77	23	III (66)
Sown at right time	55	45	VI (44)
Seed treatment was done	11.67	88.33	VII (38)
Seed was treated with Rhizobium	1.33	98.67	IX (19)
Technical advice helped	58.33	41.67	V (50)
IPM techniques was followed	1.67	98.33	VIII (31)
Fertilizer was applied in time	64	36.00	II (69)
Timely irrigation (rains and supplementary irrigation if available)	71.33	28.67	IV (62)
Favorable climatic conditions	96.33	3.67	I (81)

Source: Baseline survey report 2013

Baseline data revealed the perceptions of the farmers and it was evident that favorable climatic conditions (96.33%), good variety and quality seed (66%), timely irrigation (71.33%), and technical advice at the right time (58.33%) were the major reasons for good harvest (Table 2). However, sometimes farmers are in dilemma while assessing their own needs for increasing the yields. They perceived that the reason for low yield was mainly due to poor quality seed (poor germination and mixture of many varieties) and non-availability of improved variety seeds (Table 3).

Table 3: Reasons for low yields in pigeonpea and chickpea as perceived by the farmers (n=300) (Garrets scores)			
	Farmer's response (%)		
Reason for Low yield	**Yes**	**No**	**Rank**
Local variety and Poor quality seed	84.67	15.33	I (81)
Inadequate technical help(Extension)	40.00	60.00	VI (44)
Low soil moisture	79.00	21.00	IV (56)
Late sowing	41.33	58.67	VII (38)
Lack of Irrigation	52.00	48.00	III (62)
Attack of insect pests	35.00	65.00	V (50)
Attack of diseases	27.00	73.00	VIII (19)
Unfavourable climatic conditions (low and timely rainfall)	90.33	9.67	II (69)

Source: Baseline survey report 2013

Constraints to adoption of improved cultivars and production technologies in the project area

The available studies suggest that, in general, adoption of improved cultivars and production technologies has been low and slow in grain legumes, as compared to commercial crops.

i) **Inadequate dissemination of information to farmers** – At the most fundamental level, many farmers are not aware about the improved cultivars and production technologies available and/or their potential advantages. Various awareness activities (field days, farmers' fairs, farmers' field schools, and news programs through electronic and print media and training program) and farmer participatory varietal selection (FPVS) trials have been used by the government agencies which were also insufficient to increase the levels of awareness among farmers.

ii) **Inadequate availability of seed –** One of the key factors limiting the adoption of improved cultivars of pigeonpea and chickpea is the awareness about improved cultivars and inadequate availability of quality seed of improved cultivars to the farmers. In some cases seed may be available, but not in adequate quantity or at the place and time as required by the farmers, or at the price affordable by the farmers. The commercial (both public and private) seed industry has shown limited interest in seed production of pigeonpea and chickpea mainly because of the following factors.

Limitations of formal seed systems

- The varieties developed are often not adopted by small farmers due to complex environment stresses and low input conditions.
- The formal seed sector has difficulty in addressing the varied needs of small farmers in marginal areas.
- The commercial (both public and private) seed industry offer only a limited range of varieties.
- The formal seed sector is reluctant to produce the market varieties of the major millets, legumes, and groundnut because they may not be commercially feasible. Even if they produce such varieties, they may not be able to reach small farmers in remote rural areas.
- The interest of the private sector may cease to be served once the varieties are sold to farmers because the latter tend to save their own seed for the next season and hence will not buy again.

- Prohibitive/high seed prices are a limitation for resource-poor farmers.
- Poor logistics in seed diffusion and high seed demand constrain formal seed programs.
- Some grain legumes have a high seeding rate (eg 60 to 120 kg ha^{-1} for chickpea and groundnut) and are bulky in nature. This poses challenges in production of large quantities of seed, their transportation and distribution to farmers who are widely scattered in the inaccessible rural areas.
- Seed viability of pigeonpea and chickpea is lost due to storage, pests and good storage conditions are required to store seeds for longer duration.

Currently, there is a need for stronger public-sector seed production of legumes as the involvement of private seed sector is very limited. In addition, community based or farmers seed system (informal seed systems) needs to be strengthened especially for self-pollinated crops like chickpea and pigeonpea. The activities that can facilitate promotion of informal seed systems may include training of farmers groups/communities/cooperative societies, and facilitating these for seed production and marketing as well as promoting rural seed entrepreneurs in the absence of formal or private seed sector is a challenge.

5. Implementation of seed system model

Methodology and Approach

In 2013 a baseline survey was carried out to collect information on the household characteristics, production practices, and constraints of production with particular reference to knowledge about the improved varieties and seed availability. The main objective of the project is to improve farmer's accessibility and availability of good quality seeds of improved varieties at affordable price at right time for enhancing yield, income and household seed security; as well as for recording benchmark indicators for measuring project achievements.

Formation of Village Based Seed Enterprise

Prior to the formation of village based seed enterprise (VBSE), awareness programs were conducted with farmers and villages leaders in the Ramapuram cluster villages (project area) in Mahbubnagar district of Telangana state to get an idea about the understanding of the farmers and village leaders about the concept. Farmers expressed their concern about the seed constraints and showed eagerness to grow improved varieties (Fig. 2). Based on their assurance of seed production and storage, the formation of cooperative society was

Fig. 2. Awareness meeting with cooperative society members at Ramapuram village.

initiated to establish and manage the VBSE. As per the Seed Act, 1966 (Act No. 54, Govt. of India), for establishing village based seed enterprise a legal body "Farmers agricultural cooperative society" registered with the state cooperative department to deal with seed production and marketing is required.

An approach described by Bishaw and van Gastel (2008) was adopted in establishing VBSE with farmers as key players with the agricultural university, regional agricultural research stations, Department of Agriculture (state govt.) and KVK as the guiding force. The basic strategy was decentralized seed production, business/distribution model, access to technology, and inculcating sustainable issues from the beginning of the implementation of enterprise.

The proposed conceptual and organizational approach, strategies and partners, the linkages and support from formal sector institutions were planned (Fig. 3) and a seed supply model was developed. This model included state Department of Agriculture, State Agriculture Universities, Krishi Vigyan Kendras, Self-help groups, non-Government organizations, and the farmers.

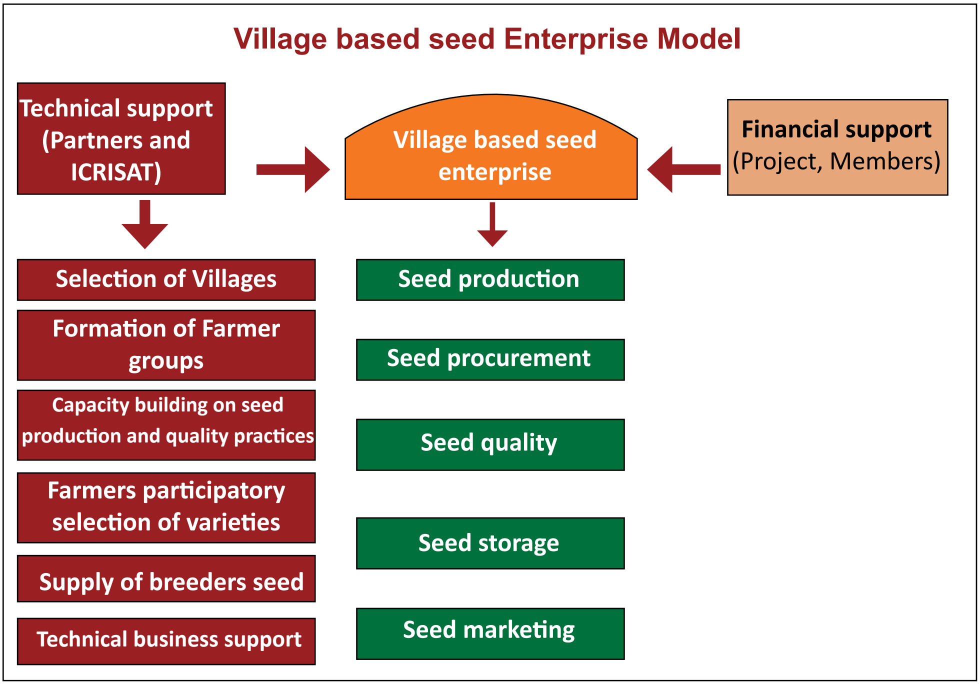

Fig. 3. Village Based Seed Enterprise model for legume crops and linkages to market.

I) The Model

Based on the finding of baseline survey on existing production and distributions of chickpea and pigeonpea varieties seeds systems in Telangana (Kadiri Mohan *et al.* 2013), a village based seed enterprise model was developed (Fig. 1) in order to multiply improved varieties of seed and distribute to farmers through a cooperative society. The formal sector (private seed companies) is very weak and is always unwilling to participate in the system for reasons of economic benefits. The public sector institutions (regional research stations of agricultural universities) are usually involved only in research and development of new varieties and production of breeder and foundation seed; even if they produce seeds it will of very limited quantity.

In this model, we envisage a centralized seed production and procurement as well as distribution in initial years to meet the requirement of cluster villages (five) but eventually we wish to shift to decentralized seed production and centralized procurement and distribution. The basic objective of the VBSE is to consider the farmer preferred varieties developed by the public sector research and development institutions (ICAR, SAUs and ICRISAT) and to play a critical role in seed production, procurement and dissemination of these improved products to farmers. For example, paddy (a self-pollinated crop) seed production and distribution in the country, which is gaining good momentum in seed replacement rate (39%) is an example for progress and scope for self-pollinated crops seed system (Rao Y, 2010).

ii) Roles and responsibilities of partners:

For establishing a VBSE ICRISAT and partners developed an integrated seed value chain model by harnessing the power of genetics, crop management, value addition, and markets based on the strengths and achievements of OCPF project. VBSE model delineated responsibilities to partners for establishing and implementing the seed business as per the targets fixed during the general body meeting of the society (Table 4).

1. **State Agriculture Universities:** Prof. Jayashankar Telangana State Agriculture University (PJTSAU) is a partner of the project and has developed pigeonpea and chickpea varieties suitable for the project area through their regional research stations. The selected released varieties in chickpea like NBG 3, JG 11, Jakhi 3, and PRG 158 and PRG 176, and ICRISAT Hybrid ICPH 2740 in pigeonpea respectively are multiplied on research farm and supply Breeder/ and Foundation seed to VBSE for production of the certified seed. The cost of foundation seed production is borne by the project. The universities, society staff and Department of Agriculture (DoA) scientists jointly selected villages and farmers for seed production.

2. **NGOs and KVKs:** These organizations agreed to encourage farmers in growing seed in addition to village seed program to meet the target area under seed production. However, one of the programs of these organiasations on seed development was merged with our program and the farmers were benefited by having access to foundation seed supply, training programs and other crop production incentives, and market linkages through partnerships.

3. **Department of Agriculture:** The DoA mainly provided Agricultural Extension services to farmers and disseminated latest technical knowledge to the farming community, introduced high yielding varieties, demonstrated and imparted training to farmers to improve their skills and knowledge to boost up the agricultural production and productivity. Under this project convergence of strengths of DoA in dissemination of project findings to other parts of state by conducting demonstrations in the farmers' fields will help in introducing improved technologies of pigeonpea and chickpea cultivation.

4. **Farmers' cooperative society:** The farmers of cluster village formed an association and registered it (REGD No. 21/2013) with the state cooperative society department to get legal status for conducting seed business as per the norms of Seed Act 1966. The society managed all activities of VBSE and other activities such as liaising with research institutions (Breeder seed), training programs, other input supplies, and financing and accounting.

iii) Capacity building

Seed producing farmers were trained on seed production technique, isolation distance, sowing practices, other agronomic practices to be followed for the pigeonpea and chickpea crops. Training was organized during flower initiations stage of the seed crop. The seed growing farmers were trained to identify off types, rogues, and its removal from these plants in the seed plots and maintain the quality of seed production. They were also trained on other agronomic practices, plant protection measures, and harvesting methods. Further training was organized after harvest and during seed processing to impart knowledge on seed cleaning, seed grading, seed treatment, seed storage, seed packaging aspects, and on drawing the representative seed sample, for seed testing/local seed testing method to assess the seed germination and quality.

Training programs were conducted on-station (University) and on- farm (in the villages) by technical staff of universities along with the DoA officials. During the seed production period, university and ICRISAT technical staff used to visit the farmers' fields and give technical advice to farmers on quality seed production practices.

iv) Seed Production

The member farmers from the cluster villages who volunteered for taking up seed production and were financially sound were selected and trained in seed production methods (Fig. 4&5). During first year (2013) of project implementation, they were able to grow seed crop on five ha and produce 13.2 tons of chickpea seed. In second year (2014) seed production area increased and produced 21 tons of chickpea (JG 11 and NBG 3) and 2 tons of Hybrid pigeonpea (ICPH 2740) and 1 ton of variety PRG 176. The second year seed will be marketed in year 2015, based on the prevailing grain prices at the time of sowing. Breeder seed of chickpea procured from regional research station, Nandiyal, Andhra Pradesh, pigeonpea parental line of hybrid given by ICRISAT and breeder seed of variety PRG 176 given by RARS, Palem, are used for seed production. The cost of seed production of pigeonpea and chickpea by the farmers is given in Annexures 1 and 2.

Fig. 4. Chickpea seed production plot monitoring by university scientists.

Fig. 5. Pegionpea seed production plot monitoring by university scientists.

Table 3: Economics of village based seed enterprise in year 1			
S.no.	Items (Expenses)	Cost (INR)	Total cost (INR) in lakhs
1	Seed procurement- 13.2 tons		4.38
2	Godown rent		0.28
3	Power bill		0.018
4	Seed cleaning and packing		0.12
5	Godown maintenance		0.05
6	Book keeping		0.04
7	Total		4.88
8	Receipts-seed sales		
9	Selling price per kg of seed	46/- kg (10% less than market price)	6.12
10	Net profit		1.24

In first year, farmers produced seeds given to cooperative society and stored in the godown for eight months without taking sale amount from the enterprise but with an understanding of getting 10% higher than market price after selling the seed (Table 3). Subsequently seed were sold to village farmers (members of the society) on preferential basis (Fig. 6) and other farmers (Non-members) were given secondary preference with 10% higher price and payments were made to seed producers after the completion of eight months. The cooperation of farmers in developing the seed enterprise remains a challenge until it is able to sustain with sufficient funds for procurement of seed from seed producers which may take couple of years. In the mean time, the enterprise is also planning to approach banks for financing the enterprise for seed production and procurement.

Fig. 6. Seed distributed to farmers during farmers day celebration.

v) Seed storage

A typical practice in semi-arid tropics to protect seeds from bruchid attack involves drying the freshly harvested chickpea seed in the sun, usually for about three to four days. While this may help, there is a continuing risk of post-treatment re-infestation. Dried seed is subsequently stored in metal bins, polyethylene fertilizer or gunny bags and earthen structures, with turning and application of inert dusts (mainly ash of fire wood) and neem leaves or castor oils (Yadav, 1997). Chemical insecticides can be used to control the storage pests, but may be hazardous, especially if the farmers do not take proper precautions in choosing and handling them. Another concern about insecticides is that they may degrade rapidly in tropical climates because of the high temperatures and humidity. Genetic resistance to bruchids could be used as a complementary way to reduce damage caused by the pest (Jadhav *et al.* 2012) but it takes time to develop new cultivars with high standards of yield and quality and multiple disease resistances. Solar heating combined with the use of transparent polyethylene bags prevents losses to storage pests in cowpea (Murdock and Shade, 1991; Ntoukam *et al.* 1997) and beans (Chinwada and Giga, 1996). Solar disinfestation was also found to be effective in controlling bruchids in pigeonpea (Chauhan and Ghaffar, 2002; Gunewardena, 2002) without negatively affecting germination. However, the storage procedures described above have been adopted by only a small proportion of farmers. There is a need for economically feasible, low labor intensive, safe (no use of chemicals), and convenient (easy to transport) storage technology that is easily adoptable and not only benefits farmers but also reduces losses due to damage caused by storage pests or reduction in germination and quality associated with long term storage. A comparative study was conducted in OCPF project to demonstrate and adopt the new seed storage technology. A building with Reinforced Cement Concrete Roof (RCC) roofing and stone flooring was taken on hire and converted into seed storage room. Precautions were taken to spray the room with malathion 50% *ethyl chloride* (EC). The seed harvested in the project villages were graded and sun dried for 2-3 days and plant materials were removed and the seed were stored in triple layer polyethylene bags (Fig. 7). Each bag weighing 50 kg a total of 13 tons of seed were stored in the room for 8 months; control samples were stored in gunny bags (farmers practice). Seed samples were drawn every two months for deriving the bruchid infestation count and germination percent (Table 5).

Table 5: Comparison of two seed storage methods on bruchid infestation and germination in chickpea seed

No. of samples	T1 (triple layer bags)				T2 (gunny bags)			
	Eggs	No. of seed	Damage seed	% damage	Eggs	No. of seed	Damage seed	% damage
1	150	337	13	3.86	2903	368	199	54.08
2	151	343	3	0.88	3323	365	209	57.26
3	160	353	10	2.83	3271	358	200	55.87
4	128	339	6	1.77	3352	361	189	52.36
5	130	342	5	1.46	3226	362	196	54.14
Total	719	1714	37	10.8	16075	1814	993	273.71
Mean	143.8	342.8	7.4	2.16	3215	362.8	198.6	54.74

Sample size: 100 grams of seed. ; Germination: T1: 95% and T2: 79%

Fig. 7. Seed stored in triple layer bags in the village.

Purdue Improved Cowpea Storage (PICS) bags control bruchid reproduction and damage in cowpeas and other crops (Baributsa *et al.* 2010; Murdock *et al.* 2012; Baoua *et al.* 2012). Our study indicates that this is also true in the case of another legume, chickpea. We confirmed this by determining the number of eggs per sample (100 gr.) of seed, and number of damaged seed per 100 seeds inside gunny and PICS bags ofter storing it for up to eight months. In PICS bags containing infested seed, the damage level was only 2.16% after eight months of storage compared with 54% seed damage in gunny bags. The seed damage in gunny bags by eight months was high, but there were nearly 986 eggs per 100 seeds and more serious damage was expected with the further extension in the storage period. The germination percent was reduced by 16% compared to T1. The effectiveness of hermetic storage for preserving grains against insect pests has long been connected with the depletion of oxygen and parallel rise in carbon dioxide (Murdock *et al.* 2012; Navarro *et al.* 1994).

vi) Seed quality

A low cost seed germination testing method developed for small-scale farmers of Telangana (Ravinder reddy *et al.* 2019) was adopted for testing seeds of chickpea and pigeonpea. Quality seed of improved varieties is an important basic input for enhancing the productivity of any crop species. Existing mechanisms to meet the quality seed of pigeonpea and chickpea germination of seed has serious limitations. The baseline studies in the project area (Mahbubnagar dist. of Telangana) identified key problems related to seed supply and seed quality. Lack of timely availability of seed, high cost of seed, and poor quality (low germination) were some of the major constraints contributing to stagnant yields of chickpea and pigeonpea crop in the project area.

The main objective of this test is to recommend quantity of seed per ha with a proper seed treatment chemical. The germination test demonstrated was simple, inexpensive, and reliable. It can be conducted at the farmer level at his residence without any additional facilities or equipment. It requires old newspapers and a plate. Four layers of a newspaper are spread on the floor and sprinkled with water to wet the paper. Chickpea/pigeonpea seeds are placed on the paper 2 cm apart (seed to seed) and 4 centimeter row to row. The newspaper is thoroughly wetted with water and rolled; the rolled newspaper tied with thread or a rubber band to keep the roll intact and was placed in the plate and incubated at room for 3-5 days. Similarly germination paper towel method was conducted (ISTA, 2015). This paper roll should be kept wet every day by pouring adequate water in the plate. Germination count was taken five days after incubation; there was no significant difference in percent germination between the newspaper method and the paper towel germination method.

Advantages of village based seed enterprise

- Availability and access to seed of improved varieties in sufficient quantities within the village.
- Assured and timely supply of seed material to farmers.
- Decentralized seed production, storage and distribution.
- Improved seed delivery mechanism to small and resource-poor farmers at reasonable price.
- Reduced dependency on external seed sources and effective curbs on spurious seed trade.
- Good opportunity for SHGs and community organizations to invest and develop a seed business at village level.
- Encourages village-level trade and improves village economy.
- Social responsibility of seed production and delivery system.
- Ensures sustainable crop production through quality seed.
- Scope for farmer-participatory varietal selection and feedback to the scientific community on the performance of cultivars in different agro-ecoregions.
- Avoid diseases carried through seed (seed-borne pathogens) or produced and imported from other agro-ecoregions.
- Availability of true-to-type varieties and quality seed within the reach of farmers at affordable prices.
- The probability of sustainability is high because farmers are involved in a business line right from the beginning of seed enterprise establishment. Additionally they are also involved in, seed production, storage and marketing through their own investment and sharing the benefits which makes it a win-win situation.

6. Way forward

Following are some important measures that could provide way forward to meet the challenges in developing alternative paradigm for sustainable seed value chain to enhance production and productivity of rainfed agriculture crops:

1. Documentation of constraints of seed systems of rainfed agriculture crops in different agro-ecosystems to develop a strategy to address these issues.

2. Identification of seed needs of specific crop varieties for a target area.

3. Seed or Cultivar replacement rate (CRR): i) State must ensure production, multiplication, and replacement of seed to increase CRR progressively, especially rainfed regionally important leguminous crops (chickpea and pigeonpea) varieties. ii) CRR will take place through technology up gradation and extension work and govt. policies. iii) For achieving the desired levels of CRR, adequate quantities of improved varieties seed has to be produced. vi) CRR and Varietal replacement rate (VRR) will improve farming income and profitability.

4. Seed mission: Developing and implementing a seed mission with a built in mechanism of supporting the cost of seed production for five years by the Govt. by adopting Public–Private–Partnership with effective coordination and convergence mechanisms.

5. Selection of cultivars: Appointing a joint committee comprising of Indian Council of Agriculture Research (ICAR), State Agriculture Universities (SAUs), public and private seed sector representatives and farmer groups to select/ certify varieties /hybrids suitable for different agro-ecological areas of India.

6. Decentralization of seed production: Promoting contract seed production program by advance indenting of the seed of specific crop variety (local or improved) to private/public institutions and with proper monitoring arrangements, rural institutions like KVKs, NGOs, CBOs, SHGs, farmers associations can also be included.

7. Policy and funding support frame: i) An enabling policy environment does help in production and dissemination of seeds of rainfed crops improved varieties in India ii) Provision of funds to rural institutions/organizations (KVKs, NGOs, CBOs, SHGs, farmers associations) and technical support for seed multiplication and dissemination activities for at least 5 years in mission, mode.

Annexure 1: Cost of pigeonpea seed production		
Operations	**Cost (INR per acre)**	
	Hybrid (ICPH 2740)	**Variety (PRG 176)**
1. Land preparation (Ploughing primary and secondary tillage) and seed bed preparation.		
• Guntaka	480.00	-
• Blade harrow (5)	480.00	480.00
• Blade harrow (9)	480.00	480.00
• Guntaka	480.00	480.00
Sub Total	**1920.00**	**1340.00**
2. FYM/C2.Compost/Sheep penning/Tank silt application	-	
• Godavari Gold/ Bhujeevan 5 bags/acre	1875.00	-
• FYM/Compost/poultry	-	1200.00
• Animal penning	-	-
Sub Total	**1875.00**	**1200.00**
Date of sowing	22-06-2014	10-07-2014
3. Planting/Sowing		
• CP + 1 M and 3 WM labours	1800.00	-
• 2 WM labours	**-**	1400.00
4. Seed cost:	600.00	240
4a. Seed treatment	50.00	-
Sub Total	**2450.00**	**1640.00**
5.Fertilizer & micro nutrient application		
• SSP Granules	1275.00	
• DAP		1265.00
• Urea 25k g	193.00	75.00 (10kg)
• MOP	449.00	
• Application of Carbofuron at time of sowing against. Ash weevil 8-10 kg	1050.00	
Sub Total	**2967.00**	**1340.00**
6. Intercultural operations	**1000.00**	**800.00**

Annexure 1: Cost of pigeonpea seed production		
Operations	**Cost (INR per acre)**	
	Hybrid (ICPH 2740)	**Variety (PRG 176)**
7. Weeding		
• Pendimethalin (chemical)	450.00	450.00
• 1 hand weeding (6 labors X Rs. 150/-	900.00	900.00
Sub Total	**1350.00**	**1350**
8. Plant protection Spraying/Dusting/Shaking /Hand picking pest)	spraying	spraying
• Carbofuron 5kg	525.00	525.00
• Rogor (400ml) + Neem oil (400ml)	200.00	-
• Chloriphyriphos 400ml + confidor (50ml) (Rs. 108 + 165)	525.00	200.00
• Corozen (60ml) + Novan (Rs. 1780 + 75)	1855.00	-
• Emamectin Benzoate	-	400.00
• Flubendamide	-	850.00
• Acephate	-	135.00
Sub Total	**3105.00**	**2110.00**
9. Source of irrigation	Bore well	Rainfed
9a. Irrigation		
• Drip irrigation	**300.00**	**-**
10. Watching (Birds, Pigs etc)	-	-
• Rouging: 2times 6 labours	**1200.00**	**600.00**
11. Harvesting : Date of Harvesting: Crop2 Crop3	**1600.00**	**800.00**
12. Threshing	**3000.00**	**2000.00**
• Sieving + Grading	**1600.00**	**800.00**
• Bagging	**550.00**	**250.00**
13. Marketing (including transport, and labour charges)	**500.00**	**200.00**
14. Fixed Cost: Land Rent (Rs per acre)	Own land	Own land
15. Grain Yield:	**725 kg**	**600 kg**

Annexure 1: Cost of pigeonpea seed production		
Operations	**Cost (INR per acre)**	
	Hybrid (ICPH 2740)	**Variety (PRG 176)**
16. Fodder yield	-	-
17. Grain Cost (sale amount)	**79,750.00**	**36,000**
18. Total cost of cultivation	23,417.00	14,430.00
19.Net returns	56,333.00	21,570.00
20. B:C ratio	2.40	1.49

Annexure 2: Cost of chickpea seed production	
Operations	**Cost (INR per acre)**
1. Land preparation (Ploughing primary and secondary tillage) and seed bed preparation.	
• Blade harrow (5)	480.00
• Guntaka	480.00
Sub Total	**960.00**
2. FYM/C2.Compost/Sheep penning/Tank silt application	
• FYM/Compost/poultry	1200.00
• Animal penning	-
Sub Total	**1200.00**
Date of sowing	02-10-2014
3. Planting/Sowing	
• 2 WM labours	**1300.00**
4. Seed cost:	**2700.00**
4a. Seed treatment	
5.Fertilizer & micro nutrient application	
• DAP	1265.00
• Urea 10k g	75.00
Sub Total	**1340.00**
6. Intercultural operations	**-**
7. Weeding	
• Pendimethalin (chemical)	450.00

Annexure 2: Cost of chickpea seed production	
Operations	**Cost (INR per acre)**
• 1 hand weeding (6 labors X Rs. 150/-)	900.00
Sub Total	**1350.00**
8. Plant protection Spraying/Dusting/Shaking /Hand picking pest)	spraying
• Flubendamide	850.00
• Emamectin Benzoate	400.00
• Corozen (60 ml)	525.00
• Flubendamide	850.00
Sub Total	**2625.00**
9. Source of irrigation	Rainfed
10. Watching (Birds, Pigs etc)	
• **Rouging:** 2times 4 labours	**600.00**
11. Harvesting[2]: Date of Harvesting: Crop2 Crop3	**1200.00**
12. Threshing	**1000.00**
• **Sieving + Grading**	**600.00**
• **Bagging**	**250.00**
13. Marketing (including transport, and labour charges)	**400.00**
14. Fixed Cost: Land Rent (Rs per acre)	**own land**
15. Grain Yield:	**900 kg**
16. Grain Cost (sale amount)	40,500 .00
17. Fodder yield:	-
18. Total cost of cultivation	15,525.00
19. Net returns	**24,975.00**
20. B:C ratio	1.60

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