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Final report

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1 Acknowledgments

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2 Executive summary

Project SMCN-2006-013 commenced in January 2007 with broad aims to improve food security, nutritional health and livelihood needs of the poor farmers and communities in the Sagaing, Mandalay and Magway Divisions of Myanmar's Central Dry Zone (CDZ). The contracted institution was the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, with collaborating agencies in Myanmar (Department of Agricultural Research (DAR) and the Myanmar Agricultural Service (MAS)) and Australia (NSW Department of Primary Industries (2 years), and the University of New England (2 years)). The specific aims of the project were to increase legume (groundnut, chickpea and pigeonpea) productivity in the CDZ through varietal improvement, provision of high-quality rhizobial inoculants and human capacity and infrastructure development.

The project commenced with an inception workshop in March 2007 and a Participatory Rural Appraisal (PRA) in the CDZ involving 163 farmers. The PRA provided information on farmer requirements for cultivars of chickpea, pigeonpea and groundnut with high yields, disease resistance and market traits, as well as the use of *Rhizobium* inoculants for enriching soils in their cropping systems. The project addressed these issues, as follows:

- New, high-yielding varieties of chickpea, pigeonpea and groundnut were identified by the Department of Agricultural Research (DAR) and ICRISAT scientists after 4 years of evaluation in 88 replicated Mother trials and 541 unreplicated Baby trials across 23 township areas in the CDZ. The new varieties yielded as much as 35% more than traditional varieties. A farmer participatory model was used throughout with more than 1,500 farmers involved in conducting on-farm trials, increasing seed or selecting preferred varieties at field days.
- The Myanmar Agricultural Service (MAS) led the village seed bank program in which the highest-yielding and farmer-preferred varieties were seed increased for dissemination to more farmers. This is a critical step in having the new, high-yielding varieties grown widely throughout the CDZ. The pilot program was effective with good quantities of pure seed produced and disseminated.
- Low-cost technologies for crop production and protection are fundamental for small holders because of limited funds for chemical inputs. Trials compared conventional (chemically-based) inputs, biological inputs and a mixture of the two. Overall, the conventional input system produced the highest yields, with the hybrid chemical-biological system the most cost-effective.
- Production of substantially improved rhizobial inoculants was achieved through post-graduate and short-term training, infrastructure development and laboratory procedural changes. A major development was the replacement of large-volume rhizobial fermentation with small-volume fermentation, culture dilution and solid-state fermentation in the peat carrier.
- Capacity building for Burmese scientists was integrated with the above through completed or on-going training in India (associated with ICRISAT) and Thailand, including 3 PhD and 1 MSc programs and 14 short-term (3 weeks–4 months) training programs in breeding, extension methodology, low-cost legume production technologies and rhizobial inoculant production.

Underpinning all project outcomes was the development of strengthened networks for R&D on the food legumes in Myanmar, linking DAR and MAS scientists in Myanmar to those at ICRISAT, the Suranaree University of Technology (SUT), Thailand and in Australia. The momentum generated by this project needs to be sustained through new activities that build on the above achievements and embrace new disciplinary fields, such as plant and soil nutrition, pest and disease management and farming systems R&D.

3 Background

Legumes play an important role in the livelihoods, nutrition and health of peoples in all countries, particularly in the less-developed countries, and in improving the incomes derived from agricultural production systems worldwide. As an integral part in the Asian diet they are the major source of protein, minerals and vitamins for a large section of the population. Of the 24 million ha of agricultural land in Myanmar under cultivation, pulses and oilseed legumes are the second most important group of crops after rice with production of 5.8 million tonnes from 4.2 million ha (Myanmar Agriculture at a Glance 2010). The area under legumes has increased steadily from 2.0 million ha in 1995 and is expected to continue to increase in the future. Legumes are primarily grown by small-holder farmers with minimal inputs. Increasing legume productivity through research and development (R&D) is one of the most potentially successful strategies to improve livelihoods, income, food and nutritional security for people in Myanmar.

Average yields of the legume crops are still low at 1.4 t ha^{-1} compared with potential yields of 2.0–4.0 t ha^{-1}. To improve productivity at the farm level, this gap needs to be bridged by incorporating high yielding varieties with preferred traits and appropriate crop management technologies. Legumes have an important role to play to address issues of soil nitrogen (N) fertility and cropping productivity because of their capacity to fix N from the atmosphere. Hence, the rotation of cereal crops with legumes, or mixed or intercrops with legumes is essential to improve soil health and productivity. Lack of high yielding cultivars, good quality inputs and the management of biotic and abiotic stresses are among the major constraints to legume production in Myanmar.

This project was focused on the Central Dry Zone (CDZ) of the country with 500-800 mm rainfall isohyets between mountain ranges to the north, east and west and the delta region to the south. Three Divisions were involved – Sagaing, Mandalay and Magway – which together constitute 26% of the land area of Myanmar and are home to about 30% of the country’s population. Sagaing, Magway and Mandalay Divisions are also the major areas of chickpea, pigeonpea and groundnut production in Myanmar. They are located 18º–23ºN latitude with differences in annual rainfall (range 858–1663 mm), but similar in temperature. The project was implemented by ICRISAT in collaboration with the NSW Department of Primary Industries (NSWDPI) (later, University of New England (UNE)), Australia and the Department of Agricultural Research (DAR) and Myanmar Agricultural Services (MAS), Myanmar.

Adoption of proper crop management practices, including application of fertilizers, is required to realize the genetic potential of an improved variety. The use of inorganic fertilisers in Myanmar is low, as it is costly and not readily available (Myanmar Agricultural Statistics, 2001; Win *et al*., 2002). The production and supply of *Rhizobium* inoculants is also a constraint in Myanmar principally because of lack of production capacity and personnel expertise. Reports from Myanmar indicate that inoculation increased grain yields of chickpea, groundnut and black gram in Myanmar by an average of 36%, equivalent to 0.27 t ha^{-1}. Hence substantial efforts were made in the project to improve rhizobial inoculant production and distribution.

Part of ICRISAT’s mandate is the improvement of chickpea, pigeonpea and groundnut. New breeding materials with enhanced resistance/tolerance to abiotic and biotic stresses and improved seed traits preferred by the market were shared with Myanmar scientists in the project. This gave an opportunity to introduce farmer participatory evaluation of the improved cultivars/breeding lines and crop improvement technologies adapted to the different cropping systems of Myanmar. Farmer participation in the varietal selection process was expected to ensure rapid adoption of the selected varieties by farmers.

4 Objectives

Identify and distribute high-yielding chickpea, groundnut and pigeonpea cultivars adapted to the relevant cropping systems of the Central Dry Zone of Myanmar, using farmer participatory varietal selection.

Increase production of high-quality rhizobial inoculants in Myanmar through application of a cost-effective strategy involving equipment and procedural changes, quality assurance, R&D and training.

Conduct training and extension programs on legume improvement and inoculant technology in order to enhance capacity for research and extension in these disciplines in Myanmar and to facilitate uptake of project outputs.

5 Methodology

Objective 1. Identify and distribute high-yielding chickpea, groundnut and pigeonpea cultivars adapted to the relevant cropping systems of the Central Dry Zone of Myanmar, using farmer participatory varietal selection

Activity 1.1. Assessing the requirements and preference of farmers for legume varieties of chickpea, pigeonpea and groundnut in the CDZ of Myanmar and current legume improvement programs

The project commenced with an inception workshop involving all stakeholders (policy makers in Myanmar, researchers from DAR, ICRISAT, Australia, extension experts from MAS) to review previous/current legume improvement activities in the CDZ and formulate the action plan for the project period. Preceding the workshop, a participatory rural appraisal (PRA) consisting of a 27-question survey was conducted with 163 farmers from the legume production areas in the three target Divisions (Sagaing, Mandalay, Magway) of the CDZ. The survey focussed on (a) preferred traits of the different legumes, (b) production constraints, (c) information about and access to new varieties, and (d) seed renewal and management. This information was processed and summarised for presentation and discussion at the inception workshop, resulting in the identification of relevant lines from ICRISAT matching the traits chosen by farmers and consumers and a time-line calendar of different tasks and responsibilities for all project partners.

Activity 1.2. Farmer participatory varietal selection trials at selected locations in the CDZ

Twenty three townships were selected as trial sites for research, and were also intended for the rhizobial inoculant research and extension and training activities. Outputs of Activity 1.1 (above) were used for identification of test materials (varieties/lines) for each of the three target legumes. Based on the PRA results and in consultation with researchers, 6 groundnut, 5 pigeonpea and 6 chickpea varieties were selected for on-farm evaluation against popular local varieties using the Mother-Baby trial model of participatory R&D.

Activity 1.3. Low-cost technologies to enhance seed germination, plant nodulation and crop protection

Seed priming involves soaking of seeds in water before sowing. In studies of upland crops (particularly post-rainy season crops such as chickpea, wheat) in Bangladesh, Nepal and India, seed priming improved germination, plant stand, nodulation (in the case of chickpea) and grain yield. Hence this low cost technology was tested at trial sites in Myanmar.

Deficiency of micronutrients can be an issue in some soils. In order to address this, soil testing was conducted at all locations to identify deficient elements and to supplement them (with relevant synthetic chemicals and/or locally available alternatives) to ensure that growth was not affected adversely. Studies were undertaken to evaluate the role of micronutrients in legume production and nodule functions (e.g. molybdenum, boron, iron, zinc) under the supervision of DAR researchers.

An ongoing on-farm activity at ICRISAT has successfully used low-cost, eco-friendly protocols for protecting crops (cotton and vegetables) from insect-pests. These involve the use of specific formulations of botanicals, entomopathogenic microorganisms, minor changes in agronomic practices (such as reduced use of N-fertiliser and use of trap crops) and traditional local knowledge. The same approach was tested in Myanmar. The botanicals such as Neem (*Azadirachta indica*), *Datura metel, Calotropis gigantia* and *Nerium indicum* are available locally. Besides the routine agronomic data, observations on pest damage and beneficial insects were also taken. Laboratory studies involved microbiology evaluation of inputs such as compost and other biological materials.

Activity 1.4. Development of a community-based seed production, storage and distribution system for improved legumes cultivars

Community-based seed production units were established in the selected villages that conducted the varietal evaluation programs. Village-based seed banks were formed and maintained by farmers across villages. Village seed bank committees were formed and were responsible for proper functioning of the bank. The same group of farmers were also trained for the safe storage of rhizobial inoculants, until distributed to farmers.

Objective 2. Increase production of high-quality rhizobial inoculants in Myanmar through application of a cost-effective strategy involving equipment and procedural changes, quality assurance, R&D and training

Activity 2.1. Increase capacity for production of high-quality inoculants at DAR

This activity commenced with a project inception workshop, with a dedicated session on ‘Legume Inoculants and Inoculant Production Technologies’ at DAR to review all aspects of inoculant production & distribution in Myanmar. The workshop provided the platform for all stakeholders (policy makers in Myanmar, researchers from DAR, ICRISAT, Australia, extension experts from MAS) plus Prof. Nantakorn Boonkerd, ex-Director of Thailand’s BNF Resource Centre to address the activity appropriately. Preceding the workshop, PRA was conducted in the project area to gather information on farmer needs and their perceptions of rhizobial inoculation (part of the PRA on legume varieties, see Activity 1.1 above for more details).

The DAR conducted simple +/- inovculation trails across the target Divisions in conjunction with activities under Objective 1 above, with results indicating widespread responses. A large amount of effort was put into the strengthen the existing laboratories and human resources through equipment purchase and staff training on-site at DAR and at the Suranaree University of Technology (SUT), Thailand. New protocols were developed for inoculant production, following the evaluation of existing production procedures during the first year of the project. Cultures of the inoculant strains used in Australia were added to the collection at DAR – these new strains would be used as the standard inoculant strains in Myanmar until such time that new, improved strains were sourced locally.

Activity 2.2. Improve shelf life and distribution of inoculants from production unit to farmers

Because of the biological nature of rhizobial inoculants, shelf-life and storage conditions are critical issues, particularly in Myanmar. There has already been research at DAR on the effects of storage temperatures on inoculant quality that formed the basis of discussion and future research in Myanmar and Australia at the inception workshop. The main determinant of shelf life is quality, i.e. numbers of rhizobia and numbers of contaminants in the inoculant. Changes made to the production protocols, particularly related to the rhizobial fermentation and peat sterilisation, should ensure enhanced shelf life.

Another intervention considered was to take advantage of village seed banks as a local agency for distribution of rhizobial inoculants along with seeds, as per the Thailand model. Because the village seed banks have not been established throughout the target production areas, the existing system of using DAR storage at Yezin followed by distribution will remain in place.

Activity 2.3. Improve inoculant quality through development and implementation of quality assurance (QA) procedures at DAR covering all aspects of inoculant production

The Australian QA procedures were followed as a model. Strain verification and maintenance is a major issue with rhizobia. Because of slow growth rates, particularly in the case of the tropical species, contamination of cultures is a persistent problem. Thus, agreed protocols for strain maintenance (freeze-drying, paraffin etc.) and recognition were implemented.

Objective 3. Conduct training and extension programs on legume improvement and inoculant technology in order to enhance capacity for research and extension in these disciplines in Myanmar and to facilitate uptake of project outputs

Activity 3.1. Training of selected DAR and MAS staff in improved legume production technologies and extension methodology at ICRISAT and visit to Indian national programs

Train-the-trainer programs were adopted such that the selected staff can serve as support for the activity in several project locations. The topics for the legume production technologies were identified and prioritised such as seed production, organizing village seedbanks, sowing, crop husbandry (integrated nutrient management, including use of microbial inoculants), management of weeds and other pests (diseases and insects) and post-harvest care. As well as training in Myanmar, selected researchers were also trained at ICRISAT and SUT for short periods (3–4 months) and project work leading to MSc and PhD degrees.

Activity 3.2: Develop and implement effective extension and training programs on legume production technologies and village seed banks for extension personnel and farmers

Resource persons from ICRISAT together with relevant DAR and MAS staff conducted this training. DAR and MAS were involved in the selection of the extension staff for the training. Experiments at the DAR research station and farmer participatory varietal selection trials were used for hands-on training covering various crop production and protection technologies.

Activity 3.3. Training of selected DAR staff in inoculant production, quality assurance and inoculants and *Rhizobium* R&D at ICRISAT and Australian Legume Inoculants Research Unit (ALIRU), Australia, and on-site at DAR

The decision was made very early in the project to use Professor Nantakorn Boonkerd and the SUT in Thailand as a training centre for the rhizobia/inoculants technologies. It proved to be far more efficient and cost-effective than sending DAR staff to Australia or ICRISAT. There were 4 different training activities at SUT – 3 technical staff from the DAR Inoculant Production Unit trained at SUT for 3 weeks during 2007; Thi Thi Aung spent 3 years training at PhD level during 2008-2011; Maw Maw Than spent 4 months training as part of her PhD program through Yezin Agricultural University; 2 technical staff spent 4 weeks training at SUT during 2010. Topics covered throughout these training programs included fermentation technologies, MPN plant-infection counting, inoculant carrier preparation, and general microbiological techniques related to growing, counting and recognising rhizobia.

Activity 3.4. Develop and implement effective extension and training programs on inoculant application

The extension and training program for farmers and extension officers in Myanmar was organized through on-farm and on-station field inoculation experiments at the project trial sites and training workshops, backed up by written resource materials.

6 Achievements against activities and outputs/milestones

Objective 1: Identify and distribute high-yielding chickpea, groundnut and pigeonpea cultivars adapted to the relevant cropping systems of the Central Dry Zone (CDZ) of Myanmar, using farmer participatory varietal selection

no.	activity	outputs/ milestones	completion date	Comments
1.1	Assessing requirements and preference of farmers in CDZ for chickpea (CP), pigeonpea (PP) and groundnut (GN) varieties and current legume improvement programs in the region	Inception workshop at DAR to review legume improvement program in Myanmar	March '07	A 5-day Project Inception Workshop was held during 19–23 March 2007. There were 40 participants including researchers from DAR, MAS, NSW-Australia, ICRISAT, two consultants (Graham O'Hara, Murdoch University, Australia and Prof. N Boonkerd University of Suranaree, Thailand) and Dr Gamini Keerthisinghe, Research Program Manager, ACIAR.
		Participatory rural appraisal (PRA) seeking information on constraints to production of target legumes and farmer and market requirements for cultivar type.	March '07	The PRA was successfully conducted during March 2007 involving 163 farmers from the Mandalay, Magway and Sagaing Divisions of the CDZ. Three farmer participatory varietal selection (FPVS) locations were identified based on PRA information and previous experience. In this survey, farmers indicated most of them need high yielding varieties and improved technologies that are adaptable to local cropping systems. Farmers also expressed interest to utilize *Rhizobium* inoculation in their legumes production if they could buy them in the market
1.2	Farmer participatory varietal selection (FPVS) trials at selected locations in the CDZ	Identify trial locations, interact with partner farmers to ensure proper protocols on crop production-protection	March '07	Based on the PRA and in-depth discussions with the researchers a total of 23 townships – Magway, Pakokku, Salin, Pwintphyu, Taungtwindgyi in Magway Division; Tatkone, Pyinmana, Nyaungoo, Myingyan, Ngahtoegyi, Kyaukpataung, Taungtha, Mahlaing and Kyauksae in Mandalay Division; Monywa, Yeoo, Budalin, Depeyin, Chaungoo, Pale,Khin Oo, Sagaing and Myinmu in Sagaing Division – were selected.

no.	activity	outputs/ milestones	completion date	Comments
		Conducting field trials years 1 to 4, at the selected sites	Years 1-4 Groundnut	In groundnut multi-location trials during 2010, the performance of Sin 11 and YZG-03008 was superior to others with a mean pod yield of 968 kg ha^{-1} compared to 700 kg ha^{-1} in a local variety. In the Magway Division, YZG-03008 performed well with a pod yield of 1852 kg ha^{-1} followed by Sin 11 (1779 kg ha^{-1}) compared with 1316 kg ha^{-1} for the local variety. A similar trend was observed in the Mandalay and Sagaing Divisions. Overall farmers (70%) liked Sin 11 for its abundant podding and uniform seed size and adaption to adverse situation.
			Pigeonpea	During 2010-11 in Sagaing Division, Yezin 7 (ICPB 2043) gave a high yield of 1799 kg ha^{-1} with good plant growth and pod set. Yezin hybrid 2 (ICPH 2740) possessed a large number of branches but fruit bearing was observed mostly at the top canopy and the yield was not superior to local Monywa shwedingar, hence farmers did not like this variety. Yezin hybrid 3 (ICPH 3461) did not perform well in Mandalay Division, due to the heavy rain during the flowering time resulting in poor yield. In Mandalay Division, Nyaung Oo township, yield performance of Yezin 7 (ICPB 2043) was superior to farmers' locals. However, local variety Thahtaykan showed wider adaptation than the new varieties. In Magway Township, Magway Division, Yezin 6 (ICPL 96061) performed better than the others. In Khin Oo Township, Sagaing Division, Yezin hybrid 3 (ICPH 3461) was good at the vegetative phase but later heavy rains at flowering affected pod setting badly.

no.	activity	outputs/ milestones	completion date	Comments
			Chickpea	In Mandalay Division, Myingyan Township, ICCV92944 (Yezin 6) performed well and farmers have accepted it for its profuse pod setting and moderate resistance to wilt. ICCV 92944 gave the highest yield of 1937 kg ha^{-1}. In the demonstrations of Hta Naung taing village, Myingyan Township, Yezin 6 (ICCV 92944) and Shwenilonegyi gave the highest yield with an average of 1565 kg ha^{-1}. In Mandalay Division, Tatkone Township, Shauk-kone village, CA 02-04 (ICCV 01308) was higher yielding with an average yield of 1660 kg ha^{-1}. In Ywatawgone and Ponenamar villages, Shwenilonegyi gave the maximum yield of 1660 – 1811 kg ha^{-1}. In Kyaukse Township, Mandalay Division, Yezin 6 (ICCV 92944) was the best with a yield of 1800 kg ha^{-1} and farmers prefer the variety for its high yielding trait.
1.3	Low-cost technologies to enhance seed germination, plant nodulation and crop protection	Collect soil-samples from target research stations and farmers' fields, and analyse them to determine scope of micronutrient deficiency.	Year 2	Soil analysis results from the project sites and research stations revealed the deficiency of available Fe, Zn, S and organic matter at all project sites in Sagaing, Mandalay and Magway Divisions. Soil pH varied from slightly alkaline to neutral in Magway and Mandalay Division. Soils in YeU township in Sagaing Division were slightly acidic to neutral and slightly alkaline in Pale township. Soil pH varied from slightly acidic to neutral and the content of micronutrient and organic matter was very low in all Divisions where groundnut trials were conducted.
		Conduct specially designed experiments at core trial locations to determine the role of seed priming, application of micronutrients on nodulation, and eco-friendly methods of crop protection	Years 2-4 Pigeonpea	To determine the role of seed priming in pigeonpea on the crop establishment, four trials had been conducted with five treatments at Magway, Zaloke, Nyaungoo and Myingyan research farms. The treatments were – seed soaking in water for 2 hr, 4 hr, 6 hr, 8 hr & control. The highest germination, plant establishment and good plant vigour at vegetative growth were found when seed soaked for 4 hr followed by the highest mean yield of 1350 kg ha^{-1} compared to control (non-soaking in water) mean yield of 740 kg ha^{-1}. Thus seed priming for 4 hr gave 80% yield superiority over the control.

no.	activity	outputs/ milestones	completion date	Comments
			Chickpea	Chickpea seed priming trials were conducted with five treatments at Zaloke and Myingyan research farms. The treatments were – seed soaking in water for 2 hr, 4 hr, 6 hr, 8 hr and control. Germination and plant establishment were not significantly different among the treatments.
			Groundnut	To evaluate the effect of non-chemical options to manage termites, experiments were conducted at Nyaungoo and Zaloke research farm. The treatments were neem cake 224 kg ha^{-1}, Tobacco leaf powder at 224 kg ha^{-1} and a control. Tobacco leaf powder applied in the furrow before sowing produced the highest yield of 998 kg ha^{-1} which was 15 % superior over control.
			Pigeonpea	At the Magway research farm, pigeonpea intercrop with sesame was sown in May 2008. The highest yield of 808 kg ha^{-1} of pigeonpea and 260 kg ha^{-1} of sesame was obtained under conventional agriculture, while 566 kg ha^{-1} of pigeonpea and 212 kg ha^{-1} of sesame was found in low-cost biological options and 647 kg ha^{-1} of pigeonpea and 236 kg ha^{-1} of sesame was realized in treatment with no chemical input. Conventional agriculture gave the highest cost: benefit ratio and the second best was the treatment with no chemicals.
				This experiment was conducted at 6 locations (Magway, Nyaungoo, Myingyan, Zaloke Pangone Research Farm, and DAR) with 5 treatments during 2009; 1.+ *Rhizobium*; 2.+*Rhizobium*+Mo 3.+ *Rhizobium* +Zn ; 4.+ *Rhizobium* +$CaCo_3$ 5. + *Rhizobium* + Sulphur. Application of MO resulted in better nodulation, plant dry weight and yield than other micronutrients in some test locations. However the results were not consistent at all locations.

no.	activity	outputs/ milestones	completion date	Comments
1.4	Develop community-based seed production, storage and distribution system for improved legumes cultivars	Formation of village seed bank committees for Villages associated with varietal trial sites.	Year 2	During 2008 a pigeonpea village seed bank was established at Sartaikan village at Magway Township in Magway Division. The farmer preferred variety, ICPL 96061 was multiplied in 2 ha. In Sagaing Division village seed bank was established at Laezin village at Monywa township. Monywaswhedinga was multiplied by two farmers on 2 ha and produced 1.2 ton of seed. A chickpea seed bank was established at Shaukkone village, Mandalay Division. The farmer preferred variety, Yezin-4 was multiplied on 2 ha. In Sagaing Division a village seed bank was established at Laezin village and Monywa township and the variety ICCV 97314 was multiplied by five farmers on 2 ha and produced 2.5 tons of seed. Three farmers were involved in groundnut seed production with YZG 03008 on 2 ha and produced 3.2 tons of pods in Laezin village of Sagaing Division. At Sartikan village Sin 8 was produced on 2 ha. Sin 7 was also produced at Laezin village on 2 ha. Farmers of Laezin village preferred ICCV 97314 and this variety has gained popularity among farmers and cultivated on about 100 ha by 2008-09 post-rainy season. This variety has 30% higher yield potential than local SSV 2 (2 t ha^{-1}).
		On-going support (extension, training) of established village seed banks (VSB)	On-going Years 3-4	MAS in collaboration with DAR provided breeder's seed of farmer preferred varieties to selected seed growers and assisted in the collection, processing, storage and distribution of foundation seed to the seed networks. MAS also provided periodic training (before sowing and after harvest) in seed production to the seed farmers.

PC = partner country, A = Australia

Objective 2: To Increase production of high-quality Rhizobial inoculants in Myanmar through application of a cost-effective strategy involving equipment and procedural changes, quality assurance, R&D and training

No.	Activity	Outputs/ milestones	Completion date	Comments

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Increase capacity for production of high-quality inoculants at DAR (Note that this Objective reviewed after Year 1 in light of outcomes of the Inception Workshop, the PRAs and surveys)	Inception workshop at DAR to review all aspects of inoculant production & distribution in Myanmar	March ‘07	Workshop was successfully conducted and details furnished in Appendix 1.
		PRA assessing farmers’ use of inoculants and attitudes to inoculation	March ‘07	PRA was successfully conducted, involving 163 farmers from Mandalay, Magway and Sagaing Divisions of the CDZ. The details are furnished in Appendix 1.
		Survey farmer legume crops in the CDZ to assess nodulation status	March ‘08	In Australia, commenced evaluation of whole soil inoculation technique (WSIT) as a glasshouse bioassay with soils from 33 field sites covering chickpea, pea and lentil crops. Successfully conducted 63 simple inoculation trials to assess the nodulation with and without inoculation. Results indicate widespread responses.
		Develop/update agreed list of highly effective inoculant strains for legumes in Myanmar	Years 2-4	During 2009, four efficient chickpea *Rhizobial* strains - CC2018, IC 2058, IC 76 and IC 2049 - from ICRISAT and four mother cultures of Australian inoculant strains - CBCB 1024 for pigeonpea, CB 1809 for soybean, CC 1192 for chickpea and NC 92 for groundnut - were added to the Myanmar collections. It is likely that the Australian commercial inoculant strains will be used as the preferred strains in Myanmar until future research identifies superior strains.
		Research on fermentation protocols for inoculant production and inoculant carriers	Ongoing	New fermentation protocols for inoculant production have now been adopted by the *Rhizobium* Research & Production Unit, DAR. The new system involves low volume fermentation (1-2 L) coupled with broth dilution 1:100 and solid state fermentation.

No.	Activity	Outputs/ milestones	Completion date	Comments
		Equipment purchase and commissioning	Ongoing	This activity commenced with the procurement of equipment and chemicals for strengthening *Rhizobium* production which enabled the unit to produce good quality cultures. Two air conditioners, 25 items of chemicals, 1 shelving for glassware &chemicals, 4 plant growth shelves, were added to the MPU facility and plant growth room. The equipment from ICRISAT such as 1 precision balance, 1 analytical balance,1 pH meter, 1 Injector (Master Flex), 3 no. of micro pipette, 1 horizontal sterilizer,1 rotary shaker, 1 horizontal laminar flow and 10 kg of mannitol and two pulverizers were received safely by DAR and established in the laboratories.
2.2	Improve the shelf life and distribution of inoculants from production unit to the farmers	Workshop at DAR (1.1 above) plus ongoing survey of the distribution chain	March '07	During 2007 project inception workshop it was proposed to follow seed system networks to strengthen the inoculant distribution chain to provide effective viable material to the farmers on time.
		Research to assess strain and additive effects on survival; select elite strains	Year 2	Micro-Production Unit (MPU) system protocol has been established to produce high quality inoculants. Sterilized moist peat carriers were utilized for quality inoculants production at DAR, Myanmar. The quality is monitored at regular intervals and a standard population count (10^9 cells/g of peat) followed.
		Research to determine optimum storage conditions for inoculants, including at rural seed banks that will serve as local source	Years 2-4	The established inoculants storage facility at DAR was utilized for the purpose of efficient storage before distribution to farms
		Develop and implement procedures for efficient distribution of inoculants to farmers	Years 2–4	DAR is taking care of storage and distribution of inoculants to farmers during sowing time through regional research stations. Since the *Rhizobium* storage facility was not established in seed villages DAR will continue the existing distribution system.
2.3	Improve inoculants quality through development and implementation of quality assurances (QA) procedures at DAR	Determine and implement appropriate protocols for strain maintenance and verification	Year 2	MPU at DAR routinely verify purity by following appropriate protocols to avoid contamination by adopting glucose peptone agar media for strain maintenance.
		Develop and implement QA protocols for inoculant production in Myanmar	Years 2-4	The DAR- MPU unit follows strict QA procedures of inoculant production and bioassays routinely to maintain quality.

Objective 3: To Conduct training and extension programs on legume improvement and inoculant technology in order to enhance capacity for research and extension in these disciplines in Myanmar and to facilitate uptake of project outputs

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Training of selected DAR and MAS staff in improved legume production technologies and extension methodology at ICRISAT	A training workshop on legume production	April '07	Training of three DAR staff in legume production focussing on breeding aspects of chickpea, pigeonpea and groundnut was organized at ICRISAT.
		A training workshop on extension methodology	April '07	Training of three MAS staff on extension methods, and village seed bank was conducted at ICRISAT.
		A study program on village seed bank, and public- and private-sectors	April '07	MAS has taken up various issues of seed systems in the target areas with farming communities to develop viable seed villages for three legumes.
3.2	Develop and implement effective extension and training programs on legume production technologies and village seed banks for extension personnel and farmers	Training workshops on legume production and improvement conducted for extension staff and farmers	Years 2-4	Five training programs in legume production and inoculation techniques conducted at each project site by regional researchers and township extension officers from DAR and MAS.
		Field days on legume production / improvement for extension officers and farmers at project trial sites	Years 2-4	During 2010-11, two chickpea field days were organized one each at Zaloke Research Farm involving 94 farmers, and Pangone Research Farm with 200 farmers. During these interactions at Zaloke field day, farmers selected CA 03-45 (ICCV 03306) with 71% of farmers in favour of that variety. During the project a total of 20 farmer field days were organized involving 1534 farmers in enhancing legume productivity in the project locations.
		In-country training of relevant members of self-help group on methods of seed multiplication and safe storage (village seed banks)	Years 2-4	MAS has organized 3 training courses for self-help groups and extension personnel (50 members each time) at Central Agricultural Research and Training Centre (CARTC).
		Produce written extension material on legume production and improvement	Years 2-4	Extension materials on production technologies of all the three crops have been developed and shared with farmers.
3.3	Training of selected DAR staff in inoculant production, QA and R&D	Training workshop conducted at ICRISAT on inoculant production and strain evaluation [Note: Location of the training workshop was	June '07	Three technical staff from the Inoculant Production Unit, DAR, participated in the training workshop on inoculant production and strain evaluation conducted at SUT, Thailand during June 2007. Daw Maw Maw Than spent 4 months in Thailand as a sandwich PhD student

No.	Activity	Outputs/ milestones	Completion date	Comments
		changed during the "Inception Workshop in March '07" to Suranaree University, Thailand due to cost effectiveness and continuity with previous similar training.]		from Oct 2008. Thi Thi Aung commenced a 3-year PhD program at SUT, Thailand in Sep 2008. Two DAR researchers undergone advanced training in *Rhizobium* research at SUT during July – Oct 2010
		Training workshop conducted in Australia on inoculant QA and strain verification and maintenance	Year 2	Funds for this activity were used for training of two DAR scientists at SUT, Thailand during 2010 and continuation of research activities of Thi Thi Aung for 2010-11 and other trainees at SUT.
3.4	Develop and implement effective extension and training programs on inoculant application	In conjunction with extension officers and farmers, conduct simple inoculation experiments at project trial sites	March '08 and ongoing	Conducted 63 simple inoculation trials, assessing nodulation with and without inoculation during 2008-09. Demonstrated the beneficial effects of *Rhizobium* through 14 field trials and 6 on-station trials at DAR during 2009-10. Eleven simple trials (with and without inoculation) were conducted during 2010-11 at project sites. Although current inoculants were found effective in improving nodulation at all locations, the results varied across soil types.
		Field days at project trial sites and training workshops on legume inoculants for extension officers and farmers	March '08 and Ongoing	This activity was covered in conjunction with varietal as well as nodulation trials at different locations. The importance of inoculants was emphasized in all field days to the farmers and extension officials.
		Produce written extension material on legume inoculation and N2 fixation	Years 2–4	Extension handouts on packages of practices for all three crops developed and shared with farmers.

7 Key results and discussion

The project was focussed on the Central Dry Zone (CDZ) of the Sagaing, Mandalay and Magway Divisions of Myanmar. The project had three components – (a) varietal testing and development of high-yielding, adapted chickpea, pigeonpea and groundnut, using farmer participatory varietal selection (FPVS). (b) improving the production and use of high-quality rhizobial inoculants for those legumes (and other legumes grown in the country), and (c) capacity building of institutions and research and extension personnel of DAR and MAS. The three legumes account for about 40% of the legume area in Myanmar and are ICRISAT's mandate crops. The project therefore had good access to advanced germplasm, combining traits of yield with pest and disease resistance. The first 6 months of the project was devoted to a project inception workshop and participatory rural appraisal (PRA), involving 163 farmers across the 3 Divisions, in order to obtain information on the status of current legume improvement activities, desirable traits for future selection, and experimental protocols, sites, treatments, and collaborators were finalized (see Appendix 1).

The PRA also highlighted the concern of farmers that rhizobial inoculants for these legumes were generally not available in the market, and that their quality and effectiveness was an issue.

The farmer participatory varietal selection (FPVS) program was the first of its kind in the country, and provided opportunity for farmers and researchers to work together in selecting preferred varieties to suit farmer requirements. Both farmers and researchers liked the FPVS approach where all stakeholders were involved in the project from the inception. Periodic interactions between experts and farming communities also provided a viable platform for two-way learning. It was evident that no single variety can satisfy local requirements hence special attention to seed production of preferred varieties is necessary to meet farmer demands in the villages.

By the end of the 4 years of FPVS, it was clear that moisture stress was the prime constraint to legume production in the CDZ of Myanmar, followed by the non-availability of good quality seed. The major biotic constraints were: for groundnut – leaf miner, early and late leaf spot and dry root rot; for chickpea – pod borer, wilt and dry root rot; for pigeonpea – pod borers (*Maruca* and *Helicoverpa),* jewel beetle, sterility mosaic, phyllody and dry root rot. Thus, farmers desired earliness to avoid the moisture stress, coupled with disease resistance in chickpea and groundnut, and medium duration and good podding in pigeonpea.

The farmer participatory varietal selection (FPVS) program was very productive in identifying high yielding varieties. FPVS involved 88 mother and 541 baby trials (36 mother trials and 258 baby trials in groundnut, 24 mother and 145 baby trials in pigeonpea and 28 mother and 141 baby trials in chickpea) covering 23 townships (Tables 1, 3 and 5). These FPVS were initiated with six groundnut, five pigeonpea and six chickpea varieties that were known to have potential to address farmer requirements, compared with conventional local varieties in the CDZ.

Note that during the project, ICRISAT supplied 215 advanced breeding lines (102 groundnut, 50 chickpea, and 63 pigeonpea) to DAR to further strengthen the on–going breeding programs in these three crops.

Chickpea varietal selection and improvement

The chickpea program involved 28 Mother and 141 Baby trials in 11 townships in the CDZ (Table 1). The test material included both kabuli (7 cultivars) and desi type (5 cultivars) chickpea (Table 2).

With the desi type, the best yielding cultivars were Yezin 6 (ICCV92944 from ICRISAT) and Schwenilonegyi, which was developed as part of the national breeding program (Table 2). On average, their yields were 22% (Yezin 6) and 17% (Schwenilonegyi) higher than Yezin 4, the check cultivar. With the kabuli type, ICCV97306 was the best performing cultivar, yielding, on average, 33% more than Yezin 3, the check cultivar.

Table 1. Location and number of Mother and Baby trials during 2007–11 in the chickpea improvement program

Division	Township	Mother trials	Baby trials
Sagaing	Monywa	3	15
	Yae U	3	15
	Pale	3	15
	Chaung U	2	12
	Budalin	1	3
Mandalay	Tatkone	3	15
	Myingyan	3	15
	Kyauksae	3	15
Magway	Pwint Phyu	3	15
	Salin	3	15
	Taungtwingyi	1	6
Total		**28**	**141**

Farmers expressed their preference for early maturing chickpea varieties with resistance to dry root rot. Most of the farmers in the Sagaing Division preferred cultivars Yezin 8 (ICCV 97314) and Yezin 6. In the Magway Division, farmers preferred Yezin 6 due to favourable traits such as high yield, short duration and tolerance to wilt disease. Mandalay farmers preferred ICCV 97316 and Yezin 4 for their early maturity.

Table 2. Summary of chickpea grain yield data from three seasons of Mother Trials across three Divisions of the CDZ. Values are % of the check cultivars, Yezin 3 (kabuli) and Yezin 4 (desi)

Chickpea type	Cultivar	2007/08	2008/09	2009/10
Kabuli	Yezin 7 (ICCV95311)	128	*	*
	ICCV97306	143	122	*
	Yezin 8 (ICCV97314)	112	99	103
	ICCV97316	*	107	*
	ICCV01308	*	*	101
	ICCV01309	*	*	109
	Yezin 3 – control (kg/ha)	**854**	**873**	**1045**
Desi	Yezin 6 (ICCV92944)	109	134	122
	ICCV93031	124	*	*
	Schwenilonegyi (local)	126	111	113
	Sinshweni	*	99	110
	Yezin 4 – control (kg/ha)	**965**	**1037**	**1064**

Seed increase and distribution of preferred cultivars was conducted in a number of villages in the Mandalay and Sagaing Divisions. Cultivars included Yezin 6, Yezin 8, Yezin 9, Schwenilonegyi, ICCV01308 and ICCV01309.

Chickpea village seed banks were established in Kyathaeaye village at Tatkone township in Mandalay Division and Laezin village at Monywa township in the Sagaing Division during 2008-09. Yezin 4 was multiplied in two ha in Kyathaeaye village and produced 2728 kg of quality seed of which 2258 kg were distributed to the farmers to sow in 29 ha. In the Sagaing Division, Yezin 8 was multiplied in 2 ha in Laezin village and produced

2477 kg of quality seeds and distributed to the farmers to cover 32 ha during 2009-10 growing season. Similarly, Yezin 8 in Sagaing and Yezin 4 in Mandalay Division were multiplied in 2 ha each and produced 4 tons seed, which were kept in the store for future use.

Farmers in six villages in Kyauksae township (Mandalay Division) widely adopted ICCV-2 (Yezin-3) in rice fallow and intercropped with sunflower as a trap crop. This cropping system reduced 50% of pod borer (*Helicoverpa armigera*) attack and also minimized the cost of insecticides. Sunflower acted as trap crop in reducing the key pod borer of chickpea. In general, farmers apply 2 sprays of insecticide to manage pod borers. By adopting sunflower as trap crop, farmers totally eliminated pesticides without sacrificing yields.

Farmers' field days were also conducted in each Division to build their capacity for improved chickpea cultivation. About 300 farmers participated in Pwintphyu in Magway Division, 553 farmers were involved in Yaeoo, Zaloke, Laezin and Chaungoo in Sagaing Division, and 75 farmers in Takone in Mandalay Division during 2009-10 post-rainy seasons. Thus, this project provided an excellent platform for the development of new improved chickpea varieties and technology to boost production to meet the domestic as well as export requirements of the country.

Pigeonpea varietal selection and improvement

The pigeonpea program involved 24 Mother and 145 Baby trials in 12 townships in the CDZ (Table 3). Five improved varieties from ICRISAT viz., ICPL96058, ICPL96061, ICPB2043, ICPL87119 and ICPH267 were compared with the popular local varieties, Thahthaykan and Monywashwedinga (Table 4). At maturity of the crops, farmers in the various townships selected the best varieties based on their preferences such as yield, seed size, color and resistance to biotic and abiotic stresses.

The best yielding cultivars were the improved ICRISAT line, ICPL96061 (99% of the average yield of the check) and Monywashwedinga (the check cultivar) (Table 4).

Table 3. Location and number of Mother and Baby trials during 2007–11 in the pigeonpea improvement program

Division	Township	Mother trials	Baby trials
Sagaing	Monywa	2	15
	Khin Oo	2	11
	Depeyin	3	14
	Sagaing	1	5
	Budalin	1	10
Mandalay	Nyaung Oo	3	20
	Myingyan	3	14
	Taungtha	2	11
	Nahtoogyi	2	11
	Mahlaing	0	4
Magway	Magway	3	19
	Pakokku	2	11
Total		**24**	**145**

Through their active participation during the past four years, farmers in the Mandalay Division identified pigeonpea cultivars ICPL 96061, Monywashwedinga, Thahtaykan and ICPB2043 (Yezin 7) as the most suitable for their environments. In Magway, farmers liked ICPL96061 and the local variety while Sagaing farmers preferred Thahtaykan and Monywashwedinga based on yield potential, seed colour, market preference and tolerance to pests, diseases and moisture stress.

The seeds of selected cultivars were multiplied using village seed banks established at Sartaikan village in Magway Division, Laezin village in Sagaing Division and Sebin, Tatkone, Nyaungoo, and Myingyan research farms in Mandalay Division. The new cultivars started spreading in to the new niches quickly. Of the seed production of 1260kg from 2.0 ha of ICPL 96061 at Sartikan village during the 2008-09 season, 982 kg were distributed to the local farmers and covered 97 ha in 2009-10 season. Similarly, 2 hectares of Monywashwedinga was multiplied in Laezin, to produced 2970 kg of quality seeds of which 1636 kg were distributed to the farmers in the same village to cover 65 hectares. During 2009-10, a total of 3 tonnes of pigeonpea seed was produced in the village seed banks and distributed to farmers to cover about 300 ha in the 2010-11 season.

Table 4. Summary of pigeonpea grain yield data from three seasons of Mother Trials across three Divisions of the CDZ. Values are % of the check cultivar, Monywashwedinga

Cultivar	2007/08	2008/09	2009/10
ICPL96058	75	*	*
ICPL87119	68	*	*
ICPL96061	109	102	86
Yezin H-1 (ICPH2671)	*	*	94
ICPB2043	*	81	111
Thahtaykan	93	94	*
Local		89	*
Monywashwedinga – control(kg/ha)	**931**	**1191**	**688**

The introduction of 15 pigeonpea hybrids from ICRISAT as part of the project triggered interest in hybrid research in Myanmar. Although some of the hybrids produced substantially higher yields (19-40%) than the controls (ICPH2671, 2740, 2751, 3461 and 3497), flower drop and pod set were main concerns for researchers and farmers. As a follow up, hybrid seed production was initiated at Tatkone Research Station during 2008. This encouraged researchers to start their own CMS research for the production of local hybrids (Yezin H-2 (ICPH2740) and Yezin H-3 (ICPH3461) to address the above constraints (more results from the hybrid program can be found in Appendix 2).

The hybrid pigeonpea breeding program at DAR is now focusing on the development of commercial hybrids using locally adapted germplasm. Under this program, a total of 61 hybrid combinations were made of which 13 exhibited 90 to 100 % fertility restoration. These hybrids will be evaluated in multi-location trials within the country. At the same time, seed multiplication of male-sterile and restorer lines will be carried out to produce quality hybrid parent seed. The adoption of high yielding varieties and hybrids of pigeonpea in larger areas is expected to enhance the income and livelihoods of the Myanmar farmers through increased productivity of the crop.

Groundnut varietal selection and improvement

A total of 36 groundnut Mother trials and 258 Baby trials were conducted during the monsoon and post-monsoon seasons in Sagaing, Mandalay, and Magway Divisions during 2007-10 (Table 5). Eight promising varieties (Sinpadatha 2, Sinpadatha 5, Sinpadatha 6, Sinpadatha 7, Sinpadatha 8, Sinpadatha 11 (all from ICRISAT), and YZG03008, and YZG04014 (from DAR) were evaluated along with local checks, Magway11 and Magway15.

The best yielding cultivars were the improved ICRISAT line, Sinpadetha 7 (35% higher yielding than the check, average of 3 seasons) and YZG03008 (27% higher yielding than the check, average of 2 seasons) (Table 6). Other cultivars of promise were Sinpadetha 6 (14% higher yields than the check) and Sinpadetha 11 (11% higher yields than the check).

Table 5. Location and number of Mother and Baby trials during 2007–11 in the groundnut improvement program. Trials conducted in the monsoon and post-monsoon seasons in each year

Division	Township	Mother trials	Baby trials
Sagaing	Monywa	6	42
	Shwebo	1	9
	Khin Oo	5	33
Mandalay	Pyinmana	6	42
	Tatkone	6	42
Magway	Magway	5	36
	Taungtwingyi	6	45
	Pakokku	1	9
Total		**36**	**258**

Results from the Baby trials were consistent with those of the Mother trials (Table 7). Best performing cultivars were YZG03008, Sinpadetha 6, Sinpadetha 7 and Sinpadetha 11.

Table 6. Summary of chickpea grain yield data from three seasons of Mother Trials across three Divisions of the CDZ. Values are % of the check cultivar, Local

Cultivar	2007/08 monsoon	2007/08 post-monsoon	2008/09 monsoon	2008/09 post-monsoon
Sinpadetha 2	103	116	*	*
Sinpadetha 5	121	93	*	*
Sinpadetha 6	102	116	124	*
Sinpadetha 7	141	114	151	*
Sinpadetha 8	139	67	91	101
Sinpadetha 11	116	110	106	110
YZG03008	*	*	116	138
YZG04014	*	*	82	103
Local – control (kg/ha)	**794**	**1155**	**1249**	**609**

Farmers preferred Sinpadetha 8 for its short duration, Sinpadetha 11 for its high yield, and YZG03008 for its high yield, high shelling percentage and resistance to foliar diseases (both early and late leaf spots). Based on trials during the post-rainy season, 70% of farmers in Sagaing and Mandalay Division preferred Sinpadetha 11 for its high shelling percentage, and uniform and large seed size. Due to the high seed requirement of the crop, and the scattered nature of crop cultivation across the country, coupled with poor storage facilities at village level, lack of seed networks, providing good quality improved variety seeds to farmers on time became an incredible task for the policy makers. In order to address this difficult task, this project made an attempt to establish formal seed production units at the village level.

Table 7. Summary of chickpea grain yield data from three seasons of Baby Trials across three Divisions of the CDZ. Values are % of the check cultivar, Local

Cultivar	2007/08 monsoon	2007/08 post-monsoon	2008/09 monsoon	2008/09 post-monsoon
Sinpadetha 2	*	105	*	*
Sinpadetha 5	*	117	*	*
Sinpadetha 6	115	115	*	*
Sinpadetha 7	125	122	*	*
Sinpadetha 8	124	93	91	110
Sinpadetha 11	103	123	94	162
YZG03008	*	*	119	135
YZG04014	*	*	99	107
Local – control (kg/ha)	**944**	**1496**	**1132**	**1257**

In this process, groundnut village seed banks were established in Sartaikan village in Magway Division, Laezin village in Sagaing Division, and Shauk-kone village in Mandalay Division. Farmers preferred Sinpadetha 7 in both Sagiang and Mandalay Divisions and Sinpadetha 8 in Magway Division. These varieties were multiplied in 2 ha in each location. In Magway Division, 12,880 kg Sinpadahta 8 was produced, of which 2,800 kg were distributed to other Divisions and 5,600 kg for the local farmers to cover 12 ha during post rainy 2009-10. In Sagaing Division, 5,900 kg of Sinpadetha 7 were produced and 5,600 kg of these quality seed were distributed to the farmers for 11 ha of sowings. Similarly, Sinpadetha 7 was multiplied in Mandalay Division and realised 10,360 kg. From that, 1750 kg were distributed to other Divisions and 8,610 kg for local farmers.

Moreover, seed multiplication of Sinpadatha 7, Sinpadatha 8, and Sinpadatha 11) were taken up at Shan Kalay Kyunn village of Amarapura township, Mandalay Division. The river bed areas of Amarapura township were found suitable for seed multiplication during post rainy season. About 1,000 ha of groundnut was successfully cultivated on the Wyitnge river bed area at Shan Kalay Kyunn village of Amarapura township in Mandalay Division. In order to boost the productivity on these soils, DARs involvement in assisting supplementary irrigation resulted in 20% increase in the productivity in this zone. Varietal screening at different locations brought out significant improvement in identifying resistance sources for foliar diseases with good yield potential as shown in the above picture.

Groundnut field days were also conducted in each township in each Division to provide information on the performance of improved varieties.

Village seed banks for seed increase and distribution

The concept of village-level seed banks was initiated during 2008. Farmers started seed production in 2009 at three villages with two groundnut (Sinpadetha 7 and Sinpadetha 8) pigeonpea (Monywashwedinga and ICPL96061) and chickpea (ICCV97314 and Yezin 4) cultivars covering 14 hectares. Most of the seed produced in the village seed banks was distributed to farmers in the same township and excess was distributed to neighbouring villages. During the establishment of the village seed banks, farmers highlighted several issues that need to be addressed to ensure effective seed flows in future years. These included: lack of appropriate storage facilities at the village level, timely rouging of off-types, seed grading, and availability of timely inputs to farmers which needs to be considered as a high priority in future projects. The breeder seed production was carried out in DAR, Yezin, under the direct supervision of breeders and foundation seed production was done at research farms under DAR.

The studies carried out by DAR researchers to evaluate the efficacy of selected organic products (plant powders and oils) for the management of pulse bruchid at different locations indicated that the application of ash and groundnut oil (1:10) provided satisfactory control for 3-6 months in both jute as well as polythene bags.

Low-cost production technologies

Low cost production technology with an emphasis on biological options organized at different locations resulted in high yields under conventional agriculture (8 out of 11 times) followed by treatments with a combination of half the dose of chemical nutrients and bio-pesticides. In terms of cost:benefit ratio, the combination treatment was found to be superior to conventional agriculture indicating the importance of balanced use of chemicals and the potential of bio-pesticides in reducing costs of cultivation and in managing biotic stresses in an eco-friendly manner.

Farmers around the Kyauksae research station (Mandalay Division), where chickpea mother and baby trials were organized, adopted ICCV-2 in the rice-fallow systems with sunflower as an intercrop (2 rows of sun flower for every 10 m of chickpea). The variety has been adopted by about 50% of farmers in the township (total area 6,000 ha). Though sunflower had *Helicoverpa* larvae, the chickpea crop was almost free from pod borers in spite of no chemical protection. Discussions with researchers also indicated a 50% reduction of insecticides on chickpea when grown with sunflower (one spray in sunflower intercrop compared with two sprays for the chickpea mono-crop). This clearly brought out the importance of trap crops in reducing chemical pesticides on the main crop. In the Tatkone region, the groundnut variety Sin 7 has been well adopted by farmers covering about 25% of the area, with the expectation that area will increase to 50% by 2011. For chickpea, Yezin 4 has proved to be the most popular variety in this region.

The demonstration of one supplementary irrigation to post-rainy season groundnut (riverbed areas) in Shan Kalay Kyunn in Mandalay Division increased yields up to 1.823 tons ha^{-1} pod yield, 20% higher than the non-irrigated crop.

Production and use of rhizobial inoculants

Low production and supply of rhizobial inoculants for legumes is a problem in Myanmar. In a review of the situation, Thein and Hein (1997) stated that increasing production of inoculants in Myanmar would be difficult to achieve because of lack of production capacity and personnel expertise, product distribution and storage problems, coupled with insufficient education of farmers and extension officers of the benefits of inoculation. Thein and Hein in the same review reported that inoculation increased yields of chickpea, groundnut and black gram in Myanmar by an average 36%, equivalent to 0.27 t ha^{-1}. In recognition of the importance of efficacious inoculation of legumes, about 20% of the project activities were devoted to improving the production capacity and quality of inoculants in Myanmar.

The March 2007 Participatory Rural Appraisal (PRA) referred to above also provided information on current knowledge and practices relevant to the use of legume inoculants and legume production. The responses indicated that:

- 88% of farmers had heard of inoculants and understood something of what they did
- 75% of farmers use or had used inoculants, the major reason for non-use was non-availability. Use would increase with greater availability
- The MAS (extension service, sources inoculants from DAR) is currently the major supplier of inoculants and information on their use
- 49% of farmers currently apply fertiliser N to their legumes at average rates of <5 kg N/ha.

At the beginning of the project, production of inoculants in Myanmar was <100,000 packets, representing <5% of sown legume area. Production to some degree reflected demand, which was also low. Quality assessment of DAR-produced inoculants early in the project established that they contained very low numbers of rhizobia and very high numbers of contaminants. As a result, efficacy would have been very low. The strategy to improve this situation involved changes to production protocols, intensive staff training and equipment and facilities renewal.

To counter the contamination problem, large volume (100 L) fermentation has been replaced by small volume (1–2 L) fermentation, coupled with broth dilution and solid state fermentation. Effects of these changes have been to increase numbers of rhizobia in the inoculants by as much as 100,000 fold and to reduce contaminants by about the same degree. Other protocols have also been implemented, such as the use of gram staining and glucose peptone testing of culture purity. The reliance on plate counting has been replaced to a large extent with the more reliable plant-infection most-probable number (MPN) counting.

Four new rhizobial strains (CB1024 for pigeonpea, CB1809 for soybean, CC1192 for chickpea and NC92 for groundnut) were added to the *Rhizobium* collection from Australia.

These four strains became the inoculant strains for Myanmar. An additional 4 strains for chickpea were sourced from ICRISAT – CC2018, IC2058, IC76 and IC2049.

A substantial amount of project and institutional funds have been used for purchase of laboratory equipment and development of facilities at DAR. New equipment includes a large autoclave, 2 digital balances, pH meter, rotary shaker, refrigerator, microwave oven, precision injection machine and a vibrating sifter and grinding chamber for the preparation of the peat carrier. An air-conditioned, artificially-lit plant growth room was also commissioned that provided temperature controlled conditions for culturing plants for rhizobial counting and effectiveness testing.

During 2007–08, a total of 63 field trials were conducted in farmers' fields (26 for groundnut, 19 for pigeonpea and 18 for chickpea) with two treatments (+ inoculation and no inoculation). Observations were made on nodulation and plant colour. The results suggested responses to inoculation at many sites and marginal improvements in crop colour that, at face value, are very promising. There was essentially no field program beyond 2008 with all effort directed at improving the capacity of the DAR Rhizobium laboratory to produce inoculants and to implement an appropriate QA program.

Three personnel from the Rhizobium group, DAR completed a 3-week training workshop during 4 – 22 June 2007 at the Suranaree University of Technology (SUT), Thailand, with Prof. Nantakorn Boonkerd (Table 8). Training focussed on inoculant production and fermentation technologies and involved lectures, laboratory training and visits to commercial production facilities. In 2010, there was a follow-up training program at SUT for 2 DAR staff in inoculant technology. Daw Maw Maw Than spent 4 months at SUT in mid 2008 with Prof. Boonkerd as part of her PhD program at Yezin Agricultural University (supervisor Dr Thein Lwin). Her PhD was awarded in early 2011. Daw Thi Thi Aung will finish her 3-year PhD program at SUT in September 2011 and return to DAR, Yezin.

Finally, there is currently no private sector involvement in the production and distribution of inoculants in Myanmar, but such involvement is envisaged in the long-term. In fact, such involvement may be crucial to the successful reintroduction of this technology into legume production in the country.

Training and capacity building

The third component of the project was training and capacity building (constituting about 30% of project activities). The aim was to have training in legume introduction and seed production and dissemination technologies, and in legume inoculant production, QA, application and R&D. Extension programs on legume production and inoculants were to be developed for farmers and extension personnel. These targets were met.

During the project, a total of 19 researchers (groundnut 3, chickpea 7, pigeonpea 2, *Rhizobium* 7) were provided short (3-4 months) and long term (1 MSc and 3 PhD) training at ICRISAT and SUT, Thailand (Table 8). During 2010, fifteen researchers of DAR had hands-on training in pigeonpea hybrid seed production in Myanmar organized by DAR and ICRISAT.

During the time of the project, DAR and MAS organized 20 farmer days involving 1,534 farmers during the project period (Table 9). Extension materials covering the package of practices for the three legume crops were developed and shared among farmers during farmer days and other interactive meeting.

Even though there were substantial achievements in the training and capacity building, much more needs to be done. Myanmar agricultural R&D has an emerging cohort of young scientists that have had very little opportunity to grain knowledge and training from outside the country. Those that have that experience are the older scientists that are now retired or soon to be retired.

Table 8. Formal training of project personnel from DAR and MAS during the 4 years of the project

Year	Name	Duration	Remarks
2007-08	Daw Kyi Kyi San	3 weeks	*Rhizobium* research - Suranaree University
	Daw Yi Yi Win	3 weeks	--do--
	Daw Win Win Mar	3 weeks	--do--
	Daw Thu Zar Aung	3 months	ICRISAT – Chickpea
	Daw Khin Lay Kyu	4 months	ICRISAT – Pigeonpea
	Daw Maw Maw Naing	4 months	ICRISAT – Groundnut
	U Myint Sein	1 month	ICRISAT – NRM
	U Than Kyaing	1 month	ICRISAT – NRM
	U Aung Shwe	1 month	ICRISAT - NRM
2008-09	Daw Maw Maw Than	4 months	*Rhizobium* research- Suranaree University
	Daw Thi Thi Aung	3 years	-- do --
	Daw Thin Maw Oo	3months	ICRISAT – Chickpea
	Daw Yin Yin Aye	3 months	ICRISAT – Chickpea
	Daw Khin Thida Hlaing	3 months	ICRISAT – Chickpea
2009-10	Daw Phyu Phyu Moe	3 months	ICRISAT – Groundnut
	Daw Sein Leai Mon	3 months	ICRISAT – Groundnut
	Daw Khin Lay Kuu	2 years	ICRISAT – Pigeonpea
	Daw Mar Mar Win	6 months	ICRISAT – Chickpea
2010-11	Daw Yi Yi Win	1 month	*Rhizobium* – Suranaree University
	Daw Myint Yee	1 month	-- do -

Table 9. Farmer field days and farmer attendance at the field days during the 4 years of the project

Crop	2007-08		2008-09		2009-10		2010-11		**Grand total**	
	Field days	No. of farmers	Field days	No. of farmers	Field days	No. of farmers	Field days	No. of farmers	**Field days**	**No. of farmers**
Groundnut	-	-	1	25	3	83	-	-	**4**	**108**
Pigeonpea	-	-	3	95	3	191	-	-	**6**	**286**
Chickpea	2	400	2	120	4	326	2	294	**10**	**1140**
Total	2	400	6	240	10	600	2	294	**20**	**1534**

8 Impacts

Through successful completion of all activities, the project has made good progress towards increased productivity of legume crops in the CDZ of Myanmar. Although special impact studies were not conducted, progress was clearly achieved through selection of farmer preferred varieties, strengthening rhizobial inoculants production, establishing village-based seed banks, research on low cost technologies and following farmer participatory approaches during the four years of the project.

8.1 Scientific impacts

- Soil analysis results from the project sites and research stations revealed a deficiency of available Fe, Zn, S and organic matter at all project sites. Soil pH varied from slightly alkaline to neutral. This has enabled farmers to apply needed micronutrients to increase crop yields and improve soil fertility.
- To counter the contamination problem in rhizobial inoculant production, large volume (100 L) fermentation has been replaced by small volume (1–2 L) fermentation, coupled with broth dilution and solid state fermentation. Effects of these changes have been to increase numbers of rhizobia in the inoculants by as much as 100,000 fold and to reduce contaminants by about the same degree. Other protocols have also been implemented, such as the use of gram staining and glucose peptone testing of culture purity. The reliance on plate counting has been replaced to a large extent with the more reliable plant-infection most-probable number (MPN) counting.
- Four new rhizobial strains (CB1024 for pigeonpea, CB1809 for soybean, CC1192 for chickpea and NC92 for groundnut) were added to the *Rhizobium* collection from Australia. These four strains became the inoculant strains for Myanmar. An additional 4 strains for chickpea were sourced from ICRISAT – CC2018, IC2058, IC76 and IC2049.
- Farmer participatory varietal selection trials were conducted. Sin 7, Sin 8, Sin 11 and YZG -03008 in groundnut; Kyawechan shwedingar, ICPB 2043 and ICPL 96061 in pigeonpea and Yezin 6, Yezin 3 and Yezin 4 in chickpea were selected and multiplied by farmers for adoption.
- Besides the potentially 20–35% higher productivity of the new varieties, compared to traditional ones, farmers also saved on inputs through adopting efficient crop management technologies such as integrated crop management (ICM).
- The effect of non-chemical options in the management of termites in groundnut at Nyaung Oo and Zaloke research farms indicated that application of tobacco leaf powder in the furrow before sowing resulted in 17% less incidence of damage and a 15% yield advantage (998 kg ha^{-1} in un-treated).
- Field trials with *Rhizobium* and micronutrients in six locations (Magway, Nyaungoo, Myingyan, Zaloke and Pangone Research Farm, and DAR) resulted in better nodulation, plant dry weight and yield in majority of locations, by adding molybdenum along with *Rhizobium*.
- Effect of 4-hr seed priming in pigeonpea gave the highest germination percent, plant establishment and good plant vigour at vegetative growth which resulted in highest yield of 1350 kg ha^{-1} compared to control (740 kg ha^{-1}) in Magway, Zaloke, Nyaungoo and Myingyan research farms. However chickpea seed priming trials organized at Zaloke and Myingyan research farms did not reveal any significant advantage among the treatments.
- Low cost production technology with an emphasis on biological options, organised at different locations, resulted in the highest yields under conventional agriculture followed by treatments with a combination of half the dose of chemical nutrient and bio-pesticides. In terms of cost:benefit ratio, the combination treatment was found to be superior to conventional agriculture indicating the importance of a balanced use of

chemicals and the potential of bio-pesticides in reducing the costs of cultivation and in managing biotic stresses in an eco-friendly manner.

- Through the introduction of hybrid pigeonpea to Myanmar, researchers have adopted CMS hybrid technology in pigeonpea and produced their own hybrids to provide farmer preferred traits.
- The very successful use of the farmer participatory model in the project, including farmer participatory varietal selection (FPVS) in the legume improvement program and participatory rural appraisal (PRA) reinforced will have spill-over effects for future projects in Myanmar.

8.2 Capacity impacts – now and in 5 years

- A training workshop on inoculant production focussing on the Micro Production Unit (MPU) and strain evaluation was successfully conducted at Suranaree University, Thailand, during June 2007. Four technical staff from the Inoculant Production Unit, DAR, were trained.
- Three scientists from MAS (U Myint Sein, U Than Kyaing and U Aung Shwe) were trained at ICRISAT in optimizing use of natural resources, low cost methods of crop production and protection, seed systems and linking farmers to markets during 2007.
- Three researchers from DAR, one each from chickpea breeding (Daw Thu Zar Aung), pigeonpea breeding (Daw Khin Lay Kyu) and groundnut Breeding (Daw Maw Maw Naing) have undergone three months training at ICRISAT during 2007-08.
- Three researchers from legume breeding of DAR (Daw Thin Maw Oo, Daw Yin Yin Aye and Daw Khin Thida Haing) have undergone training in chickpea breeding at ICRISAT during Dec 2008 to March 2009.
- Two groundnut researchers (breeding) (Daw Phyu Phyu Moe and Daw Sein Leai Mon) from DAR attended a three month training course at ICRISAT during 2009.
- In-depth training for 15 DAR researchers in pigeonpea hybrid seed production and CMS maintenance was done in collaboration with DAR and ICRISAT during 2009.
- One pigeonpea researcher Daw Khin Lay Kyu and one chickpea researcher Daw Mar Mar Win have undergone training at ICRISAT leading to MSc and PhD respectively during 2010.
- Daw Maw Maw Than spent 4 months in Thailand as a sandwich PhD student during 2008. Daw Thi Thi Aung concluded a 3-year PhD program at Suranaree University, Thailand, during 2008-11.
- Two DAR researchers received advanced training in *Rhizobium* research at Suranaree University during July - Oct 2010.
- *Rhizobium* research facility at DAR was strengthened by creating the additional infrastructure and appropriate equipment.
- The farmer participatory approach followed in this project provided ample opportunity for discussions among farmers and researchers to identify potential solutions

8.3 Community impacts – now and in 5 years

- Seed production of groundnut (Sinpadatha 7 and 8), pigeonpea (ICPL 96061 and Monywashwedinga) and chickpea (Yezin-4 and Yezin-8) was established in Laezin, Kyathaeaye, Sar-tine-kan and Shauk-kone villages covering 2 ha each. This gave a good opportunity for farmers and their communities for seed availability and, indirectly, through better prices and livelihood opportunities.
- The demonstration of supplementary irrigation to post-rainy season groundnut (riverbed areas) in Shan Kalay Kyunn in Mandalay Division increased pod yields up to 1.8 tons ha^{-1}, which was 20% higher than the control. Though irrigation water is available in this region, no attempt was made to take advantage of supplementary irrigation due to a lack of resources. This project has taken the initiative and shown

the importance of supplementary irrigation through community approaches, which should be advanced further over larger areas.
- During the project 20 farmer field days were organized involving 1,534 farmers in enhancing legume productivity in the key districts of the project. These farmers were directly involved in various project activities and the spill-over effect will be several folds considering interactions with other farmers in the same village and neighbouring groups.
- The formation of village seed banks facilitated seed production at the village level for the first time in the country. This also paved the way for collaboration amongst farmers in seed and other input exchanges for better productivity.

8.3.1 *Economic impacts*

- Groundnut variety Sinpadetha 7 has been well adopted by farmers in Tatkone region, currently covering about 25% of the area and is expected to occupy 50% of the area by 2011 (Total area of groundnut in Tatkone is 4,000ha).
- Yezin 4 is the most popular chickpea variety adopted by Tatkone farmers. Though this variety was released ten years back it had not entered the CDZ until the present project. Now it occupies 400 ha of Tatkone through farmer to farmer seed contacts.
- The Kyauksae area in Mandalay Division, where chickpea is cultivated in rice fallows, has adopted the variety ICCV-2 for its earliness. The variety has been adopted by about 50% of the farmers in the township (total area of 6,000 ha).
- The improved, high-yielding cultivars selected by farmers in this project provide potential yield gains of 20–35%, compared with the commonly-grown cultivars.

8.3.2 *Social impacts*

- The project provided 6 preferred varieties of groundnut and chickpea and 5 pigeonpea varieties for farmers and involved them in their further selection through participatory approaches. This provided ample opportunity for farmers to interact with researchers in selecting the best varieties for their region based on their trait requirements. These interactions provided excellent rapport between researchers and farming communities.
- The seed village concept developed has now been established and will develop further. The interaction with seed growers provided an insight to address various issues such as rouging at various stages, seed processing and a facility for seed store as the main ones. This also promoted co-operation among farmers in seed procurement, storage and distribution in collaboration with government agencies (DAR and MAS).
- Extension materials on production technologies of all three crops have been developed and shared with farmers. This updated technical information on the improved varieties and technologies at their sites.

8.3.3 *Environmental impacts*

- With the implementation of efficient *Rhizobium* production and distribution system, it is hoped, that the use of chemical fertilizer will be reduced substantially.
- Chickpea-sunflower intercropping was found to be an excellent eco-friendly approach towards reducing insecticide applications, without compromising productivity. This concept should be taken further to other potential crops in the country.
- At this stage, the project has successfully communicated the concept of ICM to researchers and key farmers. However, large scale implementation is awaited for greater environmental and economic impacts.

8.4 Communication and dissemination activities

- Extension materials on production technologies of all three crops have been developed and shared with farmers during field days and farm visits.
- During the project, (particularly FPVS, seed production, *Rhizobium* trials, farmer days), project staff were in close contact with farming communities through videos and extension handouts covering various important topics. Research and extension staff also interacted with farming communities through media (newspaper, radio and television).

9 Conclusions and recommendations

9.1 Conclusions

- Farmers and researchers involved in the project highly appreciated the FPVS approach which gave them an opportunity for interaction in the selection of varieties of their choice with a sense of ownership.
- The improved *Rhizobium* facility at DAR with efficient strains, production technology and human resource development is a good asset for the country which needs to be further refined in terms of storage and distribution to satisfy farmer needs.
- The pigeonpea hybrid technology introduced needs to be further strengthened with refinements to suit their requirements.
- The project initiated the seed village concept for the first time in the country, and should be used to meet the demand for seed.
- The concept of trap cropping in the management of key pests like *Helicoverpa* and the use of bio-pesticides in storage will be of immense value for future IPM programs.
- The outputs from this project, particularly the varieties, crop management technologies and trained human resources should be utilized appropriately in addressing legume production, soil nutrition, livelihoods and environmental issues.
- The human resource capacity that was developed / strengthened during the project period (in both research as well as extension areas) should be effectively utilized by placing those staff at required zones and also by using them as trainers.
- Quality seed of good varieties and crop management technologies identified during the present project need to be up-scaled to make farmers more self-sustainable.
- The seed village concept initiated in this project needs to be further strengthened to cater for needs through the formation of seed net-works through self help groups.
- The capacity of the crop improvement team needs to be further strengthened to meet future requirements (physical facilities and human resources).
- The country's capacity in *Rhizobial* research needs to be realized by the farming sector.
- The concept of ICM for enhanced productivity and a healthy environment needs to be scaled up in order to achieve greater impact in food, nutritional and environmental security.

9.2 Recommendations

Recommendations from the project are best encapsulated by the outcomes of two workshops held in Myanmar during 2010 that aimed to review the project and to capitalise on its achievements. There was consensus that there should be a follow-up project and that the geographic focus should remain the Divisions of Mandalay, Magway and Sagaing in the CDZ. The sector focus should remain food legume production systems. Although the CDZ produces almost the entire nation's pigeonpea and chickpea crops and about 70% of its groundnut, problems remain. Yield reducing constraints are both biotic (insect pests, diseases and weeds) and abiotic (low nutrient availability, low and an uneven rainfall distribution, shallow soils with low moisture holding capacity and high levels of erosion). The largely rural population is becoming increasingly poverty-prone through a combination of population pressure and a deteriorating natural resource base. Thus, the overarching aim of a new project should be to address these issues of poverty, nutritional health and livelihood needs at the individual and community levels and food security in the CDZ. The proposed project will specifically look at the following research issues:

- Integrated improvement of major food legumes – pigeonpea, groundnut and chickpea – with emphasis on yield and biotic (insect pests and diseases) stresses, with attention to
    - Pigeonpea selection and breeding, including hybrid pigeonpea, and insect management (particularly *Maruca*), using natural and synthetic products and genetic resistance
    - Groundnut selection and breeding and disease management (eg *Cercospora* leaf spot)
    - Chickpea selection and breeding , insect management (particularly *Helicoverpa armigera*) using natural and synthetic products and genetic resistance, and disease management (eg *Fusarium* wilt and *Rhizoctonia* dry root rot).
- Nutrient management for the legume-based farming systems, particularly phosphorus (P), nitrogen (N), boron (Bo) and sulphur (S), using both mineral and organic sources. Nitrogen management to be through the use by farmers of high-quality rhizobial inoculants.
- Agronomic packages that optimise system productivity and economic returns to the farmer, particularly for the pigeonpea intercrop systems. Research to focus on intercrop and planting configurations and crop and soil water relations affected by conservation tillage, crop residue mulching, windbreaks etc.

It was agreed that the project will need to develop:

- Strong, explicit linkages to funded seed production and distribution programs. As stated above, one of the challenges in Myanmar is to substantially strengthen the propagation and dissemination of seeds of elite crop varieties at the village level. This is to ensure access to and uptake of the improved varieties by farmers.
- Strong, explicit linkages to extension/technology transfer programs (eg Livelihoods and Food Security Trust Fund (LIFT)).
- Continuing capacity building through post-graduate and short-term training. If possible, much of the post-graduate training should involve the Yezin Agricultural University (YAU).

Expected project outcomes could include, but not be restricted to:

- As many as 10 new high-yielding and farmer-preferred varieties across the three target legumes
- Varieties and management packages that effectively reduce the biotic (pest and disease) threats to the target crops
- Seed of new varieties produced in volume and distributed to non-project farmers in the CDZ, through the MAS village seed bank program and through programs managed by NGOs
- Large quantities of highly effective rhizobial inoculants produced at DAR, Yezin, and distributed to and used by farmers in the CDZ
- Crop production packages, encompassing best-practice agronomy and nutrient management, for the rain-fed, legume-based systems of the CDZ developed and extended to farmers, the latter through the MAS, NGOs, UN bodies and international programs based in Myanmar
- R&D capacity of DAR and MAS scientists substantially improved through short-term and post-graduate training.

10 References

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Win SS, Tin H, Ramakrishna A, Rego TJ, Myers RJK, Soe T. 2002. Nutrient balance studies to steer soil fertility management in Myanmar Dry Zone. Proc. Annual Research Conf., Yangon, 2002. Myanmar Academy of Agriculture, Forestry, Livestock and Fishery Science.

10.2 List of publications produced by project

Post-graduate theses:

1. Daw Maw Maw Than (2010). Evaluation and Selection of Root Nodule Bacteria *Mesorhizobium ciceri* and Chickpea Germplasm for High Nitrogen Fixation, Yezin Agricultural University, Myanmar.
2. Daw Thi Thi Aung (2011). Co-inoculation Effects of Plant Growth Promoting Rhizobacteria (PGPR) and *Bradyrhizobium* on Soybean (*Glycine max*) Nodulation and Soil Microbial Community Structure, Suranaree University of Technology, Thailand.
3. Daw Mar Mar Win (2010). Evaluation of performance of chickpea genotypes under water stress conditions, Yezin Agricultural University, Myanmar.
4. Daw Khin Lay Kyu (2010) Study on Hybrid Vigour and Inbreeding Depression in CMS-based Pigeonpea Hybrids, Acharya NG Ranga Agricultural University, India.

Publications:

1. Herridge, David, John Ba Maw, Maung Maung Thein, Om Parkash Rupela, Nantakorn Boonkerd, Tran Yen Thao, Rosalind Deaker, Elizabeth Hartley and Greg Gemell (2008) Expanding production and use of legume inoculants in Myanmar and Vietnam. In. "Global Issues, Paddock Action". Proceedings of the 14th Australian Agronomy Conference, 21-25 September 2008, Adelaide, South Australia. Australian Society of Agronomy.

2. Khin Lay Kyu, Saxena KB, Kumar RV, (2010). Hybrid Seed Production Technology (Myanmar Language) pp 22.

3. Khin Lay Kyu, Saxena KB, Kumar RV, Rathore A. (2011). “Prospects of Hybrid Pigeon pea in Myanmar”, Journal of Food legumes, 1-7.

4. Mar Mar Win. (2011). Identification of traits related to drought tolerance in chickpea. Myanmar Academy of Agriculture and Forestry Proceedings (submitted).

5. Mar Mar Win. (2011). Genetic variability of drought avoidance root traits in chickpea genotypes Myanmar Academy of Agriculture and Forestry Proceedings (submitted).

Extension articles:

1. Handout on package of practices on groundnut production and characteristics of improved varieties in Myanmar language developed in collaboration with Ministry of Agriculture and Irrigation and ICRISAT.

2. Handout on package of practices on chickpea production and characteristics of improved varieties in Myanmar language developed in collaboration with Ministry of Agriculture and Irrigation and ICRISAT

3. Handout on package of practices on pigeon pea production and characteristics of improved varieties in Myanmar language developed in collaboration with Ministry of Agriculture and Irrigation and ICRISAT

4. Handout on package of storage practices on legumes in Myanmar language developed in collaboration with Ministry of Agriculture and Irrigation and ICRISAT

5. Characteristics of promising three pigeon pea hybrids viz. ICPH 2671, ICPH 2740 and ICPH 3461 in Myanmar language developed by ICRISAT and DAR

11 Appendixes

11.1 Appendix 1:

Report by Dr DF Herridge on travel to Myanmar during 10–25 March 2007

Executive Summary

Purpose of Travel

1. To survey farmers and extension officers in the Central Dry Zone (CDZ), Myanmar, about legumes and inoculants.
2. To conduct an inception workshop at DAR Yezin to review legume production in the CDZ and inoculant production facilities and protocols at the DAR facility.
3. To develop specific plans and timelines for the first 12 months of the project.

These are the first activities in recently-commenced ACIAR project SMCN-2006-013 'Increasing food security and farmer livelihoods through enhanced legume cultivation in the Central Dry Zone of Myanmar'.

Background of Travel

Inoculation of legumes with *Rhizobia* is a well-established practice in Australian agriculture and has been variously supported for more than 100 years by the State Departments of Agriculture. The NSW Department of Primary Industries maintains R&D capacity in *Rhizobium* science and inoculant technology at the Tamworth Agricultural Institute (DF Herridge) and at the Gosford Horticultural Institute (LG Gemell, E Hartley, J Hartley in the Australian Legume Inoculants Research Unit (ALIRU). This travel was to initiate activities in the new ACIAR-funded project in Myanmar that essentially aims to introduce improved varieties of groundnut, pigeonpea and chickpea into the CDZ of Myanmar and, at the same time, develop capacity to produce large quantities of high-quality legume inoculants for those legumes.

Major Outcomes of Travel

In Myanmar, a participatory rural appraisal (PRA) of farmer's attitudes to and knowledge and use of new improved legume cultivars and legume inoculants was conducted in the Central Dry Zone (CDZ). Results from the PRA were combined with presentations from local and project scientists from ICRISAT, India, Australia and Thailand in a 5-day inception workshop at the Department of Agricultural Research (DAR), Yezin. Plans (experimental, training and capacity and infrastructure building) were developed for the next 12 months of the project.

Recommendations arising from the PRA and Inception Workshop are as follows:

The MAS project budget be increased with additional funds for operating and transport requested from ACIAR. An appropriate increase would be A$4,000 p.a. (A$16,000 for the 4 years of the project). Thus, the amended 4-year budget for MAS for salaries and operating (including local travel and transport) would be increased from A$24,000 to A$40,000, compared with the unchanged budget of A$74,000 for DAR.

There is a need to re-engage the MAS and/or replace the MAS with the private sector for distribution and sale of inoculants to farmers.

Training in inoculant production is a high priority and would be more effectively done in Thailand with Nantakorn Boonkerd, rather than at ICRISAT. The training arranged to coincide with the planned training of Vietnamese scientists in the CARD project, ideally during May-June for about 6 weeks.

Scope for a technical/management workshop, possibly at ICRISAT during 2008, targeted at the senior scientists/managers who will not necessarily be part of the technical training program. Such a workshop could be funded through existing ACIAR training/workshop programs.

Report by Dr DF Herridge on travel to Myanmar during 10–25 March 2007

Itinerary

Month	Date	From	Depart	To	Arrive	Flight
February	27	Tamworth	0945	Sydney	1100	QF2003
	27	Sydney	1500	HCM City	2000	JQ2007
Feb/Mar	27-10	HCM City				
Mar	10	HCM City	1200	Bangkok	1330	TG681
	10	Bangkok	1800	Yangon	1900	TG307
	12	Yangon	1200	Naypyitaw	1300	Xxxx
	12-23	Yezin				
	23	Naypyitaw	1300	Yangon	1400	Xxxx
	25	Yangon	1400	Bangkok	1530	TG302
	25	Bangkok	1800	HCM City	2000	TG686
	27/28	HCM City	2200	Sydney	0900	JQ008
	28	Sydney	1230	Tamworth	1330	AF2004

Details of Travel

10 March: travel HCM City to Yangon, Myanmar

Travelled to Yangon, via Bangkok. Met at Yangon International Airport by U Saw Marco, from the seed Division of DAR Yangon, and taken to Inya Lake hotel.

11 March: Yangon, Myanmar

Met in the morning with Bernard Pearce, the AusAID liaison officer at the Australian Embassy, Yangon. It was his assistant, Pa Pa Khine that much of the correspondence had been through when arrangements for this visit were made. Dr OP Rupela, project leader ICRISAT, arrived from India around noon. Discussed arrangements for the following day with Rupela and U Saw Marco.

12 March: travel Yangon to Yezin

OP Rupela and I were met at Naypyitaw airport, about 40 min from Yezin by car, by U Maung Maung Thein and U Khin Maung Nyunt, both from the *Rhizobium* Unit, Plant Pathology Group at DAR. U Maung Maung Thein is the nominated coordinator of the project in Myanmar, although in reality this may not be the case. Dr U John Ba Maw, DDG of DAR, seems to have been given the overall coordinating role in the project by Dr Toe Aung, DG-DAR.

Discussed arrangements for the next 2 weeks with U John Ba Maw and Maung Maung Thein. Communication with DAR leading up to this visit has been difficult. It is impossible to determine if the emails from outside don't reach DAR or they do reach but are not referred on to the relevant people. Consequently, spent considerable time discussing the internal travel arrangements for the three ICRISAT breeders and four Australian and Thai scientists yet to arrive for next week's inception workshop. OP Rupela and I paid in USD for internal flights for all international scientists participating in the inception workshop.

OP Rupela spent a number of hours working through the draft farmer questionnaire to be used in the participatory rural appraisal (PRA) on inoculants, legume varieties and seed propagation. Once finalised, 100+ copies of the questionnaire were printed off and divided into two lots for the two PRA groups. My group would work in the Nyaung U-Magway groundnut/pigeon pea area to the north and west of Yezin (Mandalay and Magway Divisions) and OP Rupela's group would head north to Mandalay and beyond to Monywa (predominantly chickpea area in the Sagaing Division)

13 March: Yezin to Nyaung U and survey

Departed Yezin early for the 5-6 hour, 300+ km drive to Nyaung U. Arrived around 2 pm and after lunch travelled with the 5 Yezin staff and 3 local staff (see list below) the 10 km to Kuywa village.

U Maung Maung Thein	*Rhizobium*/Plant Pathology (Yezin)
U Aung Shwe	Extension Specialist, MAS (Nay Pyi Taw)
Daw Mar Mar Win	Legume agronomy (Yezin)
Daw Ohn Mar Khin	Groundnut improvement (Yezin)
Daw May Lwin Oo	Economist (Yezin)
Daw Khin Myint Kyi	Farm Manager, Nyaung U
Daw Tin Than	Pigeon pea specialist (Nyaung U)
U Win Soe	Pigeon pea specialist (Nyaung U)

Major crops for the village are groundnut and pigeon pea and every field seems to be defined by toddy palms. The farmers were a lively group and showed real interest in the survey questionnaire. There was much animated discussion and 17 forms completed here. General discussions with the farmers revealed insect (pod borer, leaf miner, soil grubs) and disease management as their priority issues. There doesn't appear to be much of a focus on plant nutrition – either no options in terms of mineral fertilisers or problems/symptoms are sub-clinical.

14 March: Nyaung U and survey

Conducted surveys at Kyauk Pa Taung township during the morning. Essentially a repeat of yesterday afternoon – very lively and interested group of farmers with much animated discussion. Total of 23 forms completed. After lunch, the third farmer group survey conducted with a total of 16 forms completed

15 March: Nyaung U to Magway and survey

Conducted a survey during the afternoon (21 respondents).

16 March: travel Magway to Yezin, DAR Yezin

About a 6-hour drive back to Yezin from Magway. Once there, spent the rest of the day finalising the travel arrangements of the remaining ICRISAT scientists, Gamini Keerthisinghe (ACIAR), Graham O'Hara (Murdoch U) and Nantakorn Boonkerd (Suranaree University, Thailand). Sent and received emails using the Yezin Agricultural University's computer.

17-18 March: DAR, Yezin

Processed with excellent assistance from 6–8 DAR staff the survey data of the 163 respondants - 86 from the Rupela chickpea group and 77 from our pigeonpea/groundnut group. Quite a task given that each response consisted of up to 90 data entries. Thus, a total of about 12,000 entries were keyed into an excel worksheet for analysis. The survey data on chickpea, pigeonpea and groundnut improvement and on farmer knowledge and use of legume inoculants were graphed out and inserted into 4 power point presentations for the Inception Workshop.

19 March: DAR Yezin, Inception Workshop Day 1

There were about 30 participants present at any one time. The three ICRISAT breeders – Dr SN Nigam (groundnut), Dr PM Gaur (chickpea) and Dr KB Saxena (pigeonpea) – plus Dr Gamini Keerthisinghe, ACIAR, arrived from Yangon and the program commenced with a few words from Dr Toe Aung, DG-DAR, Gamini and Dr Nigam. Presentations included updates on the status of each of the project crops in Myanmar, results of the previous week's PRA relevant to those crops and comments from the ICRISAT breeders. The last session, 5–6.30 pm, participants broke into 3 crop groups to plan the experimental program for 2007.

20 March: DAR Yezin, Inception Workshop Day 2

Reports by Daw Khin Mar Mar Nwe (groundnut), and Daw Aung May Than (pigeonpea and chickpea) on the outcomes of the previous evening's planning sessions for on-farm and on-station varietal evaluation, followed by comments by Drs Nigam, Saxena and Gaur. All three plans were different, creating confusion. In the following session, a compromise structure for the varietal trials was developed, using bits and pieces from each of the three sets of plans. The design for the on-farm work was basically:

3 Divisions – Mandalay, Magway and Sagaing
2 Townships in each
2 Villages associated with each township
In each village, there would be:
    2 Mother trials – 6 test cvs + check cv (replicated x2)
    9 Baby trials – cvs 1, 2, check   cvs 3, 4, check   cvs 5, 6, check (replicated x3)

Plot size – different for mother and baby trials and different for groundnut.

Measurements/observations – all visual except yield.

Thus, there would be 132 trials for each crop. The mother trials and associated R&D trials would also be conducted on DAR research stations at Magway (groundnut), Nyaung U (pigeonpea) and Monywa (chickpea).

After lunch, discussions about the experimental program continued. A list was put together of personnel that would be involved in the three crop improvement programs. A list of extension personnel from MAS that were involved in the project was requested also. That list was not available/finalised and would be put together later. It became apparent that commitment of MAS was weak and becoming weaker all the time. Their project budget is small (A$6,000 p.a.) and insufficient to cover the high costs of transport associated with on-farm activities. This does create some problems because of their key role in extension/training and in seed propagation and distribution. To a large extent, success of the project will depend on positive contributions by the MAS. After much discussion, it was agreed that the MAS project budget be increased and that additional funds should be requested from ACIAR. An appropriate increase would be A$4,000 p.a. (A$16,000 for the 4 years of the project) with the additional funds used for operating and transport. Thus, the amended 4-year budget for MAS for salaries and operating (including local travel and transport) would be increased from A$24,000 to A$40,000, compared with the unchanged budget of A$74,000 for DAR.

Training was also discussed in this afternoon session. The ICRISAT breeders had previously indicated that the length of training of the four Myanmar breeders should be for the duration of the crop, i.e. 3–4 months, starting in Aug-Sept 2007. Training of extension personnel should be for about 1 month. Clearly, training duration will depend to a large extent on how well the budget can be stretched to fund the extra time (to be worked through and organised by the ICRISAT and DASR/MAS groups.

21 March: DAR Yezin, Inception Workshop Day 3

Presentations by U Aung Shwe (MAS) and U Maung Muang Thein (DAR) on results of the PRA and on the current status of inoculant production in Myanmar. The PRA data indicated that Myanmar farmers were familiar with inoculants and the practice of inoculation, had an understanding of what inoculants did, and would readily use inoculants if available. They were quite prepared to purchase them in the market-place as well as source them from MAS/DAR staff. However, for continued long-term use, they would need to see benefits of the practice.

The current (2007) status of inoculant production and use in Myanmar is bleak. Production by DAR, Yezin, has declined from about 300,000 packets p.a. during the 25-year period from 1978 to 2002, to just 50,000 packets in 2006-07. It appears that declining production reflects declining demand by the MAS for inoculants to distribute to the farmers. The rationale behind the decision of the MAS to pull out of inoculant distribution was not articulated. Clearly, there is a need to re-engage the MAS and/or replace the MAS with the private sector for distribution and sale of inoculants to farmers.

There is also the issue of quality. It appears that the main fermentation in the 100 L fermentors takes just 24 h, rather than the 5–8 days that we would normally expect. The fermented broths are checked by plate count, but not by plant-infection count. Plate counts are usually in the order of log 9, but it is quite probable that the count is of an unknown contaminant and not *Rhizobia*. Actual *Rhizobial* counts could be very low, in the order of log 2–3. Thus, inoculant quality may be very poor and efficacy very low.

Inspection of the inoculant production facility followed. There is a need for equipment – both large items such as an autoclave, lamina flow unit, plant growth facilities etc. and small items such as auto pipettes, glassware etc. Nantakorn Boonkerd and Graham O'Hara are to provide a report on how the inoculant production facility might be improved through equipment upgrades and procedural changes.

In the afternoon, presentations and discussions about strains, carriers, packaging and storage at DAR. Nantakorn Boonkerd made a presentation about the micro-production unit (MPU), a NifTAL technology that utilises the ability of a diluted broth-culture of *Rhizobia* to multiply rapidly in sterile peat. Thus, instead of adding 50 mL of fermented broth containing log 9.0 *Rhizobia*/mol to a 100-g packet of peat, just 0.05 or 0.5 mL broth made up to 50 mL with sterile water can be added. Using the 1:100 dilution, a 1 L flask of broth can be used to inoculate the same number of packets as a 100 L fermentor. The MPU would appear to be a very relevant technology for the inoculant production unit at DAR, Yezin.

All in all, a day that highlighted the difficulties encountered by the DAR group. They are hampered by lack of funding and resources and cut off from outside knowledge and training. The lack of funding has meant that equipment and facilities were not upgraded/replaced or even repaired and maintained. A lot of the data presented during the day was data from the 1980s. Current data appeared to be mainly from Daw Thi Thi Aung. Training (suggested that we use the term 'training workshop') is a high priority at this stage. We agreed that the training in inoculant production, scheduled to be held at ICRISAT, would be better done in Thailand with Nantakorn Boonkerd. The wealth of experience of Nantakorn could be tapped into, particularly in the practical aspects of inoculant production. The training should be arranged to coincide with the planned training of Vietnamese scientists in the CARD project and would ideally be held during May-June for about 6 weeks.

22 March: DAR Yezin, Inception Workshop Day 4

Sessions 3 and 4 covered distribution of inoculants, on-farm and township storage and inoculant QA. As indicated above, the MAS played a key role in determining demand for inoculants in Myanmar. The number of packets needed for each season would be set by the MAS. The Yezin group would then produce the inoculants to be picked up by MAS personnel for distribution to the farmers. The system has now changed. MAS no longer distribute the inoculants and therefore do not targets for production. Thus, production has declined substantially during the past 4 years in concert with declining demand. In this session, much discussion about the need to reinvent storage and distribution systems, and the potential for involvement of the private sector. Other discussion about potential involvement of the DAR research stations in storage and distribution, as well as discussion about re-engagement of the MAS.

Dar Maw Maw Than presented a paper on QA in Myanmar. It appears that counting numbers of *Rhizobia* in peat relies exclusively on plate counts with no cross checking using plant infection. It is highly likely that the peat inoculants contain high numbers of contaminants, but low numbers of *Rhizobia*. Packets of inoculant produced at Yezin were taken back to Thailand, ICRISAT and Australia (ALIRU via Murdoch University) for testing. I presented an overview of QA in Australia.

We inspected the Plant Pathology labs. Most (about 60%) of the equipment was not working and there was little sign of technical activity (see Table below). From discussions with U Maung Maung Thein and Daw Myint Myint San, the major reason for the equipment problem was lack of funding for maintenance. U Maung Maung Thein indicated to us that he had just A$100 p.a. for maintenance of facilities for his 24-person Plant Pathology/*Rhizobium* group.

No	Item	Total number	Working	Not working
1	Incubators	4	0	4
2	Microscopes	3	0	3
3	Binocular microscopes	2	1	1
4	Autoclaves	5	4	1
5	Ovens	3	1	2
6	Balances	3	2	1
7	Isolation chambers	2	0	2
8	Deep freezers	1	1	0
9	Distillation units	1	0	1
10	Shakers	3	2	1
11	Fermentors	4	4	0
12	Soil sterilisers	5	0	5
13	Air conditioners	4	2	2

We met with Dr Toe Aung (DG, DAR) and Dr John Ba Maw (DDG-DAR) in the evening. Discussions about the transfer of project funds to DAR - difficult and waiting advice from ACIAR through Gamini, the training programs - names to be sent later, and communication with ICRISAT and Australia - hopefully will improve as they move from satellite communications to other more reliable forms – ADSL?.

23 March: DAR Yezin, Inception Workshop Day 5 and travel Yezin to Yangon

Final session today focussing on activities for the next 12 months. Prepared a 12-month timeline of activities for the *Rhizobium* component of the project and presented for discussion. Unfortunately, not a lot of discussion – likely that everyone tired after a couple of intensive weeks. The timeline of activities agreed to.

At this stage, my next project visit will likely be in December ’07 or January ’08. There was quite a bit of discussion about a technical/management workshop, possibly at ICRISAT during 2008, targeted at the more senior scientists/managers who would not necessarily be part of the technical training program. It would be cost-effective to hold the workshop at the same time as other project activities at ICRISAT. Such a workshop could be funded through existing ACIAR training/workshop programs.

At noon, travelled Yezin/Naypyitaw to Yangon. Met at Yangon airport by U Saw Marco. Called by the Australian Embassy in the early afternoon and met with Bob Davis, the Australian Ambassador to Myanmar. Very good discussion with the Ambassador about the project and about Myanmar in general. We talked about the transfer of project funds to DAR and MAS. He indicated that it was not possible through the Embassy and that transfer through FAO or other UN offices should be explored. The problem is the exchange rate. Officially, 1 USD buys just 5 kyat. The rate for all Australian Embassy transactions is 450 kyat. The actual rate on the street is 1250–1300 kyat. There is always a service charge of about 10%.

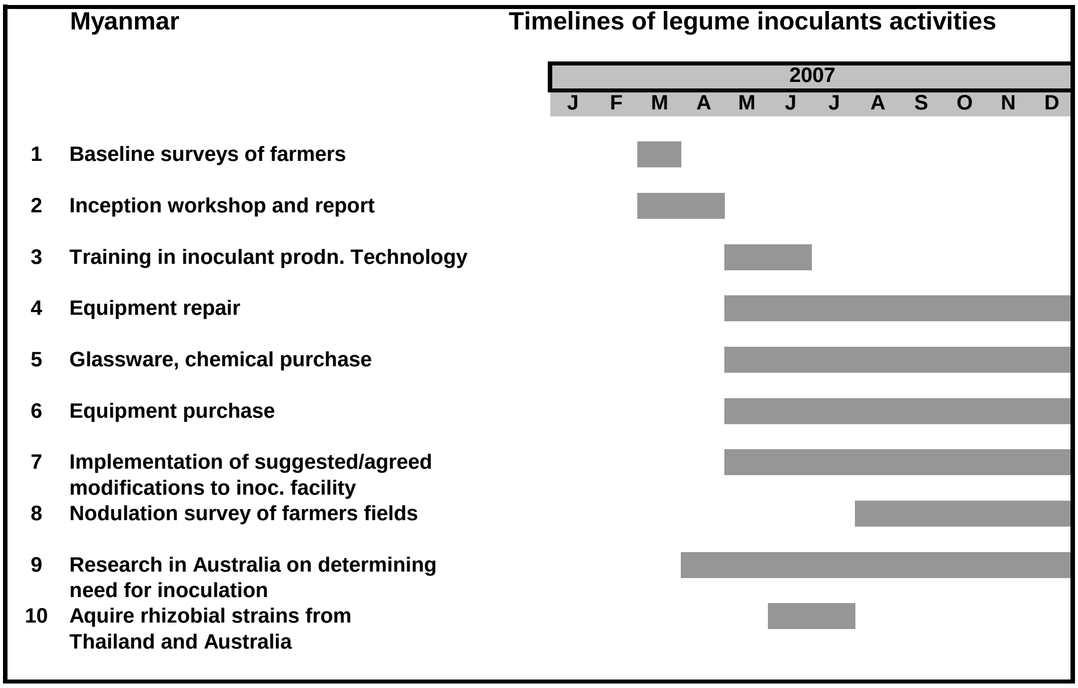
24 March: Yangon : Report writing

25 March: travel Yangon to HCM City via Bangkok, then on to Australia

Lists of Myanmar personnel in the 3 crop improvement and inoculant programs

Program	Name	Address
Groundnut	Daw Khin Mar Mar Nwe	Yezin
	Daw Ohn Mar Khin	Yezin
	Daw Maw Maw Naing	Yezin
	U Myo Kyaw Hlaing	Yezin
	Daw Hla Hla Win	Magway
	Daw Than Than Nwe	Magway
Pigeonpea	Daw Khin Myint Kyi	Nyaung U
	U Kyaw Swa Win	Yezin
	Daw Myint Myint San	Nyaung U
	Daw Tin Mar Than	Nyaung U
	Daw Sandar Moe	Yezin
	Daw Myint Myint	Magway
	U Kyaw Win	Yezin
Chickpea	Daw Aung May Than	Yezin
	Daw Aye Aye Win	Zaloke (Monywa)
	Daw Kyi Shwe	Pankone
	Daw Mar Mar Win	Yezin
	Daw Thuzar Aung	Nuaung U
	Daw Nwe Nwe Yin	Yezin
Rhizobium inoculant	U Maung Maung Thein	Yezin
	Daw Myint Myint San	Yezin
	Daw Maw Maw Than	Yezin
	Daw Yi Yi Win	Yezin
	U Khin Maung Nyunt	Yezin
	Daw Win Win Mar	Yezin
	Daw Thi Thi Aung	Yezin
	Daw Kyi Kyi San	Yezin

Timeline of activities for the *Rhizobium* part of the program



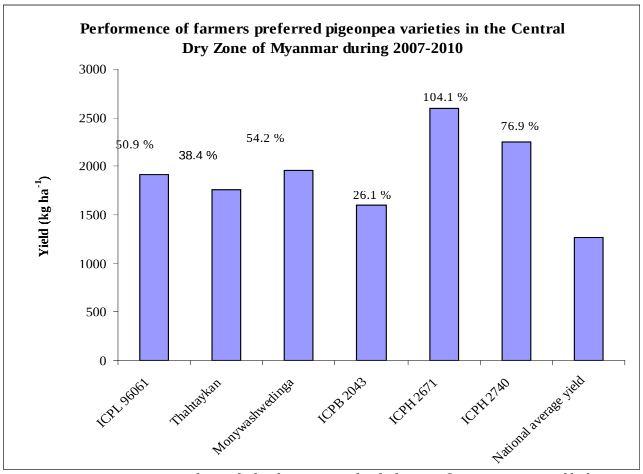
11.2 Appendix 2:

Success stories of pigeonpea, chickpea and groundnut developed from ACIAR project

Improved Pigeonpea Productivity in Myanmar through ACIAR Project

Among legume crops, pigeonpea (*Cajanus cajanus* (L) occupies an important place in rainfed agriculture in Myanmar. This crop is cultivated in Myanmar in about 0.6 m ha with an average productivity of 1.2 t ha^{-1}. Area and production of pigeonpea increased steadily from 240,000 ha in 1995 to 612,000 ha in 2008-09 (Myanmar Agriculture at a glance 2009). Yields of pigeonpea crops are still low against the potential yields realized by Myanmar researchers (2.5 t/ha). Still the gap between potential and actual yield is large particularly in subsistence farming. Majority of the soils are degraded and deficient in soil organic matter, and obviously most of the major and micro nutrients especially N, P, K, S, Fe and Zn and the occurrence of biotic constraints such as insect pests and diseases. To improve the productivity at farm level, this gap needs to be bridged by incorporating high yielding varieties with market preferred traits and appropriate agronomic management. To pursue this objective ACIAR project SMCN/2006/013 commenced in 2007 with Myanmar's Department of Agricultural Research (DAR) and Myanmar Agricultural Service (MAS), the University of New England (UNE), Australia, and ICRISAT, Patancheru, India as partners.

A total of 24 pigeonpea mother trials and 142 baby trials were conducted in Sagaing (Monywa, Budalin, Depeyin, Khinoo), Mandalay (Nyaungoo, Myingyan, Mahaling, Nhahtoegyi), and Magway (Magway and Pakokku) Divisions in the Central Dry Zone of Myanmar during 2007-10. Five ICRISAT's improved varieties viz., ICPL 96061, ICPB 2043, ICPL 87119, ICPH 2671 and ICPH 2740 were compared with the popular local varieties (Shwedinga, Thathaykan and Monywashwedinga). At maturity stage of the crop farmers in various townships selected the best varieties based on their preferences such as yield, seed size, color and resistance to biotic and abiotic stresses.



From the experience of three year farmer participatory research, farmers preferred ICPL 96061 in Magway township and two local varieties (Shwedinga & Thathaykan) in Pakokku township. These varieties were resistant to drought and biotic stress such as chafer beetle and termites. In Mandalay Division (Taungtha township), most of the farmers selected improved local variety, Monywashwedinga due to its drought tolerance and ICPB 2043 due to its higher number of podding and earliness. In Sagaing Division, though ICPH 2671 was the highest yielder, farmers did not prefer it due to its undesirable purple seed color and liked Monywashwedinga and ICPB 2043. Another hybrid, ICPH 2740 was identified as promising across the townships. The mean performance of various lines over three years is furnished in the figure.

The seeds of selected varieties were multiplied using village seed banks established at Sartaikan village in Magway Division, Laezin village in Sagaing Division and Sebin, Tatkone, Nyaungoo, and Myingyan research farms in Mandalay Division. The new varieties started spreading in to the new niches quickly. Of the seeds production of

1260kg from 2.0 ha of ICPL 96061 at Sartikan village during 2008-09 season 982 kg were distributed to the local farmers and covered 97 ha in 2009-10 season. Similarly, 2 hectares of Monywashwedinga was multiplied in Laezin and produced 2970 kg of quality seeds of which 1636 kg were distributed to the farmers in the same village and it covered 65 hectares. During 2009-10, a total of 3 tonnes of pigeonpea seed was produced under village seed banks and distributed to farmers to cover about 300 ha under these selected varieties in 2010-11 season.

Hybrid Pigeonpea in Myanmar

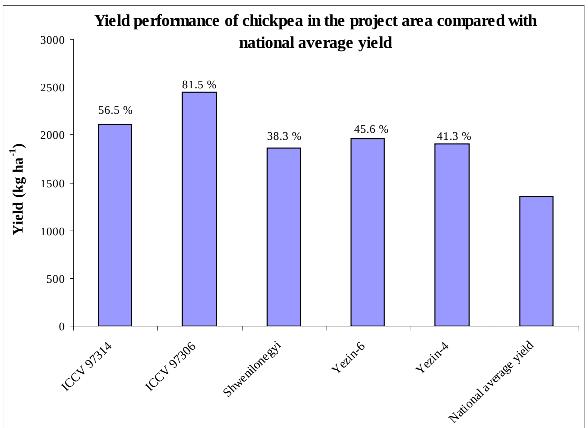
Fifteen hybrid lines supplied by ICRISAT were screened at Zaloke, Myingyan, and Sebein research stations during 2008-09 of which seven were promising. The first hybrid seed (A x R) production of ICPH 2671 was initiated at Tatkone and Pankone research farms and produced 1069 kg ha^{-1} and 1169 kg ha^{-1} hybrid seed respectively. These seed were used in mother and baby trials during 2009-10 cropping season. The hybrid ICPH 2671 produced 11.9 to 53.1 % superior yield over the control in six townships in Sagaing and Mandalay Divisions. Though this hybrid has produced better yield, its purple colour was not liked by the farmers. Further screening of hybrids resulted in the identification of two promising hybrids ICPH 3461 and ICPH 2740 with good yield and preferred seed colour. During 2009-10 seed production of these selected hybrids was undertaken using a row ratio of 3 female: 1 male and produced 1596 kg ha^{-1} of ICPH 2740 and 2931 kg ha^{-1} of ICPH 3461. These hybrid seeds were used in the on-farm trials in Sagaing and Mandalay Divisions during 2010-11. Thus, hybrid seed production was established successfully in the country.

Prospects of Hybrid Pigeonpea

The hybrid pigeonpea breeding program at DAR is now focusing on the development of commercial hybrids using locally adapted germplasm. Under this program, a total of 61 hybrid combinations were made of which 13 exhibited 90 to 100 % fertility restoration. These hybrids will be evaluated in multi-location trials within the country. At the same time, seed multiplication of male-sterile and restorer lines will be carried out to produce quality hybrid parent seed. The adoption of pigeonpea high yielding varieties and hybrids in larger areas is expected to enhance the income and livelihoods of the Myanmar farmers through increased productivity of the crop.

Enhanced chickpea productivity through integrated crop management

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops, which is grown in about 300,000 hectares in Myanmar with an average productivity of 1.35 t ha^{-1} (Myanmar Agriculture at a glance 2009). Besides being a very rich source of protein, it also maintains soil fertility through biological nitrogen fixation. Among various constraints of chickpea production, non-availability of seeds of good quality high yielding varieties, low soil fertility and eco-friendly crop management strategies are considered as important. Among various insect pests pod borer *H. armigera,* cutworm *Agrotis ipsilon* (Hufnagel) and aphids *Aphis craccivora* koch as field pests and bruchid (*Callasobruchus chinensis* (L.)) in the storage were well recognized. To overcome these insect pests farmers generally apply two sprays of insecticide. In order to address the above constraints ACIAR funded project SMCN/2006/013 commenced in 2007 in collaboration with Myanmar's Department of Agricultural Research (DAR) and Myanmar Agricultural Service (MAS), the University of New England (UNE),



Australia, and ICRISAT, Patancheru, India.

In order to boost the chickpea production and productivity during the project phase (2007-10), a total of 28 chickpea mother trials and 141 baby trials were conducted in five townships in Sagaing Division (Monywa, Budalin, Yaeoo, Pale, Chaungoo), three townships in Mandalay Division (Myingyan, Kyauksae, Tatkone) and two townships in Magway (Pwintphyu, Salin) Division. The test material included kabuli types (ICCV 97306, ICCV 97314, ICCV 97316), and desi varieties (ICCV 92944, Shwenilonegyi and Sinshweni (ZCHL 98907)) along with check Yezin-3 (ICCV 2) and Yezin-4 (ICCV 88202).

Based on the results, farmers expressed their desire for good yielding, early maturing chickpea varieties with resistance to dry root rot. Most of the farmers in Sagaing and Magway preferred ICCV 97314, Shwenilonegyi and Yezin-6 for their good traits such as higher yield, short duration and tolerance to diseases while farmers in Mandalay liked Yezin-4 for its early maturity. Farmers of Sagaing Division cultivated about 100 ha of ICCV 97314. The farmer participatory research brought out 38-82% yield increase in various test lines. However, farmers gave their own reasons (duration, seed size, market value, resistance to biotic stresses) in the final selection of the varieties for their region. The performances of various lines across the project period are shown in the figure. In view of the seed demand farmers in Laezin village initiated seed production of ICCV 97314 and 2 ha during 2009-10 cropping season.

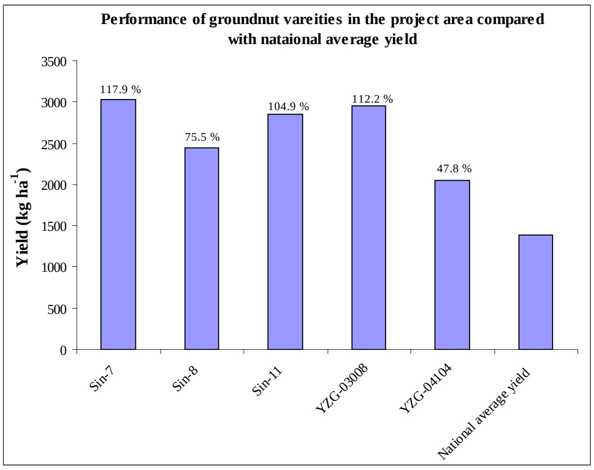
Farmers in six villages in Kyauksae township (Mandalay Division) widely adopted ICCV-2 (Yezin-3) in rice fallow and intercropped with sunflower as trap crop. This cropping system reduced 50% of pod borer (*Helicoverpa armigera*) attack and also minimized the cost of insecticides. Sunflower acted as trap crop in reducing the key pod borer of chickpea. In general, farmers apply 2 sprays of insecticide to manage pod borers. By adopting sunflower as trap crop, farmers totally eliminated pesticides without sacrificing the yields.

Chickpea village seed banks were established in Kyathaeaye village at Tatkone township in Mandalay Division and Laezin village at Monywa township in Sagaing Division during 2008-09. Yezin-4 was multiplied in two ha in Kyathaeaye village and produced 2728 kg of quality seed of which 2258 kg were distributed to the farmers to sow in 29 ha. In Sagaing Division, ICCV 97314 (Yezin-8) was multiplied in 2 ha in Laezin village and produced 2477 kg of quality seeds and distributed to the farmers to cover 32 ha during 2009-10 growing season. Similarly, the chickpea variety Yezin-8 in Sagaing and Yezin-4 in Mandalay Division were multiplied in 2 ha each and produced 4 tons. These seeds were kept in the store for future use.

Farmers' field days were also conducted in each Division to build their capacity in understanding the improved ways of chickpea cultivation. About 300 farmers participated in Pwintphyu in Magway Division, 553 farmers involved in Yaeoo, Zaloke, Laezin, Chaungoo in Sagaing Division, and 75 farmers in Takone in Mandalay Division during 2009-10 post-rainy seasons. Most of the farmers selected ICCV 97314 for its early maturity and tolerant to *Fusarium* wilt and Shwenilonegyi due to higher number of pods per plant, large seed size, erect plant type, and tolerance to wilt. Thus, this project provided excellent platform for chickpea varieties and technology to boost the production to meet the domestic as well as export requirements of the country.

Improve the groundnut productivity through village seed banks

Groundnut (*Arachis hypogaea* L) is a major oil seed crop in Myanmar agriculture, cultivated in about 0.8 million ha. Although groundnut crop occupies unique place in Myanmar oilseed cultivation, the average productivity was very low with about 1.5 t pods ha^{-1} in rain fed situation and 2 ton pods under irrigated conditions. In recent years this crop gained lot of importance due to shortage of edible oil in the country. Though, this crop has been widely adopted well by the Myanmar farmers there is a wide gap between the farmer's yields and the potential yields realized by the researchers. Among various constraints, non-availability of good quality seeds, high yielding varieties, problem of insect pests and diseases are considered as important yield limiting factors. In addressing the above constraints, Directorate of Agricultural Research (DAR), Ministry of Agricultural Sciences (MAS) in technical collaboration with ICRISAT initiated a project with financial support from ACIAR during 2007.



A total of 36 groundnut mother trials and 258 baby trials were organized in both monsoon and post-monsoon season in Sagaing, Mandalay, and Magway Divisions during 2007-10. The project covered three townships in Sagaing (Monywa, Shwebo, Khinoo), three townships in Mandalay (Pyinmana, Tatkone, Amarapura), and four townships in Magway Division (Magway, Taungtwingyi, Pakokku, Kinpontaung). Eight promising varieties (Sinpadatha-2, Sinpadatha-5, Sinpadatha-6, Sinpadatha-7, Sinpadatha-8, Sinpadatha-11, YZG 03008, and YZG 04014) from Department of Agricultural Research (DAR) were evaluated along with local checks, Magway-11 and Magway-15. These farmer participatory trials brought out 48-120% yield superiority of some of the lines against local varieties.

Of the various groundnut lines tested farmers preferred Sinpadetha-8 for its short duration, Sinpadatha-11 for its high yield, good filling and YZG 03008 for its good yield, high shelling percentage and resistance to foliar diseases (both early and late leaf spots). Based on the performance of these lines during post-rainy season, 70% of farmers in Sagaing and Mandalay Division preferred Sinpadatha-11 for its high shelling percentage, uniform and large seed size. Due to the high seed requirement of the crop, and the scattered nature of crop cultivation across the country, coupled with poor storage facilities at village level, lack of seed networks, providing good quality improved variety seeds to farmers on time in achieving high yields became an incredible task for the policy makers. In order to address this difficult task, this project made an attempt to establish formal seed production units at village level.

In this process, groundnut village seed banks were established in Sartaikan village in Magway Division, Laezin village in Sagaing Division, and Shauk-kone village in Mandalay Division. Farmers preferred Sinpadatha-7 in both Sagiang and Mandaly Divisions and

Sinpadatha-8 in Magway Division. These varieties were multiplied in 2 ha in each location. In Magway Division, 12,880 kg Sinpadahta-8 was produced, of which 2,800 kg were distributed to other Divisions and 5600 kg for the local farmers to cover for 12 ha during post rainy 2009-10. In Sagaing Division, 5895 kg of Sinpadatha-7 were produced and 5600 kg of these quality seed were distributed to the farmers for 11 ha. Similarly, farmers' preference variety, Sinpadatha-7 was multiplied in Mandalay Division and realised 10,360 kg. Among these, 1750 kg were distributed to other Divisions and 8,610 kg for local farmers. Moreover, seed multiplication of three groundnut varieties (Sinpadatha-7, Sinpadatha-8, and Sinpadatha-11) were taken up at Shan Kalay Kyunn village of Amarapura township, Mandalay Division. The river bed areas of Amarapura township were found suitable for seed multiplication during post rainy season. About 1000 ha of groundnut was successfully cultivated on the Wyitnge river bed area at Shan Kalay Kyunn village of Amarapura township in Mandalay Division. In order to boost the productivity on these soils, DARs involvement in assisting supplementary irrigation resulted in 20% increase in the productivity in this zone. Varietal screening at different locations brought out significant improvement in identifying resistance sources for foliar diseases with good yield potential as shown in the above picture.

Groundnut field days were also conducted in each township in each Division to provide information on the performance of improved varieties.