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1 Acknowledgments

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List of acronyms

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AusAID	Australian Agency for International Development (until 2013)
B	Boron
BD	Bulk density
CDZ	Central Dry Zone
CLAN	Cereals and Legumes Asia Network
DAP	Department of Agricultural Planning
DAR	Department of Agricultural Research
DAS	Days after sowing
DFAT	Department of Foreign Affairs and Trade (Australia)
DoA	Department of Agriculture (formerly MAS)
DS	Decision support
EC	Electrical conductivity
FAO	Food and Agricultural Organization of the United Nations
FPCB	Farmer participatory crop benchmarking
FPVS	Farmer participatory varietal selection
FYM	Farm-yard manure
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IPM	Integrated pest management
JAF	John Allwright Fellowship
K	Potassium
LIFT	Livelihoods and Food Security Trust Fund
LUD	Land Use Division
MOALI	Ministry of Agriculture, Livestock & Irrigation
MOU	Memorandum of Understanding
N	Nitrogen
NGO	Non-government organisation
P	Phosphorus
PRA	Participatory Rural Appraisal
QA	Quality assurance
R&D	Research and Development
RD&E	Research, Development & Extension
S	Sulfur
SAT	Semi-arid tropics
SMCN	Soil Management & Crop Nutrition
TOT	Transfer of technology
UA	University of Adelaide
UNE	University of New England
VSB	Village seed bank
YAU	Yezin Agricultural University
YMV	Yellow mosaic virus
Zn	Zinc

2 Executive summary

The Central Dry Zone (CDZ) of Myanmar is an area of about 80,000 km^2 in the centre of the country defined by the 500–1,000 mm rainfall isohyets. It represents about 12% of the land area of Myanmar and is home to 12 million people, of which 80% (10 million people) are classified as rural. Central Dry Zone farmers cultivate 3.3 Mha land to grow 5.5 Mha grain crops. Major crop types are the 2.5 Mha pulse and oilseed legumes and 1.5 Mha sesame and sunflower. Rice is grown as a rainfed monsoon crop and under irrigation in the CDZ, with the estimated planted area of 1.1 Mha representing 15% of Myanmar's total. On the other hand, an estimated 46% of Myanmar's pulse and oilseed legumes and 74% of sesame and sunflower are grown in the CDZ.

The CDZ is regarded, however, as one of the most food-insecure, water-stressed, climate-sensitive, natural resource-poor and least-developed regions of the country and is therefore a priority focus of the Ministry of Agriculture, Livestock and Irrigation (MOALI) because of its clear economic and social needs coupled with its development potential.

The MyPulses project was conceived in planning workshops and scoping missions during 2010–11 and implemented in 2013 with the overarching aim of improving the livelihoods and food security of small-holder farmers, their families and communities in the CDZ through RD&E targeted at the legume-based farming systems. Specific objectives were:

- Develop improved varieties of major food legumes – pigeonpea, groundnut, chickpea, green gram and black gram – linked to institutional and community-based seed production and distribution
- Improve nutrient management of the legume-based farming systems focussing on the supply of phosphorus (P), nitrogen (N), boron (B), sulphur (S), potassium (K) and zinc (Zn), and including legume inoculants
- Improve the agronomic management of the legume-based systems through crop benchmarking with farmers to increase efficiency of water use and effectively integrate new technologies
- Enhance capacity for RD&E in the relevant agencies in Myanmar through implementation of the collaborative ACIAR project model and through targeted infrastructure improvement, training and extension.

Partners in MyPulses were the Department of Agricultural Research (DAR), Department of Agriculture (DoA) and Yezin Agricultural University (YAU) in Myanmar, the University of New England (UNE) and University of Adelaide (UA) in Australia and ICRISAT in India. During the 5 years of MyPulses, i.e. 2013–18:

- More than 700 simple, unreplicated on-farm and replicated on-station trials in varietal evaluation, crop nutrition, rhizobial inoculation and agronomy were conducted across the CDZ
- A total of 31 DAR and DoA staff received overseas training, ranging from 7 days to 4 years (68% women, 32% men)
- More than 1,900 persons from DAR, DoA, YAU and NGOs were involved in on-site training in Myanmar (68% women, 32% men)
- A total of 30 small projects including PhD (x1) and MSc projects (x6) were funded at YAU. A total of 43 academics and students were involved (77% women, 23% men)
- A total of 180 outreach/extension activities were conducted involving 7,870 farmers (32% women, 68% men)
- Improvements, both physical and procedural, were made to the DAR soil chemistry laboratory and the DAR Rhizobium/microbiology laboratory
- There were 130 visits by Australian and ICRISAT project team scientists to Myanmar

Major achievements/impacts of MyPulses were:

- Release of 4 new legume varieties (2 chickpea, 2 groundnut) with another 4 scheduled for release in 2019 (3 pigeonpea, 1 groundnut).
- Successful roll-out of the village seed bank (VSB) program involving almost 1,600 farmers directly and potentially 83,000 other farmers through farmer-to-farmer distribution of the improved VSB varieties.
- Potential economic benefits of the VSB program estimated at A$33 million during 2015–18.
- Improved understanding of climate, particularly rainfall, impacts on soil water and nutrient movement through soils affecting crop productivity in the CDZ. Climate analysis and soil water modelling revealed a sharp decline in the number of rainy days in the growing season, with fewer but larger rainfall events resulting in increased drying of the soil surface in the absence of rain and deep drainage and leaching of nutrients during and after heavy rainfall.
- Implementation of farmer participatory crop benchmarking (FPCB) as an effective research and extension methodology during 2016–18 in the southern CDZ. The program involved 94 farming households (men and women) in 4 villages near Magway Township. A total of 210 groundnut and 188 sesame fields were benchmarked during the two years. Multisite nutrient leaching experiments were conducted in the second year (12 sites) in concert with comprehensive soil sampling to define texture and nutrient movement.
- Improved guidelines for rates and timing of inputs of farm-yard manure and mineral fertilisers for groundnut and sesame in the CDZ, including development of a decision support tool for nutrient management. The guidelines and DS tool were outcomes of the climate analysis/soil water modelling and the FPCB and aimed to counter the specific problems of nutrient isolation (immobile phosphorus) and leaching (nitrogen, sulfur, potassium) as well as the more general problems of under fertilisation.
- Substantially improved capacity for soil and plant analysis to underpin cropping in the CDZ.

Notwithstanding the achievements of MyPulses, the yield gap between average crop yields and those of the best farmers remains large and could be further reduced. Broad adoption of conservation farming principles in the CDZ would not only help to reduce the yield gap but would also help to ensure the sustainability of the cropping. Other recommendations for future R&D in Myanmar's CDZ include:

- Continue pulse breeding and selection, if possible in collaboration with the ICRISAT breeding programs, to produce future high-yielding varieties with specified traits, such as drought tolerance, oil content, mechanical harvestability.
- Continue and expand of the VSB program.
- Continue and broaden nutrient management research to address other possible deficiencies, e.g. boron and zinc.
- Improve and finalise the fertiliser decision-support tool, including the development of a smart phone version.
- Develop a training package (in English and Myanmar language) on the theory and processes of the farmer participatory crop benchmarking (FPCB) and assist DoA extension staff through training to apply the methodology in their villages.
- Ensure the long-term viability and credibility of soil chemistry analytical facilities in Myanmar through ongoing support and training.
- Continue to build capacity for production of quality-assured, efficacious legume inoculants in Myanmar in sufficiently-large volumes to meet potential demand.
- Further research for development investment, based on the participatory model used in the FPCB, to better understand the key crop management practices that make the top 5-10% of farmers so profitable, and to promote adoption of these practices through farmer-to-farmer communication.

3 Background

Agriculture is the most important economic and social sector in Myanmar, accounting for about 30% of GDP and more than 60% of the workforce. Grain cropping dominates with rice (Oryza sativa) grown on 7.0 Mha, pulse and oilseed legumes on 5.5 Mha and non-legume oilseeds on 2.0 Mha (MOALI 2016; FAOSTAT 2017). Black gram (Vigna mungo), green gram (Vigna radiata), groundnut (Arachis hypogaea) and chickpea (Cicer arietinum) are grown in rotation with lowland rice while, in the upland systems, green gram, groundnut, pigeonpea (Cajanus cajan) and cowpea (Vigna unguiculata) are commonly grown in sequence with sesame (Sesamum indicum) and the coarse grains, pearl millet (Pennisetum glaucum), sorghum (Sorghum bicolor) and maize (Zea mays). Rice production is concentrated in the lower half of Myanmar with upland cropping primarily in the middle of the country in the Central Dry Zone (CDZ) (MOALI 2016).

The legume and oilseed crops represent 44% of Myanmar's total crop area compared with just 5–10% for China, Laos, Bangladesh and Thailand (MOALI 2016; FAOSTAT 2017). The difference between Myanmar and its close neighbours reflects the large areas of upland cropping in the country that are not suitable for rice and the substantive but volatile market in India for pulses. Myanmar is currently the world's second largest pulse exporter (World Bank Group 2016).

Myanmar's agriculture has underperformed during the past five decades. Low productivity, unequal distribution of land and other assets, the high cost of credit, and volatility of grain production and price have all been identified in numerous reports as key factors in the underperformance (e.g. Haggblade et al. 2013; World Bank Group 2016). These reports, based primarily on production statistics, demographics and responses in livelihoods surveys, were strong in socio-economic analysis but lacked depth in the analysis of biophysical aspects of farming systems that underpin improved rural livelihoods.

Underperformance is nowhere more evident than in the CDZ, the centre of rainfed, upland cropping in Myanmar. The Asian Development Bank concluded that the CDZ is one of the most food-insecure, water-stressed, climate-sensitive, natural resource-poor and least-developed regions of the country (ADB 2016). The 2013 LIFT household survey (LIFT 2014) reported that 18% of CDZ households had inadequate food, and more than a quarter of young children were underweight.

The CDZ is a priority focus of the Ministry of Agriculture, Livestock and Irrigation (MOALI) because of the clear economic and social needs of the region coupled with its development potential. The CDZ is an area of about 80,000 km^2 in the centre of the country defined by the 500–1,000 mm rainfall isohyets and lying between the mountain ranges to the north, east and west and the Ayeyarwady River delta to the south. It represents about 12% of the land area of Myanmar and is home to 12 million people, equivalent to 23% of the country's population. About 80% (10 million) of the population of the CDZ are classified as rural. Best figures indicate the CDZ encompasses 25%, 80% and 80% of the land area of Sagaing, Mandalay and Magway Regions, respectively, and 70%, 80% and 95% of the crop lands in those same Regions (LIFT 2012; MIMU 2013; FAO 2014; Vaughan and Levine 2015; Tun et al. 2015; MOALI 2016).

Central Dry Zone farmers cultivate 3.3 Mha land to grow 5.5 Mha grain crops. Major crop types are the 2.5 Mha pulse and oilseed legumes and 1.5 Mha sesame and sunflower. Rice is grown as a rainfed monsoon crop and under irrigation in the CDZ, with the estimated planted area of 1.1 Mha representing 15% of Myanmar's total. On the other hand, an estimated 46% of Myanmar's pulse and oilseed legumes and 74% of sesame and sunflower are grown in the CDZ.

About 75% of cropping in the CDZ is upland during the monsoon (May to August) and post-monsoon seasons (August to November, and August to January for pigeonpea) (Fig. 3.1). Note that the term post-monsoon refers to the second crop during the monsoon, not the dry season after the monsoon. Crops grown by individual farmers in the upland and lowland systems are a combination of the crops in Fig. 3.1 plus other crops, such as vegetables and other pulses. The long-duration pigeonpea is often intercropped, either with sesame, groundnut, green gram or cowpea grown in succession in monsoon and post-monsoon seasons.

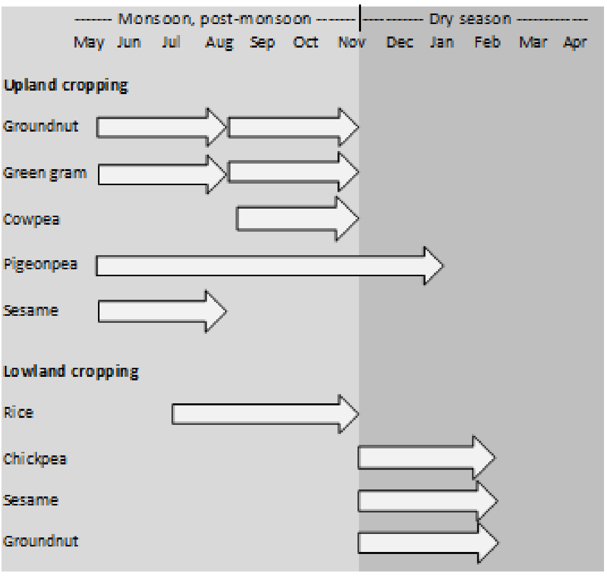


Figure 3.1. Timing of the major upland and lowland crops in Myanmar's CDZ (source: U Than Htut, personal communication, agricultural statistical data for 2016/17 from Land Record and Statistical Department, MOALI, Myanmar). Note that monsoon and post-monsoon refer to the crops cultivated during the wet period.

One of the challenges for the CDZ farmers is to successfully cultivate the two, i.e. monsoon and post-monsoon, crops during the wet season. There is substantial year-to-year variability in the timing of the onset of the wet period, the amount of rainfall and frequency of rainfall events and the timing of the end of the wet period. The rainfall patterns also tend to be bimodal, creating problems for plant establishment and early growth (see Section 7.3.3. and Cornish et al. 2018) for further discussion). Rainfall also varies across the CDZ. Rainfall in the Magway Township area of the southern CDZ is higher than at Pakokku, which is more in the centre of the CDZ (Fig. 3.2). As a consequence, the Magway growing season is about 180 days vs 150 days for Pakokku. The risk of a post-monsoon crop failure is therefore much greater at Pakokku than at Magway.

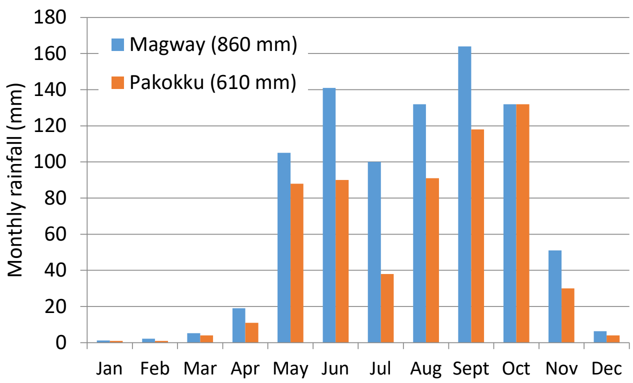


Figure 3.2. Average rainfall patterns for Magway and Pakokku Townships in Myanmar's CDZ. The growing season for Magway is 180 days vs 150 days for Pakokku. Data sourced from Cornish et al. (2018); McCartney et al. (2013)

Average crop yields across the CDZ are low at 30–50% of potential yields principally because of the lack of nutrient inputs and nutrient deficiencies, the limited access to improved high-yielding varieties, limited options for pest and disease management, the ever-growing scarcity of labour and a climate that has become progressively more variable and hostile. The dominance of coarse-textured, low organic matter soils throughout the region adds to the challenges facing its estimated 1.2 million farmers.

Pulses and groundnut are regarded by CDZ households as cash crops, rather than sources of household food. The top four income generators for CDZ households in the 2013 LIFT survey were, in descending order: the sale of pulses and groundnut; sale of labour; sale of coarse (cereal) grains and receipts from small businesses involved in production and trading. The same survey identified the major household foods to be rice, vegetables and oil, with pulses a distant fourth (LIFT 2014).

The majority of households in the CDZ are also under financial strain, with about 80% taking out loans in the previous 12-months (LIFT 2014). Loans were used primarily for food and agricultural inputs with, unsurprisingly, the wealthier households spending relatively more on agricultural inputs than food and the poorer households the opposite. About one-third of households indicated that their debt was increasing (LIFT 2014), presumably leaving little capacity to invest in innovation or to take risks with unproven technology.

Against this backdrop and building on the outcomes of ACIAR project SMCN/2006/013, a record of understanding (ROU) was signed between Australia's AusAID and ACIAR in mid-2011 to conduct a collaborative multidisciplinary program to improve food security and farmer livelihoods in Myanmar. The program aimed through applied technical, social and economic research to achieve practical impacts for Myanmar smallholders. To achieve these goals, a framework for a multilateral, multidisciplinary program was developed in consultation with the Myanmar counterparts, donors and potential research providers. The program comprised the following components:

1. Multidisciplinary research on legume-based farming systems in the Central Dry Zone (SMCN/2011/047, named MyPulses)
2. Diversification and intensification of rice-based systems in the Ayeyarwady Delta (SMCN/2011/046, named MyRice)
3. Smallholder and community aquaculture development/Post Nargis community remediation in Ayeyarwady Delta (FIS/2011/052, named MyFish))
4. Research support for smallholder livestock-based enterprises in the Central Dry Zone (AH/2011/054, named Dahat Pan)
5. Socio-economic factors affecting the acceptability and adoption of promising technologies (ASEM/2011/043, named MyLife)

The components cover the crops, fisheries and livestock sectors which account for essentially all sources of food and income for rural households. The priorities and specific objectives of MyPulses were determined in two end-of-SMCN/2006/013 project workshops in 2010 and a scoping mission in 2011. There was consensus that the geographic focus should remain the Regions of Mandalay, Magway and Sagaing and the Union Territory of Nay Pyi Taw in the CDZ and the sector focus the food legume production systems, particularly involving groundnut, chickpea and pigeonpea.

There was consensus also that the model of collaborative RD&E was the most effective means of tackling constraints to the productivity of these systems. It was agreed that the RD&E should continue to be focussed on technological improvement through the government institutions and adoption of those technologies by farmers, with the adoption facilitated by both government and non-government (NGO) organisations.

The planning workshops and scoping mission highlighted that the yield-reducing constraints of the legume-based production systems in the CDZ were both biotic (insect pests, diseases and weeds) and abiotic (low nutrient availability, drought, highly-erodible coarse-textured soils low in organic matter and with low moisture holding capacity). The consensus from the exhaustive planning sessions was that MyPulses should address the following issues:

- Improved varieties of major food legumes – pigeonpea, groundnut, chickpea, green gram and black gram – in Myanmar's CDZ (and Delta region) linked to production and distribution of high-quality pure seed of those varieties
- Improved nutrient management of the legume-based farming systems focussing on the supply of phosphorus (P), nitrogen (N), boron (B), sulphur (S), potassium (K) and zinc (Zn), and including legume inoculants

- Improved agronomic packages that optimise system productivity and economic returns to the farmer particularly through efficient capture and use of water
- Strong, explicit linkages to extension/technology-transfer programs
- Capacity building through infrastructure development and post-graduate and short-term training.

Partners in MyPulses would include the University of New England (UNE) and University of Adelaide (UA) in Australia, ICRISAT in India and the Department of Agricultural Research (DAR), Department of Agriculture (DoA) and Yezin Agricultural University (YAU) in Myanmar. The time-frame of the project was originally four years, commencing in July 2013 and involving four sets of monsoon and post-monsoon growing seasons. The project was planned to involve component and participatory RD&E, supported by capacity building through infrastructure development and training and extension activities. The participatory approach to RD&E was to be used as much as possible to aid adoption of outcomes (new varieties, inoculants, crop management practices). Project activities were planned to be spread across approximately 30 township areas of the CDZ. Variety, nutrient management and agronomy trials were to be conducted on-farm and on the DAR and DoA field stations. As was the case with SMCN/2006/013, it was expected that at least 2,000 farmers would be involved, either directly or indirectly, in the project.

4 Objectives

MyPulses aimed to improve the livelihoods and food security of small-holder farmers, their families and communities in the CDZ of Myanmar through RD&E targeted at the legume-based farming systems. Specific objectives and activities were:

1. Develop new, high-yielding varieties of pigeonpea, groundnut and chickpea (major crops) and green and black gram (minor crops) through genetic improvement to link with institutional and community-based seed production and distribution
    - Pigeonpea varietal selection, including hybrid pigeonpea, for yield, market traits and insect (particularly *Maruca*) resistance/tolerance
    - Groundnut varietal selection for yield, market traits and disease (e.g. *Cercospora personatum* (late leaf spot)) resistance/tolerance
    - Chickpea varietal selection for yield, market traits and insect (particularly *Helicoverpa armigera*) and disease (e.g. *Fusarium* wilt and *Rhizoctonia*) resistance/tolerance
    - Green and black gram varietal selection for yield and market traits from material accessed from Australia and World Vegetable Centre
    - Development and expansion of a community-based and institutional seed production, storage and distribution system for improved legume cultivars
2. Improve nutrient management of the legume-based farming systems, particularly P, N, B, S, K and Zn, using mineral and organic sources, including inoculants
    - Define extent of P, B, S, K and Zn deficiencies in the cropping areas of the CDZ and recommendations for farmers to address those deficiencies
    - Enhance capacity at DAR, Yezin, for soil and plant analysis through revision of protocols and infrastructure development and expand demand for soil testing by farmers, extension & technology transfer groups
    - Enhance capacity at DAR, Yezin, for soil and plant nutrient RD&E
    - Expand production of quality legume inoculants at DAR, Yezin, and demand by farmers for inoculants through replicated and demonstration field trials
3. Improve the agronomic management of the legume-based systems through crop benchmarking with farmers to increase efficiency of water use and effectively integrate new high-yielding varieties and pest, disease and nutrient management
    - Conduct on-farm benchmarking and trials across the CDZ involving farmers and DoA extension personnel to develop more productive farming systems
    - Incorporate, where appropriate, outcomes of the crop selection, pest, disease and nutrient management themes in the farming systems experiments
    - Promote new farming systems with effective extension campaigns
4. Enhance capacity for RD&E in the relevant agencies in Myanmar through effective implementation of the collaborative ACIAR project model and through targeted training, extension and capacity building activities
    - Post graduate and short-term training of DAR and DoA staff, linked, where possible, to YAU
    - Purchase of key experimental and training resources using project funds
    - Linkages with established government and NGO technology transfer programs.

5 Methodology

5.1 Development of high yielding varieties of pigeonpea, groundnut and chickpea (major crops) and green and black gram (minor crops) linked to seed production and distribution

Development of new genotypes was through accession of germplasm from the breeding programs at ICRISAT and through the breeding programs at DAR, Yezin. Evaluation of material from the two sources was conducted by the DAR scientists in Myanmar, first in unreplicated preliminary yield and seed increase trails, then later in multi-site yield trials. Promising genotypes were then subjected to more extensive yield assessment across the CDZ in mother-baby trials, used with success in previous project SMCN/2006/013 with the replicated mother trials on DAR and DoA research farms and the more numerous, non-replicated baby trials conducted on-farm. Central to the mother-baby model was farmer participatory varietal selection (FPVS) whereby the on-farm baby trials were used to determine farmer preferences, based on traits such as seed colour, maturity, insect and disease tolerance etc. Once cultivars were identified for release, the final step in the process involved at least two years of demonstration and seed increase trials in farmers' fields and on DAR/DoA farms across the CDZ.

5.1.1 Pigeonpea farmer-participatory varietal selection

Farmer participatory varietal selection during 2014–18 involved 28 mother and 268 baby trials in 20 townships in the CDZ (Table 5.1). Material tested was Nyaung Oo Shwedinga, Yezin 9, Monywa Shwedinga and local check for the long-season cultivars and Yezin 10, ICPL 98015, ICPL 98010 and Yezin 3 (check) for the mid-season cultivars.

Table 5.1. Location and number of mother and baby trials during 2014/15 to 2017/18 in the pigeonpea improvement program

Division	Township	Mother trials	Baby trials
Sagaing	Monywa, Depeyin, Myinmu, Butalin, Sagaing	6	80
Mandalay	Nyaung Oo, Myingyan, Yemethin, Mahaling, Nga Htoe Gyi, Pyawbwe, Meikthila, Taungtha, Tharsi	17	99
Magway	Magway, Myaing, Minbu, Pakokku, Yesago, Natmaut	5	89
Total		**28**	**268**

NyaungOo Shwedinga (to be released in 2019), Yezin 9 (to be released in 2019) and Monywa Shwedinga (to be released in 2019) were developed through the DAR national plant breeding and selection program. Yezin 10 (ICPL 88039), ICPL 98015 and ICPL 98010 were introduced from ICRISAT during the previous SMCN/2006/013 project. None of these cultivars have been released by the DAR. All the tested varieties were selected based on farmers' preferred traits, including medium seed size, yellowish brown to brown seed coat colour and high yields in preliminary trials.

5.1.2 Groundnut farmer-participatory varietal selection

Farmer participatory varietal selection for groundnut involved 11 mother and 66 baby trials in 13 townships in the CDZ and adjacent Nay Pyi Taw Union Territory during 2014–16 (Table 5.2). Material tested was Sinpadetha 7, Sinpadetha 10, Sinpadetha 11, Sinpadetha 12, Sinpadetha 13 and YZG 08075 (Table 5.3).

Table 5.2. Location and number of mother-baby trials, specific trait trials and seed production/demonstration activities in the CDZ and adjacent Nay Pyi Taw Union Territory during 2014–18

	Sagaing Division		Mandalay Division		Magway Division		Nay Pyi Taw Union Territory		Total	
Year	Mother	Baby	Mother	Baby	Mother	Baby	Mother	Baby	Mother	Baby
2014/15	*	9	*	6	1	9	4	6	**5**	**30**
2015/16	*	9	2	9	1	9	3	9	**6**	**36**
2016/17	Mother-Baby trials not conducted. All activities directed at seed production and distribution to farmers									
2017/18	Mother-Baby trials not conducted. Field evaluation of genotypes sent from ICRISAT in 2017 with particular traits, e.g. short-duration, disease resistance, drought tolerance									
Townships	Monywa, Kani, Butalin, Yayoo, Chaungoo		Myingyan, Nyaung Oo		Pakokku, Yaesakyo		Yezin, Tatkone Pyinmana, Popepathiri,			

In previous project SMCN/2006/013, a total of 36 mother and 258 baby trials were conducted across the CDZ during 2007–10. Sinpadetha 7, Sinpadetha 11 and Sinpadetha 12 were included in some of those trials and continued to be included in the current FPVS to confirm previous findings and provide mechanisms for extension and pure seed propagation and distribution.

Table 5.3. Improved cultivars assessed in the 2013/14 to 2015/16 mother-baby trails in the CDZ and adjacent Nay Pyi Taw Union Territory

Cultivar	Bred by (pedigree)	Remarks
Sinpadetha 7	ICRISAT (ICGV 93382)	Short duration (95–100 days), high yield (1750–1975 kg/ha)
Sinpadetha 10	ICRISAT (ICGV 91167)	Medium duration (120 days), high yield (1975–2220 kg/ha), foliar disease resistance,
Sinpadetha 11	DAR (Sinpadetha 7 x Luhua 14)	Short duration (95–100 days), very high yield (1975–2600 kg/ha), uniform matured kernel
Sinpadetha 12	YZG 03008 DAR (Myaepenet x ICGV 86707)	Medium duration (110–115 days), good podding, high shelling percentage, resistant to pest and diseases, drought tolerant
Sinpadetha 13	YZG 98017 DAR (Sp 121/070 x Vietnam)	Short duration (95–100 days), high yield (1850–2100 kg/ha), drought tolerant
YZG 08075	J 11	High pod yield, high % shelling.

It is worth noting that varieties Sinpadetha 2, released in 1982, through to Sinpadetha 10, released in 2010, were all bred at ICRISAT and released in Myanmar after extensive field testing. Sinpadetha 11, also released in 2010, was bred by DAR scientists and was the first of the locally-bred cultivars to be released. Sinpadetha 11 has since proved to be a highly productive and popular variety. Sinpadetha 12 and Sinpadetha 13 were also bred by DAR scientists and subsequently released, in 2013 and 2015, respectively.

5.1.3 Chickpea farmer-participatory varietal selection

Farmer participatory varietal selection for chickpea involved 10 mother and 72 baby trials in 13 townships in the CDZ (Table 5.4). The test material included both Kabuli (5 cultivars) and Desi type chickpea (5 cultivars).

Table 5.4. Location and number of mother and baby trials during 2014/15 and 2015/16 in the chickpea improvement program

Division	Township	Mother trials	Baby trials
Sagaing	Monywa, Yae U, Chaung U, Budalin	4	24
Mandalay	Tatkone, Myingyan, Kyaukse, Madaya, Myitthar	4	24
Magway	Pwint Phyu, Myaing, Salin	2	24
	Pakokku	0	6
Total		**10**	**72**

5.1.4 Green gram and black gram farmer-participatory varietal selection

Details for green gram, but not for black gram, are presented here. The geographic focus of black gram improvement, research and extension was in the rice-based systems of lower Myanmar, rather than in the CDZ. Details of the black gram program can be found in the Final Report of SMCN/2011/046 'Diversification and intensification of rice-based cropping systems in lower Myanmar (MyRice)' (accessed at https://www.aciar.gov.au/publication/Diversification-and-intensification-rice-based-cropping-systems-lower-Myanmar-MyRice)

Farmer participatory varietal selection for green gram involved 14 mother and 6 baby trials in the CDZ during 2014–16. Material tested were high-yielding cultivars, resistant to yellow mosaic virus (YMV) (Table 5.5).

Table 5.5. Improved cultivars assessed in the 2013/14 to 2015/16 mother-baby trials in the CDZ and adjacent Nay Pyi Taw Union Territory

Cultivar	Bred by (pedigree)	Remarks
YM 03-2-5	DAR, Myanmar	Resistant to yellow mosaic virus
YM 03-4-21	DAR, Myanmar	Resistant to yellow mosaic virus
Yezin 11	Pakistan, FAO (2010)	Resistant to yellow mosaic virus
Yezin 14	DAR, Myanmar (2013)	Resistant to yellow mosaic virus
Local	*	*

5.1.5 Village seed bank program

Effective seed production, storage and distribution systems are critical to the successful adoption of new varieties by farmers, and it is the lack of such systems in many countries that hold back varietal improvement and adoption. The formal government and private sector seed system in Myanmar is underdeveloped with any activities in the sector tending to be focussed on rice, oilseeds and vegetables.

In previous project SMCN/2006/013, ICRISAT worked closely with the DoA to conceptualise and implement a community-based village seed bank (VSB) system for disseminating new, improved cultivars/varieties of the target legumes, groundnut, pigeonpea and chickpea. By the end of the project, the concept had been realised with 15 farmers in three villages producing seed of two groundnut (Sinpadetha 7 and Sinpadetha 8), two pigeonpea (Monywashwedinga and ICPL96061) and two chickpea (ICCV97314 and Yezin 4) cultivars covering 14 hectares. Most of the seed produced in the VSBs was distributed to farmers in the same village with excess distributed to neighbouring villages. During the establishment of the VSBs, farmers highlighted several issues that needed to be addressed to ensure effective seed flows in future years, including: lack of appropriate storage facilities at the village level, timely rouging of off-types, seed grading, and availability of inputs such as sprays for insect control. The breeder seed production was conducted by DAR, Yezin, under the direct supervision of breeders with the foundation seed produced at DAR research farms.

The VSB model was implemented in MyPulses in 2015/16 by the DoA with back-stopping from ICRISAT, then expanded during 2016/17 and 2017/18. Farmers in the program were supplied with pure, good quality seed of the target legume and cultivar and advice about its cultivation. At the end of the season, the farmers were then obliged to reimburse the same amount of seed back to the DoA which was then supplied to other farmers. They were free to use the excess improved cultivar seed as they wished, including to sell to other farmers. The average quantity seed supplied to each VSB farmer by the DoA was 14 kg for pigeonpea, 50 kg for chickpea and 120 kg for groundnut.

In 2017 an evaluation study was conducted to quantify the formal and informal distribution of the new, improved VSB cultivars in the target areas and to examine the extent to which the VSB program was successful in facilitating spread and adoption of the improved legume cultivars as well as the productivity and economic benefits of those cultivars.

5.2 Nutrient management of the legume-based farming systems of the CDZ, particularly P, N, B, S, K and Zn

Adoption of proper crop management practices, including application of fertilisers for nutrient supply, is required to fully realise the genetic potential of improved varieties. In the development phase of MyPulses, nutrient management was identified as a priority area for research because there was good evidence that nutrient supply was sub optimal in Myanmar agriculture and was severely limiting productivity of the legume crops as well as rice, other cereals and oilseeds.

5.2.1 Defining extent of P, B, S, K and Zn deficiencies in the cropping areas of the CDZ and updating recommendations for farmers to address those deficiencies

Defining crop nutrient deficiencies in the soils of the CDZ consisted of two planned research activities. The first was to sample representative soils from farmers' fields across the CDZ and analyse them for key nutrients and other characteristics such as texture, pH, organic C and EC. The second was to conduct fertiliser trials to determine responsiveness of soils to key nutrient inputs and appropriate rates of the inputs. A guide to nutrient management in the CDZ was to be developed from the research outlining symptoms and critical soil values for economic nutrient responses.

For the soil survey, surface soil, i.e. 0–10 cm, samples were collected in 2013 from 319 fields located in 148 farms in 57 villages across the CDZ. Samples were randomly taken from 10 locations in each field, bulked, and transported to the DAR soil chemistry laboratories, Yezin, for analysis. Soils were dried, ground to <2 mm using a mortar and pestle, then sieved prior to analysis using standard soil analytical techniques for Myanmar. Details of procedures can be found in Guppy et al. (2017).

In the first (2014–15) season, on-farm demonstration trials were conducted in the monsoon and post-monsoon seasons at 61 locations, from Sagaing Region in the north of the CDZ to Magway Region in the southern CDZ. These trials examined responses in groundnut (25 trials) and chickpea (36 trials) to broadcast applications of 10 kg P/ha and 20 kg S/ha at planting (groundnut) and 20 kg P/ha at planting (chickpea). Once the fertilisers had been applied, the collaborating farmers then planted crops over the top of the fertilised areas and DAR staff harvested the adjacent +/- P or P+S plots just prior to normal harvest. Two chickpea trials with P, S and Zn basal nutrients added as single elements or in combination, were also conducted on alkaline clay chickpea fields in the Sagaing region. Biomass cuts and grain yields were recorded from all trials.

In the second (2015–16) season, 21 replicated nutrient omission trials were established in farmers' fields selected from the 2013 soil survey (Guppy et al. 2017). This was done in order that critical soil values could be determined when data from all of the sites were pooled. Treatments were inputs of P (20 kg/ha), K (50 kg/ha) and S (20 kg/ha as both sulfate and elemental S). Crops were groundnut (9 sites), chickpea (9 sites) and green gram (3 sites). Basal B was also applied. Biomass cuts were done at 40 DAS to record fertiliser uptake and early season nutrient responses. Surface soil samples were taken before and after the trials to indicate the fate of applied nutrients.

In the third (2016–17) season, research on nutrient management was almost entirely conducted in the context of the farmer participatory crop benchmarking (FPCB; see sections in this report on FPCB). Across the 94 participating FPCB farms from Nat Kan, Magyeekan, Aung Myay Kone and Pho Lay Lone villages, 33 had fertiliser strips. Fertilisers were triple superphosphate (TSP), KCl, gypsum and urea (sesame only) to deliver 20 kg/ha P, 50 kg/ha K, 50 kg/ha S and 50 kg/ha N (sesame only), applied as a basal application at sowing. Crops were groundnut, pigeonpea and sesame, planted in May in the early monsoon. The single nutrient field experiment during 2016–17 involved groundnut in the Nay Pyi Taw Union Territory and designed to evaluate effects of P and S placement strategies on nutrient uptake and yield. The experiment was part of Daw Khin Myo Thant's MSc program at UNE (Sections 10.2.2 and 10.2.3. for details of publication).

In the fourth (2017–18) season, 12 unreplicated trials in 3 villages, i.e. 4 sites per village, near to Magway Township were again conducted as part of the FPCB activities. Crops were groundnut (3) and sesame (9), planted in April at Nat Kan and Magyeekan villages and in May at Pho Lay Lone village at the start of the monsoon. Treatments were unfertilised control, fertiliser (15 kg/ha P, 60 kg/ha K, 60 kg/ha S and 60 kg/ha N (sesame only)) applied as a basal application at sowing, or fertiliser split into 2 (Nat Kan and Magyeekan on 10 May and 8–9 June) or 3 applications (Pho Lay Lone on 29 May, 8 June and 23 June) during the growing season to account for potential leaching. Soils were sampled to a depth of 1.2, 1.5 or 1.8 m in 15–30 cm segments prior to planting (Pho Lay Lone) or 17 days after planting (Magyeekan and Nat Kan). Soils were dried, ground and analysed at the DAR soils laboratory, Yezin, for pH, EC, available P, available K, extractable S, exchangeable Ca and exchangeable Mg. Grain yield was recorded at harvest.

5.2.2 Enhancing capacity at DAR, Yezin, for soil and plant analysis through revision of protocols and infrastructure development and expanding demand for soil testing by farmers, extension & technology transfer groups

This involved technical exchanges for project personnel between Myanmar and Australia, intensive on-site training at the DAR soils laboratory, revision of current and development of new laboratory procedures and targeted equipment purchase. A planned major output was the production and publication of a revised laboratory manual for the analysis of soils and plants. Expansion of demand involved advertising to the DoA, farmers etc the laboratory services of the DAR, together with the sampling of farmer's field soils as part of project activities and analysis and rapid reporting of interpreted results back to those same farmers. It was anticipated that exposure of farmers and the associated DoA and DAR field staff would, in time, stimulate interest in soil and plant testing. The objective was to at least double the throughput of soil and plant samples.

5.2.3 Enhancing capacity at DAR, Yezin, for soil and plant nutrient RD&E

Enhanced capacity for crop nutrition and soil chemistry RD&E was to be achieved through the collaborative research conducted across the CDZ and through the on-site, workshop post-graduate and short-term overseas training of DAR personnel. By the end of MyPulses, the collaborative research involved the 319-field 2013 soil survey, 97simple unreplicated and multi-treatment replicated field experiments and 33 fertiliser strip interventions during 2014-18 and the involvement of DAR soil chemistry personnel in the FPCB activities during 2016–18 in the Magway Township area. Details of training can be found in Section 7.4.

5.2.4 Expanding production of quality legume inoculants at DAR, Yezin

The overall aims with the rhizobial inoculants theme were to increase capacity at DAR to produce large volumes of high-quality inoculants, to create demand amongst Myanmar farmers for rhizobial inoculants through demonstration of their impact on crop yield and profitability and to develop skills and technical capacity at DAR and YAU through on-site, short-term and post graduate training.

Research on inoculant production aimed to (i) access potential supplies of peat in Myanmar and assess their suitability as a carrier in laboratory storage experiments and (ii) examine different options for producing pure, high-titre broths of different rhizobial strains for use in inoculants. These activities were combined with on-site, workshop and post-graduate training, with laboratory infrastructure improvement and with development and implementation of a documented QA protocol for inoculant production at DAR. A major priority was the development and implementation of plant-infection, most-probable number counting of rhizobia in broths, peats and soil to replace the traditional plate counting method.

5.2.5 Expanding demand by farmers for legume inoculants through understanding the nature of rhizobia in Myanmar soils and replicated and demonstration field trials

Achieved through a survey of chickpea-growing soils in the northern areas of the CDZ, where the majority of chickpea are cultivated, and replicated and demonstration field trials in those same areas during 2014–17. The target legume was chickpea because of its economic importance coupled with the specific nature of the chickpea-*Rhizobium* symbiosis. Despite the importance of chickpea and other legumes to Myanmar, the use of rhizobial inoculants is extremely limited. The history of inoculation of chickpea by farmers in Myanmar is poorly understood and there is currently no established supply chain for rhizobial inoculants. Although chickpea plants are generally nodulated in the absence of inoculation, there is little information on the genetic diversity or effectiveness of chickpea rhizobia in the soils of the chickpea-growing areas and almost no knowledge on how those rhizobia might have initially established. Finally, there has been an absence of research to determine if grain yields of chickpea could be increased through application of inoculants containing highly-effective rhizobia.

This research, therefore, aimed to 1) quantify the abundance and symbiotic effectiveness of chickpea rhizobia in Myanmar soils, and 2) test the extent to which existing soil rhizobia contribute to N_2 fixation and 3) determine if inoculation with highly-effective rhizobia might improve chickpea nodulation, N_2 fixation and grain yields.

Field soils, 0-10 cm depth, from 16 farmers' fields and four DAR research farms (Zaloke, Pankone, Kyaukse and Tatkone) in the chickpea growing areas of the CDZ were sampled in the 2014/15 season and the number of rhizobia was determined using the most probable number (MPN) plant-infection test.

Field experiments were established on 16 farmers' fields (same ones that were soil sampled for chickpea population counts) in 2014/15 and at various times in 2014/15, 2015/16 and 2016/17 at seven DAR research farms (Zaloke, Pankone, Myittha, Myingyan, Tatkone, Sebin and Kyaukse) in the CDZ. The experimental design was a 2 x 2 factorial comprising (+/-) inoculation using the Australian commercial chickpea strain (CC1192) applied as a slurry to seed just before sowing and (+/-) phosphorus (P) fertiliser (20 kg P/ha as triple super phosphate (TSP)). Treatment plots for the DAR farms' experiments were arranged in complete randomised blocks with 5 replicates. Plots in the farmers' fields were unreplicated. Phosphorus was drilled into furrows next to the seed rows at approximately 10 cm depth. Chickpeas Yezin 6 (ICCV 92944 Desi type) and Yezin 8 (ICCV97314 Kabuli type) were hand sown in rows that varied 30–37.5 cm. Plots were hand-weeded and fungicides were used as necessary to prevent disease. Numbers of inoculation *x* fertiliser P experiments were: farmers' fields 2014/15 (16 sown, 12 harvested); DAR farm 2014/15 (4 sown, 4 harvested), DAR farm 2015/16 (7 sown, 6 harvested) and DAR farm 2016/17 (3 sown, 3 harvested).

Generally, chickpeas were sampled at early pod fill, approximately 80 days after sowing (DAS). Plant biomass was measured from 1 m^2 quadrats/plot. Plant N_2 fixation was assessed at the Myittha site in 2015/16 using the ^{15}N natural abundance method. Plants were dug from the soil and nodules assessed by scoring. Grain yield was determined at approximately 100 DAS by hand harvesting plants and threshing.

5.2.6 Analysis of fertiliser quality in the CDZ and rapid assessment using NIR

Poor fertiliser quality had been recognised as a potential problem for farmers in Myanmar for a number of years. Chemical analysis in Australia in April 2016 of two samples of triple superphosphate confirmed the concerns. In June 2016, a larger survey of fertilisers involving 78 samples was conducted in conjunction with research at the University of Adelaide to develop a simple NIR-based method for analysis that could be used in Myanmar. Standard analytical methods for measuring nutrient elemental concentrations were and remain available in Myanmar but the turnaround is slow. The Land Use Division (LUD) of MOALI is responsible for administering fertiliser regulations, under direction of the Fertiliser Committee and the MOALI. Typical concerns over fertiliser include mixing of fertilisers, adulteration of fertilisers with inert materials, the use of inferior product, misleading labels on bags and underweight bags (Gregory, 2015). A rapid, accurate and cost-effective test of the quality of fertiliser products could potentially provide farmers and re-sellers with more timely assurance of product integrity and confidence in applying fertilisers.

Nutrients in fertilisers were analysed using standard analytical methods (Rayment and Lyons 2011) in the Agronomy and Soil Science laboratory, University of New England, Australia. Near Infrared analysis was conducted using The MicroNIR™ spectrometer, a relatively new instrument developed and commercialised by JDSU Corporation (Santa Rosa, CA, USA). Details of the actual methodology can be found in Denton et al. (2017) (see Section 10.2.3).

5.3 Agronomic management of the legume-based farming systems of the CDZ through increased system water use and integration of new technologies

5.3.1 Participatory rural appraisal (PRA) of CDZ farming systems

In November 2012, a participatory rural appraisal (PRA) was conducted by Australian and Myanmar project scientists across the CDZ in order to:

- Plan more effectively project research during the next 4+ years
- Define baselines for nutrient management, agronomic practices etc at the start of the project that can be checked against at completion of the project to determine progress or lack of it
- Gain insights for the Australian scientists into the agriculture, livelihoods, farming practices, farmer knowledge and decision-making processes.

Three teams, one for each of Magway, Sagaing and Mandalay Divisions, conducted the surveys, with 7 people in each team. Teams were joined by local DAR and DoA staff at each of the townships.

There were 23 questions in the survey, covering agronomic practices, water management, nutrient (fertiliser) management, varieties and rhizobial inoculation. Data from the 3 surveys of total of 259 farmers were immediately processed and key findings presented at the MyPulses Inception Workshop on 10–11 November 2012. Details of the PRA and the master file of all survey data can be sourced from David Herridge (Myanmar survey answers MASTER (1).xlsx).

5.3.2 Research on practices affecting crop yield and water use

During 2013–16, a total of 22 replicated field trials examined a range of management practices on grain yield and water use. Treatments included (i) N and P fertilisers in the presence and absence of retained residues (Magway DAR farm), (ii) windbreak effects on mungbean (Nyaung Oo DAR farm), (iii) cover crop effects (Nyaung Oo farm) and (iv) reduced/zero tillage and mechanisation vs traditional cultivation effects on productivity and production costs (Magway, Zaloke, Tatkone and Nyaung Oo DAR farms). The latter was made possible with the purchase in September 2015 of four small hand-guided mechanical planters imported by the project from China (Good Brothers Gongli planters). The planters were located at the Magway, Zaloke, Tatkone and Nyaung Oo DAR farms with appropriate training by Craig Birchall.

Research across the globe has demonstrated the benefits of mulching/retention of crop residues for soil water capture and retention and, ultimately, crop yield. The PhD program of U Aung Kyaw Thu at the YAU, co-supervised by Dr Khin Mar Htay, DAR, and Craig Birchall, UNE, investigated effects of crop residues as mulches on soil water capture and retention and biomass and grain production in five different crop sequences – sesame-green gram, sesame-groundnut, groundnut-groundnut, groundnut-green gram and groundnut-sorghum. The experimental site was at the DAR Magway farm. Site characteristics were typical for much of the MyPulses research conducted in the Magway Township area. The soil was a well-drained sand (93% sand, 3% clay) of pH 7.4 and bulk density of 1.6 g/m^3. The experiment was conducted for 2 successive years (2014/15 and 2015/16), during which time four (two monsoon and two post-monsoon) crops were grown. Each treatment of crop *x* ±residues was replicated three times in a randomised complete block design. For the mulched treatments, residues of the previous crop, coarsely chopped, were applied at a rate of 5 t/ha one week after planting.

Soil water was measured gravimetrically at planting for each of the two monsoon and two post-monsoon crops and at 15-day intervals throughout the subsequent growing season to a depth of 1.5 m in 0.3 m increments. Crop water-use efficiency was defined as grain yield (kg/ha) per mm water used, calculated as the difference between soil water content at planting and harvest plus in-season rainfall.

5.3.3 The MyPulses mid-term review and change of direction for agronomy and soil water research

In March 2016, the focus of the agronomy and soil water research shifted from small plot experimentation to farmer participatory crop benchmarking (FPCB). This change resulted from the major recommendation of the project's mid-term review in December 2015, conducted by Professor Peter Cornish, Australia, and Dr John Ba Maw, ex DG-DAR. The reviewers had been informed that yields of pulses in the CDZ were variable and that two years of crop nutrition experiments across the region showed weak and inconsistent responses to fertiliser applications and rhizobial inoculants, even though both were low/likely to be low in many of the soils in which the experiments were conducted. Major recommendations were that MyPulses becomes more interdisciplinary and focused on yield improvement through coordinated planning of activities, co-locating field experiments and using benchmarking of farmer crops with the active participation of farmers.

Other recommendations were that MyPulses collaborate with ASEM/2011/043 (MyLife project) on the benchmarking to take advantage of MyLife's expertise in facilitation, working with groups and gender issues. To that end, funding was obtained for a new, small collaborative research project (C2016/021) under the ACIAR/DFAT Myanmar Program with MyLife entitled 'Undertaking research on engaging women and men farmers in participatory research and extension in Myanmar'. Implementation of this project also commenced in March 2016 with travel to Myanmar by the MyPulses and MyLife teams and continued in May 2016 with more travel for farmer meetings, training workshops and soil sampling.

What is farmer participatory crop benchmarking?

Benchmarking is a process in which farmers measure their crop yields to then compare with estimated potential yields, i.e. 'benchmarks'. Farmers also observe key soil and management variables (factors). Each of these generally has a benchmark, like plant population or time of sowing. The approach can allow farmers to monitor a small number of highly relevant factors that contribute to good yields and work out why their yields fall below the benchmark – it is both a tool for evaluating past results and planning for future crops. For example, a farmer may work out his/her yields were low partly because his/her plant population was too low, so they plan to check seed quality in future and increase sowing rate. The benchmark yield might be the best yield in the village/district or district, or it might be a calculated yield based on factors like the availability of water.

Benchmarking is both a research methodology, to understand the causes of yield variation, and an extension methodology, to achieve farmer practice change and improve livelihoods. The other key elements of benchmarking are that it is participatory whereby farmers, extension officers and researchers work together as partners. Benchmarking often involves groups of farmers, rather than individual farmers, and for the groups to meet regularly to share findings with the aim of learning how to improve crop management, crop yields and profits.

Biophysical factors are many and they interact in complex ways to determine yield and profitability. Progress is rarely achieved by addressing any one factor in isolation from the rest. Benchmarking allows the exploration of effects of many factors at one time, enabling farmers and researchers to identify the key factors for achieving high-yielding, profitable crops. Benchmarking is done on farmer's fields and crops. It is not essential to apply any experimental treatments, but interventions can be instructive and farmers can learn to do this.

Although benchmarking is focused on biophysical soil and crop measurements, it is conducted in a social context that allows individual farmers to make sense of what they observe and to decide about changing management in the context of their own personal circumstances. Because of this complexity, the approach is best thought of as 'improving the household situation' rather than 'solving' the farmer's problems, although at times there is a need to address particular problems, such as pests and diseases. Benchmarking is based on the premise that farmers themselves are the best people to integrate all of these interacting factors and decide what new technology to adopt, amongst making other changes in their lives.

To summarise the elements of farmer participatory crop benchmarking and differences with the more traditional transfer of technology (TOT) methodology:

- The researchers/extension staff work with groups of farming families rather than individual, predominantly male, farmers
- All work together to test treatments (e.g. fertiliser P) and to collect data

- At the end of the season, data are combined for each group of farmers and, together they interpret the data, and learn about the constraints to yield. Based on the new knowledge, farmers then plan to implement (do) something different in the next crop to improve yield.
- The purpose is to determine and use benchmarks for grain yield (what's attainable) and identify the key factors that affect yield (what's needed)
- FPCB uses a 'participatory' action learning process, in which farmers and researchers learn together as equals but with different knowledge, skills and experience, rather than researchers learning by themselves and then passing the new knowledge on to farmers, i.e. the traditional technology transfer approach.

Implementing FPCB

In March 2016, two workshops were conducted, at DAR, Yezin, and at the DoA office, Magway Township, to seek engagement and involvement in the new initiative by the DAR and DoA as institutions and also by DAR and DoA staff. It was decided at the workshops that the geographic focus of the work would be the Magway Township because it is a good agricultural area with diverse cropping and is well-supported by DAR, DoA and YAU.

Eight DoA extension staff from the Magway Township working at the village/village tract level were recruited into the project (4 women and 4 men). Each pair was already assigned to one of the four FPCB villages for their regular extension work. Six out of eight staff held a Diploma of Agriculture, while two held a Bachelor of Agriculture. Their experience in DoA ranged from 2.5 to 6 years, and all had attended just 2–4 weeks in-service training within the last five years.

The eight DoA extension staff attended two training sessions on introductory facilitation techniques and managing farmer groups. Trainers included three YAU Faculty members who had previously attended a 'training of trainers' workshop. The same DoA staff had training sessions on collecting relevant agronomic data and recording benchmarking data in March, May and August 2016. In addition, the team held meetings in October 2016 and February 2017 where the data was analysed and discussed, and the team worked together to make agronomic conclusions.

Participating villages, farmers and project staff

In May 2016, the benchmarking project was launched in four villages in the Magway district, with a full day workshop in each village to introduce the benchmarking concept and the participatory approach. There were 94 farming households (husband + wife) involved in the benchmarking from four villages in the Magway Township area – Nat Kan village, Pho Lay Lone village, Magyeekan village and Aung Myay Kone village (Fig. 5.1). The aim was to recruit a minimum of 20 farming families in each village (husbands and wives). In one village, Magyeekan, the project worked with only 20 male farmers as this was an existing male-only farmer group. Although the focus of MyPulses was the food (pulse) and oilseed legumes, farmers growing sesame were included in the study. This was for the convenience of benchmarking the same farmers' fields across the monsoon and post-monsoon seasons. It is common for farmers in this area to grow pulse and oilseed legumes and sesame in rotation and/or as part of inter-cropped systems.

During the monsoon and post-monsoon seasons of 2016 and 2017, a total of 210 groundnut and 188 sesame fields were monitored (grand total of 398 fields). There were also interventions. In the 2016 monsoon season, 33 fields had fertiliser strips, 29 fields had a pigeonpea variety strip and 31 fields had a groundnut variety strip. In the 2017 monsoon season, nutrient leaching and response experiments were conducted on 12 fields.

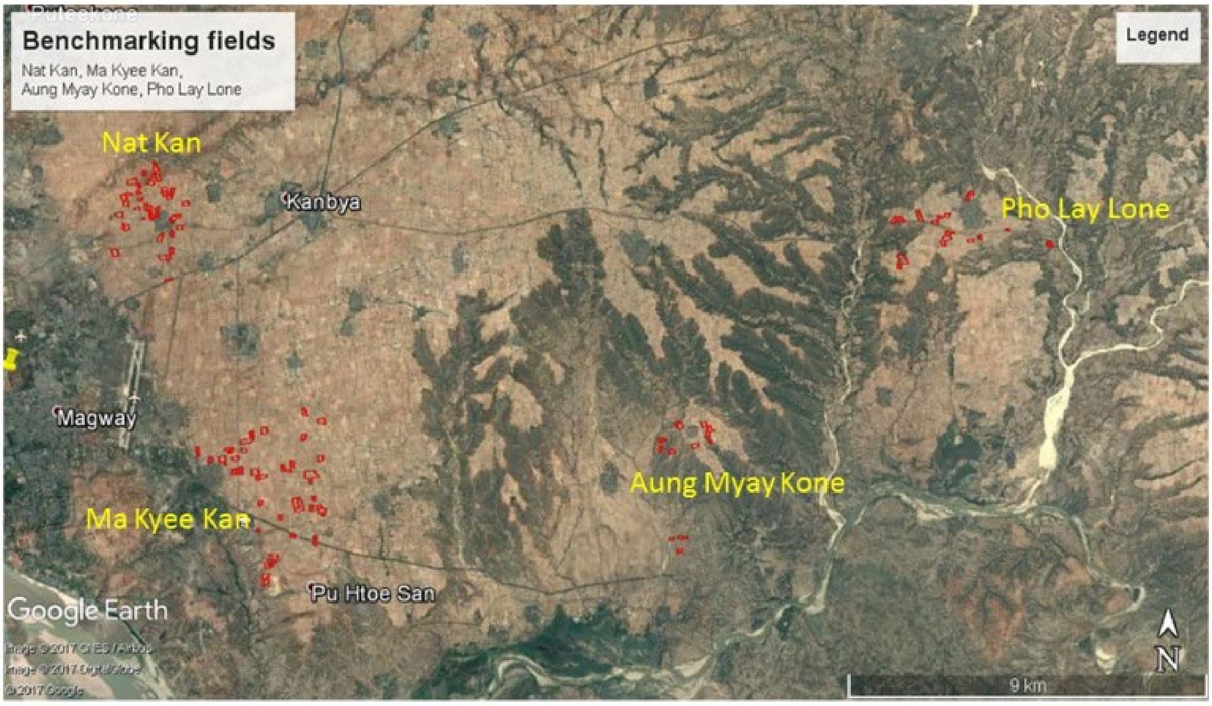


Fig. 5.1 Map showing the four participating villages in relation to Magway Township

Details of villages, DoA extension staff as of March 2016 and researchers:

- Nat Kan village
    - 24 husbands + wives
    - DoA extension staff – Daw Thida and U Aung Naing Lin
- Pho Lay Lone village
    - 30 husbands + wives
    - DoA extension staff – Daw Ei Phyu Kyi and Daw May Myat Swe
- Magyeekan village
    - 20 men
    - DoA extension staff – U Thiha Aung and U Ye Min Han
- Aung Myay Kone village
    - 20 husbands + wives
    - DoA extension staff – Daw Aye Aye Khaing and U Moe Min Aung

xProject (C2016/021), MyLife (ASEM/2011/043) team:

- Dr Michelle Carnegie, University of New England
- Dr Nyein Nyein Htwe, YAU Agronomy
- Daw Khaing Khaing Htwe, DAR

MyPulses (SMCN/2011/047) team:

- Mr Craig Birchall, University of New England
- Daw Thuzar Win, Dr Ti Ti Aung, Dr Khin Mar Htay, DAR
- Dr San San Yi, Deputy Director, DOA Nay Pyi Taw
- Dr Matt Denton, University of Adelaide
- Dr Chris Guppy, University of New England
- Dr David Herridge, University of New England

Research Coordinator

- U Kyaw Zin Win, DoA

Consultant:

- Prof. Peter Cornish, Western Sydney University

FPCB data collection

In May of 2016 and 2017, participating farmers were given data sheets with space for recording relevant management practices and inputs, field observations, and yield at harvest. The topics recorded are shown in Table 5.6.

Table 5.6. Variables for farmer field data collection

Farmer ID • Name and village *Field characteristics* • Area • Soil type • Crop history from previous year *Nutrient inputs* • Dry season – organic input type and rates • In crop fertilizer type, rate and timing *Crop* • Crop species and variety • Date of sowing, sowing rate, row spacing • Application of rhizobia or seed dressing	*Plant observations* • Population per 10 feet row • Nodulation score *Weeds* • Most important species • Timing and method of control *Pests* • Insect populations, control methods and efficacy *Diseases* • Incidence, timing and severity *Yield* • Comments on anything farmers think affected yield

Data collection was undertaken by farmers and overseen by the DoA staff. Data were later entered into excel for checking and analysis. DoA staff had to check the data with farmers as many as three times to ensure that it was correct, due to unfamiliarity with how farmers described things, and DoA staff still learning the importance of some information. In addition, soil samples were taken from most fields in 2016 and analysed for organic C, P, K, S, Ca, Mg, B, texture, pH and EC. These data were also included in the analyses, and given to the farmers during one of the 2016 meetings, along with a discussion on what it meant.

Key weights and measures, conversions

The following are the weights, measures and conversion factors of harvested grain and organic and mineral fertilisers (Table 5.7).

Table 5.7. Conversions of land area and N, P, K and S mineral fertilisers

Local to International	International to local
Acre x 2.47 = hectare	Hectare x 0.40 = acre
lbs x 0.454 = kg	Kg x 2.20 = lbs
P_2O_5 x 0.437 = P	P x 2.29 = P_2O_5
K_2O x 0.836 = K	K x 1.21 = K_2O
Urea x 0.46 = N	N x 2.17 = urea
TSP x 0.21 = P	P x 4.76 = TSP
Potash x 0.50 = K	K x 2.00 = Potash
Gypsum x 0.18 = S	S x 5.56 = Gypsum

Weights in kg and lb for baskets of groundnut, pigeonpea, chickpea, green gram, rice and sesame as well as baskets and carts of FYM are shown in Table 5.8. Also shown are the factors used to convert baskets/acre to kg/ha. Note that the cart weight varied between 10 and 20 baskets on different farms, so 15 baskets manure/cart was used as an average.

Table 5.8. Weights measures and conversions factors for grains and FYM

Item	Metric (kg)	Imperial (lb)	Baskets/ac to kg/ha
Basket groundnut pod	11.4	25	x 28.2
Basket sesame	24.5	54	x 60.5
Basket pigeonpea	32.7	72	x 80.8
Basket chickpea	31.3	69	x 77.3
Basket green gram	32.7	72	x 80.8
Basket rice (paddy)	20.9	46	x 51.6
Basket manure	20	44	x 49.4
Cart manure	300	660	x 741

In Table 5.9 are the values used for N, P, P_2O_5, K, K_2O and S in FYM and clay soil. The FYM values were aggregated from a 2016 survey of FYMs from the 4 villages (see Section 7.3 of this report) plus earlier data of the DAR. Values for the clay/silt soils are taken from published literature.

Table 5.9. Concentrations of N, P, P_2O_5, K, K_2O and S in FYM and clay/silt soil

Organic fertiliser	%N	%P	%K	%S
FYM	0.57	0.20	0.20	0.25
Clay/silt soil	0.09	0.04	0.30	0.00
Organic fertiliser	**%N**	**%P_2O_5**	**%K_2O**	**%S**
FYM	0.57	0.46	0.24	0.25
Clay/silt soil	0.09	0.09	0.36	0.00

The %N, P, P_2O_5, K, K_2O and S values for FYM and clay/silt soil in the table above can be used to calculate amounts of those elements in 25, 50, 75 and 100 baskets of FYM and clay/silt soil (Table 5.10).

Table 5.10. Amounts (kg) of N, P, P_2O_5, K, K_2O and S in 1–100 baskets FYM and clay/silt soil

Baskets	kg N	kg P	kg P_2O_5	kg K	kg K_2O	kg S
FYM						
1	0.11	0.04	0.09	0.04	0.05	0.05
25	2.9	1.0	2.3	1.0	1.2	1.3
50	5.7	2.0	4.5	2.0	2.4	2.5
75	8.6	3.0	6.8	3.0	3.6	3.8
100	11.4	4.0	9.0	4.0	4.8	5.0
Clay/silt soil						
1	0.018	0.008	0.018	0.060	0.072	0.050
25	0.5	0.2	0.5	1.5	1.8	1.3
50	0.9	0.4	0.9	3.0	3.6	2.5
75	1.4	0.6	1.4	4.5	5.4	3.8
100	1.8	0.8	1.8	6.0	7.2	5.0

The mass of soil of bulk density (BD) of 1.0 to a depth of 10 cm is 400 tonnes in 1 acre and 1,000 tonnes in 1 hectare of land. For soil with BD of 1.5, the mass of soil is 600 tonnes in 1 acre and 1,500 tonnes in 1 hectare. A BD of 1.0 is typical of a clay soil and 1.5 is typical of a coarse-textured sandy soil. Those values can then be combined with soil test data for available P, K etc to calculate an approximate amount of the particular nutrient that might be available to the growing crop.

Table 5.11. Amounts of nutrient that might be available in soils of different BDs, expressed as kg or lb per ppm

	Mass nutrient, 0–10 cm			
	(kg per ppm)		(lb per ppm)	
	BD = 1.0*	BD = 1.5	BD = 1.0	BD = 1.5
1 acre	0.4	0.6	0.88	1.32
1 hectare	1	1.5	2.2	3.3

5.3.4 Contracting Peter Cornish and soil water modelling, climate and climate change analyses

Professor Peter Cornish was contracted by MyPulses in January 2016 to guide the implementation of crop benchmarking and to support water modelling and participatory action-learning, including the engagement of women (Cornish et al. 2015a, b). He designed the templates of the farmer meetings in Magway, assisted in the conduct of the meetings on two occasions (May and August 2016) and provided training to the Australian and Myanmar team members. Peter Cornish also participated in a number of meetings in Sydney to review data and plan the FPCB activities. In April 2017, he was contracted to the xProject (C2016/021) to continue his involvement. One of the defined objectives of his contract with MyPulses was to examine climate records from Magway and other parts of the CDZ to determine if patterns of rainfall were changing and, if so, what the implications of those changes might be for soil water availability and crop growth. Changing patterns of rainfall could have implications for surface soil drying, seedling establishment and access by crops of non-mobile nutrients on one hand and leaching of mobile nutrients out of the root zone on the other. Details of methodology used in the soil water and climate analyses can be found in Cornish et al. (2018) (Section 10.2.1).

5.3.5 Survey of farmers in the CDZ about changes to cropping patterns, fertiliser use, mechanisation and climate

In July 2017, a survey of 190 farmers from 33 villages across the CDZ was conducted, organised by Dr Mar Mar Win, Daw Khin Mar Mar Nwe and Daw Khin Lay Kyu from DAR with assistance from extension and management staff in DoA. The survey consisted of 20 questions, related to current cropping, 10-year changes in cropping, 10-year changes in the relative use of draft animals and mechanical implements, 10-year changes in fertiliser use and type, effectiveness and use of information about fertilisers and 40–50 year changes in climate and effects on crops.

The surveyed farmers were selected by local DAR and DoA extension staff with the expectation that the cohort of farmers would provide a reasonable spread of demographics, farm attributes and farming practices and be representative of farmers of the district. The farmers represented three classes of cropping: rainfed (n=116), irrigated (n=34) and a mixture of both (n = 34). For most questions, the farmers' responses were aggregated. Of the 190 farmers surveyed, 17 were from the Sagaing Region, 86 from the Mandalay Region, 35 from the Magway Region and 52 from the Nay Pyi Taw Union Territory on the south-eastern edge of the CDZ.

5.3.6 Training and capacity building

As was the case in the crop improvement and nutrient management themes of MyPulses, a large amount of time was devoted to on-site and off-site training, infrastructure enhancement and general capacity building.

5.4 Capacity building for RD&E and technology transfer in Myanmar

Building research capacity in the country through scientific collaboration and disciplinary training was a key project strategy and identified as a specific project objective. There continues to be a strong need for training in all aspects of legume improvement and nutrient and agronomic management due to the isolation of many of Myanmar's agricultural scientists and teachers from international co-operation during the past 3 decades. Capacity building and technology transfer was focussed on the following:

- Post-graduate training in Australia, funded through John Allwright Fellowships and Endeavour Scholarships
- Post-graduate training in Myanmar at YAU
- Formal short-term training (2 weeks to 4 months) in India (ICRISAT) and Australia
- On-site soil chemistry laboratory and rhizobial inoculants laboratory training
- Workshop training in Myanmar on crop nutrition, IPM, rhizobial inoculant production and quality assurance, soil water, legume production technologies, benchmarking etc
- Small projects funded at YAU, involving post-graduate students and academic staff
- Equipment purchase, e.g. soil coring apparatus, and laboratory enhancement
- On-farm trials, e.g. baby trials in the mother-baby trial design of the FPVS, crop benchmarking
- Field days and farmer workshops

6 Achievements against activities and outputs/milestones

Objective 1: Develop high-yielding varieties of pigeonpea, groundnut and chickpea (major crops) and green and black gram (minor crops) for the CDZ through genetic improvement to link with institutional and community-based seed production and distribution systems

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Pigeonpea varietal selection, including hybrid pigeonpea, for yield, market traits and insect (particularly Helicoverpa and *Maruca*) resistance/tolerance	Detailed planning of activities at Inception workshop, i.e. field sites, exptl design, insect screening, co-operators etc	November 2012	Achieved November 2012. Five mother and 150–180 baby trials, covering 20 townships, planned for each year. The mother trials to include 6 improved cvs plus local check. The baby trials to have 3 improved cvs and 2 checks.
		Elite lines sent from ICRISAT to DAR, Myanmar for evaluation	Dec 2015 Sept 2017	Achieved 2015 (30 lines) and 2017 (68 lines). Seed increase and evaluation of the lines completed and in progress. Super early (short-season) lines included which were evaluated in multisite trials during 2015–18.
		Seasonal trials sown, harvested, compiled and evaluated	Feb 2015 Feb 2016 Feb 2017 Feb 2018	Achieved. During 2014–18, a total of 28 mother and 268 baby trials conducted across the CDZ. Field days for farmers conducted at field sites. Demonstration and seed multiplication trials conducted across the CDZ during 2016/17 and 2017/18.
		Best lines distributed widely via DOA and NGOs	Feb 2015 Feb 2016 Feb 2017 Feb 2018	Achieved. Seeds of best lines, Nyaungoo Shwedinga, Yezin 9 and Monywa Shwedinga increased for distribution to new farmers and the DoA.
		As many as 4 new varieties released together with effective insect management package	2018/2019	To be achieved in 2019 (Nyaungoo Shwedinga , Yezin 9 and Monywa Shwedinga) with appropriate documentation and extension material.
1.2	Groundnut varietal selection for yield, market traits and disease (e.g. *Cercospora* leaf spot) resistance/tolerance	Detailed planning of activities at Inception workshop, i.e. field sites, exptl design, disease screening, co-operators etc	November 2012	Achieved November 2012 with 5–6 mother and 30–36 baby trials, covering 13 townships, planned for the monsoon and post-monsoon seasons each year. The trials include as many as 6 improved cvs plus local check.
		Elite lines sent from ICRISAT to Myanmar for evaluation	April 2016 Sept 2017	Achieved 2016 (32 lines) and 2017 (150 lines). Seed increase and evaluation of the lines completed and in progress.
		Monsoon and post-monsoon trials sown, harvested, compiled and evaluated	Feb 2015 Feb 2016 Feb 2017 Feb 2018	Achieved. During 2014–16, a total of 11 mother and 66 baby trials conducted. Field days for farmers conducted. Research (short duration, foliar disease resistance, drought tolerance) demonstration and seed multiplication trials conducted across the CDZ during 2016/17 and 2017/18.
		Best lines distributed widely via DOA and NGOs	Feb 2015 Feb 2016 Feb 2017 Feb 2018	Achieved. Seed of best lines, Sinpadetha 7, Sinpadetha 11, Sinpadetha 12 and Sinpadetha 13 increased for distribution via DoA to new farmers and villages.

		As many as 4 new varieties released together with effective disease management package	2018/19	Sinpadetha 13 released in 2015. Releases of Sinpadetha 14 (YZG 08075) uncertain because of inconsistent performance in yield trails and lack of acceptance by farmers.
1.3	Chickpea varietal selection for yield, market traits and insect (particularly *Helicoverpa armigera*) and disease (e.g. *Fusarium* wilt and *Rhizoctonia*) resistance/tolerance	Detailed planning of activities at Inception workshop, i.e. field sites, exptl design, insect and disease screening, co-operators etc	November 2012	Achieved November 2012 with 5 mother and 36 baby trials, covering 12 townships, planned for each year. Note that the trials include both Desi and Kabuli types of chickpea. The trials included 3–4 improved cvs plus local check.
		Elite lines sent from ICRISAT to Myanmar for evaluation	Dec 2015 Sept 2017	Achieved. Material sent from ICRISAT to DAR, Yezin, in Dec 2015 (60 lines) and Sept 2017 (148 lines). Seed increase and evaluation of the lines completed and in progress.
		Seasonal trials sown, harvested, compiled and evaluated	March 2015 March 2016 March 2017 March 2018	Achieved. A total of 10 mother and 72 baby trials conducted during 2014/15 and 2015/16. Totals of 36 and 46 on-station and on-farm seed increase, observation and demonstration trials conducted across the CDZ during 2016/17 and 2017/18.
		Best lines distributed widely via DOA and NGOs	March 2015 March 2016 March 2017 March 2018	Achieved. 150 baskets (4.7 tonnes) seed of Yezin 12 (ICCV 07118) distributed to farmers in 2016/17 and 250 baskets (7.5 tonnes) seed of Yezin 13 (ICCV 07308) distributed to farmers in 2017/18
		As many as 4 new varieties released together with effective insect and disease management package	2018/19	Achieved with release of Kabuli-type chickpea Yezin 11 in 2015 and Yezin 13 in 2018. Decision made not to release Desi-type chickpea ICCV 00108 as Yezin 14 (no improvement over Yezin 12) or ICCV 08106 as Yezin 15 (not acceptable to farmers even though high-yielding).
1.4	Green and black gram varietal selection for yield and market traits from material accessed from Australia	Detailed planning of activities at Inception workshop, i.e. field sites, exptl design, co-operators etc	November 2012	Achieved November 2012 with 6–8 mother and 2–4 baby trials planned for each year.
		Elite lines (20-40) accessed from Australia for evaluation	December 2014	Achieved with 22 lines sent from ICRISAT to DAR, Yezin, in 2014. Seed increase of the lines in progress.
		Seasonal trials sown, harvested, compiled and evaluated	March 2015 March 2016 March 2017	Partially achieved March 2015 and 2016 with 14 mother and 6 baby trials. The green and black gram varietal improvement no longer part of MyPulses but part of ACIAR project CIM/2014/079 ‘Establishing the International Mungbean Improvement Network’, which commenced in December 2016
		Best lines distributed widely via DOA and NGOs	March 2015 March 2016 March 2017	Partially achieved. See comment above.
		As many as 1–2 new varieties released together with effective insect and disease management package	June 2017	Not achieved. See comment above.

1.5	Development and expansion of a community-based and institutional seed production, storage and distribution system for improved legume cultivars	Detailed planning of activities at Inception workshop, i.e. field sites, design, co-operators etc	November 2012	Achieved December 2012. Initial discussion at the Inception Workshop with DoA personnel in collaboration with DAR.
		Formation of village seed bank (VSB) committees and commencement of activities	March 2014 March 2015 March 2016 March 2017 March 2018	Achieved. Coordinated by DoA in partnership with ICRISAT. There were an estimated 650 VSBs, covering >700 acres, operating in the 2017/18 seasons. The impact of the VSB program was assessed in 2017 and found to be very effective.
		Ongoing support of village seed banks for wider dissemination of seed through DOA and NGOs	June 2014 – March 2015 June 2015 – March 2016 June 2016 – March 2017 June 2017 – March 2018	Achieved, ongoing and expanding. Coordinated by DoA. Linkages established with private sector for distribution of seeds. Ongoing training by DoA for other DoA staff, NGOs and farmers in the operations of the VSBs. During the 3 years of the VSB program, 1,592 farmers from 500 villages across the CDZ have been involved. An estimated 83,000 farmers potentially received improved seed via informal farmer-farmer distribution.

PC = partner country, A = Australia

Objective 2: Improve nutrient management for the farming systems of the CDZ, particularly P, N, B, S, K and Zn, using both mineral and organic sources, including rhizobial inoculants

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Define extent of P, B, S, K and Zn deficiencies in the cropping areas of the CDZ and recommendations for farmers to address those deficiencies	Detailed planning of activities at Inception workshop, i.e. field sites, benchmarking survey design, co-operators etc	November 2012	Achieved November 2012 at Inception Workshop, DAR Yezin.
		First survey and samples collected and processed, map generated	June 2015	Partially achieved June 2015. First survey of 319 soils from farmers' fields across CDZ completed. Analyses completed. Data shows soils very low in SOC and nutrient supply, particularly P, K and K. Map not generated. Published in Proc. IFDC Soils Conf., 2017 (Section 10.2).

		On-farm omission trials sown, harvested, compiled and evaluated	March 2015 March 2016 March 2017	Achieved in 2014/15 and 2015/16. In 2014/15, 63 on-farm unreplicated +/- single element experiments conducted with few responses. In 2015/16, total of 21 replicated multi-elemental expts conducted, again with inconsistent responses to nutrient additions. Overall, <10% sites responded to single or multiple nutrient additions. In 2016/17, there was a single replicated P and S placement trial (Daw Khin Myo Thant MSc program). The inconsistent responses to fertilisers was a major challenge to resolve as soil testing had shown wide-scale soil nutrient deficiencies. In response to the recommendations of the mid-term review, crop nutrient management subsequently addressed through Farmer Participatory Crop Benchmarking (FPCB) in 2016-18. In 2016/17 there were 33 fertiliser strips in the FPCB program. In 2017/18 there were 12 unreplicated nutrient leaching trials.
		Pocket guide to nutrient deficiency and response in the CDZ	December 2015	Partially achieved. Attempt to grow nutrient-specific deficient plants failed for a second time at DAR. Third attempt at UNE successful, and images collated for presentation to DAR workers at pre-review Program meeting in December 2015. Pocket guide not published.
2.2	Enhance capacity at DAR, Yezin, for soil and plant analysis through revision of protocols and infrastructure development and expand demand for soil testing by farmers, extension & technology transfer groups	Laboratory visits and scientific exchanges to revise and develop lab manual, Lab manual written	Nov2012 – June 2013 July 2013 – June 2018	Partially achieved (November 2012 – June 2013) and ongoing (July 2013 – June 2018). ASPAC standards tested to determine precision and accuracy of lab protocols. New protocols introduced. A 60-page Lab Manual produced (e-version, but not printed), incorporating new methods. Use of reference soil and plant standards not fully implemented.
		Infrastructure purchased and installed, training developed	July 2013 – June 2018	Achieved and ongoing (July 2013 – June 2017). Pipettes and glassware purchased, and training in use undertaken at UNE in April 2014. Centrifuge purchased with delivery and training in June 2015. Soil tumbler purchased and delivered in July 2017.
		Sample throughput of laboratory increased by at least 100%	June 2018	Achieved. Soils analysed increased from about 850 in 2012 to 1800 in 2017. The increased throughput would have been much greater if total analyses for each sample calculated.
2.3	Enhance capacity at DAR, Yezin, for soil and plant nutrient RD&E	Detailed planning of activities at Inception workshop, i.e. field sites, survey design, co-operators etc	November 2012	Achieved in November 2012
		Organic resource management trials established, sown, harvested, compiled and evaluated	May 2014	Partially achieved. Original trial designed, but farmer implementation withheld as farmers did not believe that it was useful to increase manure density in furrows due to inability to manage increased weed density. With the adoption of FPCB in early 2016 came a different focus of the role of FYM in crop nutrition.

		Fertiliser trials established, sown, harvested, compiled and evaluated	March 2015 March 2016 March 2017 March 2018	Partially achieved. Inconsistent results from the 2014/15 and 2015/16 seasons (see Figs 7.5 and 7.6) resulted in implementation of FPCB methodology in 2016/17 and 2017/18 with simple fertiliser strip interventions in 33 groundnut and sesame fields in 2016/17 and the nutrient leaching experiment on 12 farms across three of the benchmarking villages in 2017/18 (Fig. 7.7).
		Manual on 'Crop nutrition and fertilisers for upland cropping in the CDZ'	June 2018	Not achieved during the life of the project. Depending on the level enthusiasm to complete this milestone by the DAR and DoA, it may still materialise.
2.4	Expand production of quality legume inoculants at DAR, Yezin, and demand by farmers for inoculants through replicated and demonstration field trials throughout the CDZ	Detailed planning of activities at Inception workshop, i.e. laboratory work, field sites, benchmarking production etc	November 2012	Achieved November 2012.
		Examine potential supplies of peat in Myanmar and assess for use as carrier for inoculants	Oct 2013 – June 2014	Achieved June 2013. Peat identified from near HeHo township and collected in tonne lots for processing and assessment as carrier
		Assess different options for producing high-titre broths of rhizobia for use in inoculants, e.g. freeze-dried cells	Jan – Dec 2014	Achieved December 2014. Different dilutions tested for efficacy in producing high-titre broths using freeze-dried inoculants and comparing Australian and Myanmar peats and chickpea and peanut rhizobia. Further testing required.
		Develop and implement a documented QA protocol for inoculants produced at DAR, Yezin	July 2014 – June 2015	Partially achieved. Establishment of plant growth facilities at the DAR laboratory completed. A plant-based infection test for counting rhizobia in peats, soil etc was initiated. This process has now been embedded through the delivery of two training courses at YAU and DAR by Greg Gemell and Elizabeth Hartley, funded through MyPulses and Crawford funds. Note that manuals also written for each of the training courses. Not achieved was a manual produced by the DAR Rhizobiology group, as per the manual produced by the Soil Chemistry laboratory. Such a manual would have represented ownership of the new protocols by the DAR group.
		Conduct need-to-inoculate experiments in the CDZ, using the established network of field sites	July 2014 – March 2015 July 2015 – March 2016 July 2016 – March 2017 July 2017 – March 2018	Achieved and ongoing. The focus was on chickpea in the Sagaing and Mandalay Regions. A total of 30 replicated field trial trials and on-farm monitoring sites were established for assessing the need for inoculation and the nature of the soil populations of chickpea rhizobia. Data indicate an overall marginal response to inoculation, despite large variations in population sizes and effectiveness of the native soil rhizobia.

		Large quantities, i.e. 50,000 packets, of efficacious inoculants produced by DAR and used by farmers	June 2018	Partially achieved June 2017 and ongoing. The DAR Rhizobium laboratory has supplied a USAID-funded project in the Shan State with about 4,000 packets of soybean inoculant annually for the past 2 years. Note from Mid-term review (MTR): Question the value of producing commercial inoculant unless there is a clear pathway to commercialisation and an exit strategy for the lab.

Objective 3: Improve the agronomic management of the farming systems of the CDZ through increased efficiency of water use and effective integration of new high-yielding legume varieties and pest, disease and nutrient management

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Benchmark existing farming systems to allow drivers, and strengths and weaknesses, of current systems to be determined	Comprehensive data on farmers rotations, yields, nutrient use, decision making, etc for up to 20 groups in cooperation with nutrient management theme and socioeconomic project	November 2012 July 2013 – June 2018	Achieved. Initial survey of farm practices, yields, rotations, nutrient use conducted in Nov 2012. Data presented at the MyPulses Inception meeting, also Nov 2012. Further data on soil nutrients and fertiliser-use surveyed in 2014. Farmer participatory crop benchmarking (FPCB) introduced as the preferred research-extension methodology in March 2016, following recommendations from the MyPulses Mid Term Review. Geographic focus is the Magway Township area, involving 94 farming families across 4 villages.
		Assessment of disease and pest prevalence and impacts on crops and field trials being monitored as part of 2.1 and 3.2	March 2016 March 2017 March 2018	Partly achieved. Assessments conducted on the benchmarked crops in the Magway Township area. Involvement of DAR pathology and entomology and YAU soil biology (pathology)
3.2	Conduct on-farm and on-station field trials across the CDZ to measure WUE of current crops and rotations, and the effect of improving crop nutrition, planting configurations and rotations. Involving farmers and DOA extension personnel to develop more productive farming systems	Intercropping and planting configuration field trials established and evaluated and done as part of the farmer crop benchmarking	March 2016 March 2017	Achieved. A total of 22 experiments examining water use and crop management conducted. Treatments included fertilisers, residues, tillage, mechanisation particularly for planting, agronomy (time of planting, row spacing etc) and wind breaks In March 2016, focus shifted from small plot trials on research farms to the benchmarked farmer crops (see below).
		Determine effect of improved crop nutrition on WUE and productivity of the farming system by monitoring of nutrition trials (2.1)	March 2015 March 2016 March 2017 March 2018	Achieved. From Nov 2012 to March 2016, replicated nutrition x residue expts, and monitoring of selected nutrient demonstrations in 2014/15 and 2015/16. From March 2016, FPCB initiated involving 94 farming families across 4 villages in the Magway Township area. Comprehensive crop and soil data from the 2016/17 and 2017/18 seasons combined with long-term rainfall and evaporation data to determine potential WUE and water-limited yield and changing pattern of rainfall and water stress on crops.

		Integrated R&D design for rhizobial inoculants, NUE and WUE research across Divisions/sections at DAR Yezin	June 2014 – March 2015 June 2015 – March 2016 June 2016 – March 2017	Not achieved. Note from MTR for 3.2: The work in 3.2 would benefit from being scaled back to allow more careful observation of soil and plant water at a smaller number of sites – perhaps more farmer fields but not replicated experiments.
3.3	Conduct on-farm and on-station trials to evaluate systems changes to increase rainfall capture and reduce evaporation and erosion	Establish trials to evaluate practicality and impact of late monsoon/dry season cover crops.	June 2014 – March 2015 June 2015 – March 2016	Achieved (March 2015 and 2016). Note from MTR: Some results, but this is not going to be resolved. Consider abandon beyond 2016.
		Evaluate existing DAR windbreak trials. In conjunction with DOA, DAR and farmer groups, determine design of future windbreak trials	March 2015	Achieved March 2015. Note from MTR: Some results, but this is not going to be resolved. Consider abandon beyond 2016
		Establish trials and demonstrations to evaluate the use of reduced tillage techniques in existing and improved farming systems to reduce erosion and improve rainfall capture	June 2015 – March 2016 June 2016 – March 2017 June 2017 – March 2018	Achieved (March 2015 and 2016). Zero till demonstrations established at Magway and Tatkone in 2013 and 2014; PhD trial established in Magway 2014. Note from MTR: This work far too ambitious. Consider if work can be scaled back to the PhD project. This is important work that merits its own project. Benefits of mulching were noted. Further note: A recent survey of farmers in the CDZ established that many have started to use herbicides for weed control because of labour shortage. Development of reduced/zero tillage expertise in the CDZ is important to underpin the changes in farming practices that are happening.
3.4	Development and extension of improved farming systems through incorporation of outcomes from varietal selection, pest and disease, and nutrient management activities	Improved farming system developed through integration of R&D outcomes of project themes and discussions with all participants	June 2018	Partially achieved, particularly related to nutrient management. Comprehensive manuals on (i) crop nutrition and fertilisers and (ii) effective water management and crop water use were signalled for completion by June 2018. The manuals were not delivered. However, modifications to the Magway-CDZ farming systems suggested from the FPCB activities, published as two papers in the Ag Systems journal (Cornish et al. 2018; Herridge et al. 2019).
		Development and implementation of extension activities with DAR, DoA, NGO and farmer participants	June 2018	Achieved through the FPCB. DoA extension staff and DoA and DAR research staff directly involved in the FPCB activities at Magway, including field walks, field days, farmer workshops etc. A total of 36 FPCB farmer group meetings and 5 DAR/DoA training meetings held.

Objective 4: Enhance capacity for RD&E in the relevant agencies in Myanmar through effective implementation of the collaborative ACIAR project model and through targeted training, extension and capacity building programs

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Post-graduate graduate and short-term training of selected DAR and DOA staff, linked, where possible, to YAU	Up to 30 persons from DAR, DOA and YAU trained in either post-graduate or short-term courses resulting in enhanced institutional RD&E capacity	July 2013 – June 2018	Achieved and ongoing. A total of 20 persons from DAR and DoA received short-term training at ICRISAT in legume breeding and seed-production technologies between Dec 2013 and February 2018 Two persons received short-term training in soil chemistry at UNE in 2013 and 2017. Two PhDs, Aung Kyaw Thu (2016) and Hla Myo Thwe (2016), and one MSc, Khin Myo Thant (2018) awarded. Three PhDs, Daw Kyin Kyin Htwe, U Myint Zaw and Daw Khin Lay Kyu continue at Australian universities. Daw Thuzar Win to commence MSc program at UNE in October 2018. Dr Maw Maw Than and Daw Nilar received short-term training in Rhizobiology at Adelaide University in 2017. Dr Mar Mar Win participated in the Int Food Legumes conference, Morocco, in May 2018 In addition, >40 workshops (incl. on-site training) on Rhizobiology, IPM, crop nutrition, soil water, plant and soil nutrient analysis, participatory crop benchmarking and village seed bank technologies conducted during 2012–2018.
4.2	Purchase of key experimental and training resources using project funds	Infrastructure development at DAR and YAU as project requirement	July 2013 – June 2018	Achieved and ongoing. Purchase and delivery of soil chemistry laboratory materials and equipment (centrifuge, soil tumbler and auto pipettes etc) and equipment for deep soil coring and measuring soil water. Rhizobium laboratory infrastructure improved through laboratory refurbishment, including growth room facilities and additional laboratory space. Two laptops purchased for the group.
4.3	Linkages with established government (DoA) and NGO (e.g. LIFT) technology transfer programs	Strengthened networks for agricultural RD&E in Myanmar, amongst the government institutions (DAR, DoA and YAU) and between these and the NGOs.	July 2013 – June 2018	Partially achieved and ongoing. Involved in discussions between DAR, DoA, ICRISAT and LIFT regarding funding for seed propagation and distribution networks for legumes and between DAR and Syngenta Foundation, then Awba Group, regarding improved variety seed production and distribution.

7 Key results and discussion

Key results and discussion are presented for each of the four themes of SMCN-2011-047 as follows:

7.1 Development of high-yielding varieties of pigeonpea, groundnut and chickpea (major crops) and green and black gram (minor crops) linked to seed production and distribution

The overall objective of the varietal improvement theme of MyPulses was to identify superior genotypes that were acceptable to farmers, release them as varieties and provide access to them for as many farmers as possible. Activities involved:

- acquisition of new germplasm with particular traits from ICRISAT
- seed increase and preliminary genotype screening of that germplasm by DAR
- hybridisation of selected genotypes and evaluation of segregating material
- multi-site farmer participatory varietal selection (FPVS) of a small number of potentially commercial varieties across the CDZ
- seed production and dissemination of farmer-preferred improved varieties via the village seed bank (VSB) system
- varietal release involving ratification by the Technical Seed Committee (TSC), then by the National Seed Committee (NSC) followed by registration and release.

The FPVS approach was first used in Myanmar in the previous ACIAR-funded pulse project, SMCN/2006/013, and provided the opportunity for farmers and researchers to work together in selecting varieties to suit farmer requirements and preferences. Both farmers and researchers liked the FPVS approach where all stakeholders were involved as partners from the beginning. Periodic interactions between experts and farming communities also provided a viable platform for two-way learning.

The VSB system was also introduced to Myanmar in SMCN/2006/013. Farmers commenced seed production in 2009 at three villages with two groundnut, two pigeonpea and two chickpea cultivars/genotypes covering 14 ha. Most of the seed produced in the VSBs was distributed to farmers in the same township and excess was distributed to neighbouring villages.

7.1.1 Acquisition of new germplasm from ICRISAT

Pigeonpea, groundnut and chickpea are mandate crops of ICRISAT and it was the collaborating breeding programs at ICRISAT that provided new, high-yielding biotic- and abiotic-stress tolerant germplasm to the DAR as well as the technical expertise and backup. During 2007–11 in previous project SMCN/2006/013, ICRISAT supplied 348 advanced breeding lines, comprising 235 groundnut, 50 chickpea, and 63 pigeonpea genotypes to DAR. Adding to that were the 510 genotypes sent to DAR from ICRISAT during 2014–17 (Table 7.1).

Table 7.1. Germplasm sent from the ICRISAT breeding programs to DAR during 2014–17 as part of MyPulses

Crop	Received at DAR	Number genotypes	Traits
Pigeonpea	Dec ‘15	30	High yield, super-early duration (110–120 days)
	Sept ‘17	68	High yield, mid (150–160 days)- and medium (170–180 days) duration, fusarium wilt and sterility mosaic disease resistance
Groundnut	April ‘16	32	Various

	Sept '17	150	Short and medium duration, high oleic acid, high oil content, collar rot resistance, foliar disease resistance, drought and heat tolerance, aflatoxin resistance, confectionary types, fresh seed dormancy, high Fe and Zn lines
Chickpea	Dec '15	60	High yield
	Sept '17	148	High yield, heat tolerant, drought tolerant, machine-harvestable
Green gram	*	*	*
Black gram	June '14	22	High yield.

7.1.2 Farmer participatory varietal selection (FPVS) and breeding and selection for discrete traits

Pigeonpea

Across the 4 years of assessment in the 296 FPVS mother-baby trials, Nyaungoo Shwedinga and Yezin 9 produced slightly lower yields (5–7%) than standard check, Monywa Shwedinga (Table 7.2). All three improved cultivars outyielded the local check cultivar. Farmers from Sagaing region prefer Monywa Shwedinga because they consider it best suited to their region. In Magway Region, farmers prefer Yezin 9 because of its excellent pod setting and high branching pattern. Yezin 9 was derived from a cross between local variety Kaingkar and ICPB 2043 (from ICRISAT). It has good seed quality and suitable seed size. Nyaungoo Shwedinga was selected from Thahtaykan (local variety) and increased at the DAR Nyaung Oo research farm.

Foundation seed of Yezin 9 (3.5 tonnes) and Monywa Shwedinga (7.9 tonnes) was generated in the DAR research farms during 2014–18 and distributed to DoA farms for further seed increase as well as directly provided to farmers for DoA/DAR demonstration trials. Certified seed of Nyaungoo Shwedinga was disseminated to farmers directly from the DAR Nyaung Oo research farm through collaboration with JICA.

Table 7.2. Summary of pigeonpea grain yield data (kg/ha and % of check cv) from the 296 mother and baby trials across three Divisions of the CDZ during 2014–18.

	2014/15	2015/16	2016/17	2017/18
Long-season genotypes (170–180 days)				
Yezin 9	1199 (101)	1041 (91)	1563 (96)	1121 (93)
Nyaungoo Shwedinga	1238 (105)	1014 (89)	1491 (92)	1148 (95)
Monywa Shwedinga	1182 (100)	1141 (100)	1620 (100)	1211 (100)
Local check	1127 (95)	949 (83)	*	*
Mid-season genotypes (150–160 days)				
Yezin 10	732 (85)	1090 (94)	958 (105)	1160 (108)
ICPL 98015	1133 (113)	1510 (130)	1034 (113)	1186 (111)
ICPL 98010	690 (80)	1445 (124)	982 (107)	1636 (153)
Yezin 3 (check)	858 (100)	1162 (100)	916 (100)	1070 (100)

Farmers generally prefer long-season, i.e. 170–180 days to maturity, cultivars of pigeonpea to intercrop with sesame, groundnut and other short-duration legumes. For various reasons farmers are also looking to grow pigeonpea as a sole crop, particularly in the Sagaing region and around Pakokku in the north of the Magway Region. In response, promising mid-season, i.e. 150–160 day, genotypes of pigeonpea were assessed in mother-baby trials at 45 sites during 2014–18. ICRISAT mid-season variety, Yezin 3 (ICPL 87) was used as standard check. Results indicated ICPL 98015 (indeterminate type) outyielded Yezin 3 by an average of 17% across all sites and years. Farmers preferred ICPL 98015 to the other cultivars in the trials because of its branching pattern, high pod setting and high yields. Cultivar ICPL 98010 also yielded well overall (16% above Yezin 3). Cultivar ICPL 98015 could be released as a new variety in 2019. In the meantime, more evaluation is needed to determine the true potential of mid-season pigeonpea.

Additionally, 8 super-early pigeonpea germplasm lines were introduced from ICRISAT in 2015 and evaluated in preliminary observations trials at Yezin and 5 DAR research farms during 2015–18 seasons. Super early pigeonpea lines flower around 53–60 days after sowing and mature at 110–120 days. Data from the trials indicated above-average yields for ICPL 20325 and ICPL 11242 (Fig. 7.1), but they also needed effective control of insect pests. The super-early lines appear to have potential as a post-monsoon crop, i.e. to be planted in August following the first monsoon crop in the double crop system common in the CDZ.

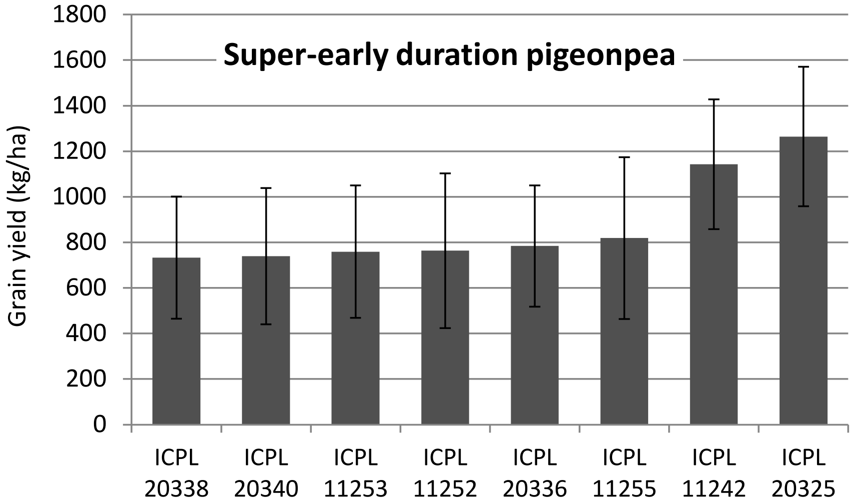


Figure 7.1. Grain yields (±SD) of a cohort of super-early genotypes of pigeonpea, sent from ICRISAT in 2015 and evaluated during the 2015/16, 016/17 and 2017/18 seasons. Values are the means of 6 observations from 4 sites.

Pigeonpea field days were organized at 10 project sites in concert with DoA and DAR staff and local farmers. Altogether, 600 farmers participated in the field days across the three Regions during the 2014–18 growing seasons.

The following observations were made in a visit by the ICRISAT project team to Myanmar in December 2016. The observations are relevant to MyPulses achievements and to ongoing and future directions of pigeonpea improvement in Myanmar.

Pigeonpea, because it is readily cross pollinated and photo- and thermo-sensitive, is highly complicated in behaviour, highly influenced by its growing environment and a challenge for breeders. The principles of both self and cross pollination can be successfully applied to pigeonpea crop improvement. Breeders and researchers working with pigeonpea need to have a particularly good understanding of the principles of crop breeding and physiology.

Additional training is required in crop improvement methodologies, in particular selection of parents, hybridisation techniques and handling of segregating generations. Further aspects of hybrid breeding, such as selection of parental lines, development of male sterile and maintainer and restorer lines and hybrid combinations for different agro-ecologies of the country, needs to be strengthened.

There is a need for the continued supply of elite lines of varieties and hybrid parents and different segregating populations for super-early, mid- and long-season maturity groups to combat climate change and to develop high yielding varieties and hybrids for different ecologies of Myanmar.

Systematic studies are required into fusarium wilt and sterility mosaic diseases of pigeonpea, including developing a wilt-sick plot area for screening germplasm. DAR researchers need training on disease screening methodologies and in developing sick plots.

Seed production has been strengthened in Myanmar through development of seed systems and proper seed road maps. Additional training is required on maintenance breeding and reconstitution of popular existing cultivars, e.g. Monywa Shwedinga, ICPL 87, ICPL 87119. At the same time, additional training is required for DoA officials on seed production principles for the supply of quality seeds to Myanmar's farmers.

Extension packages with information on best practices for pigeonpea production need to be developed and promoted to farmers. The packages to include:

- Optimum dates of sowings, row ratios (Intercropping), spacing's, plant populations for sole- and inter-cropping
- Integrated pest management (IPM) and use of insecticides by pigeonpea farmers needs to be encouraged through effective extension, as is the case with vegetable production.

Groundnut

Sinpadetha 11 was the highest yielding of the tested cultivars with an average yield of 1.6 t/ha, which was 35% higher than the check cultivar (Table 7.3). Next were Sinpadetha 7 (20% higher than the check), Sinpadetha 12 (18% higher) and Sinpadetha 13 (14% higher). Sinpadetha 10 and YZG 08075 were the lowest yielding of the tested genotypes. YZG 08075 at one stage was earmarked for release as Sinpadetha 14, but its poor performance in the 2014/15 trials and lack of acceptance by the farmers has effectively put a halt on that.

Sinpadetha 11 was not only the highest yielding genotype but the most preferred by the farmers, followed by Sinpadetha 13 and Sinpadetha 7. As a result, 23 tonnes pure seed of Sinpadetha 11 was produced during 2015–18 for distribution to 190 farmers directly and via the VSB system. In addition, 8.3 tonnes pure seed of Sinpadetha 7, 12 and 13 was generated and distributed to 120 farmers.

Groundnut field days were organized at 8 project sites in concert with DoA and DAR staff and local farmers. Altogether, 550 farmers participated in the field days during 2014–17.

Table 7.3. Summary of groundnut grain yield data (% of check cv) from 51 of the 66 mother and baby Trials across three Divisions of the CDZ during 2014–16

	------------ 2014/15 ------------			----- 2015/16 -----		**Average**
	Baby (M)	Baby (PM)	Mother	Baby (M)	Mother	**(%)**
Sinpadetha 7	128	129	112	*	110	**120**
Sinpadetha 10	71	*	84	*	*	**78**
Sinpadetha 11	153	141	111	139	131	**135**
Sinpadetha 12	109	161	97	*	106	**118**
Sinpadetha 13	118	121	100	118	112	**114**
YZG 08075	*	89	*	*	*	**89**
Check (kg/ha)	**1177**	**1190**	**1080**	**1352**	**1173**	**1194**

Genotypes received from ICRISAT in 2016 were assessed in a number of replicated experiments during 2017/18. Data from the early maturity (95 day) experiment indicated a substantial range of yields (818–1353 kg/ha) with the best-performing cultivar, YZG 16018 out-yielding Sinpadetha 11 by 60% (data not shown).

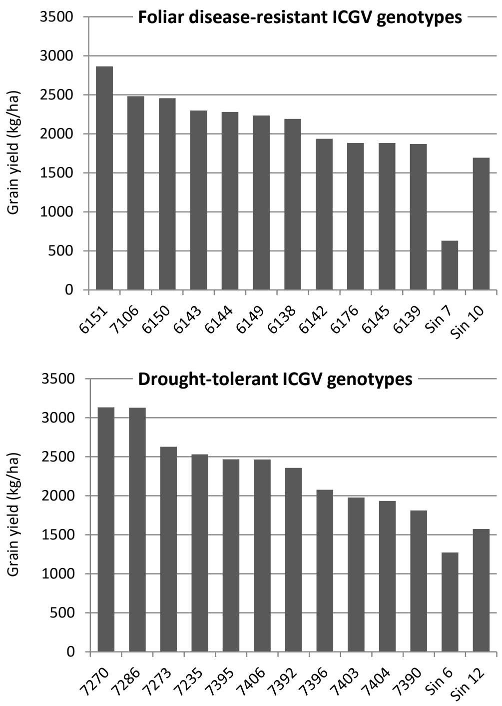


Figure 7.2. Initial yield-assessment of disease-resistant and drought-tolerant groundnut genotypes received from ICRISAT in 2016. Experiments were conducted during 2017/18.

Two other experiments assessed genotypes selected for foliar disease-resistance and drought tolerance (Fig. 7.2). Data from those experiments indicated good yield potential, specifically ICGV 06151, ICGV 07106, ICGV 06150 in the disease resistant cohort and ICGV 07270, ICGV 07286, ICGV 07273, ICGV 07235 in the drought-tolerant cohort.

The following observations were made in a visit by the ICRISAT project team to Myanmar in December 2016. The observations are relevant to MyPulses achievements and to ongoing and future directions of groundnut improvement in Myanmar.

New groundnut varieties, suitable to different production ecologies in Myanmar, should continue to be achieved through:

- Ongoing provision by ICRISAT of trait-specific advanced breeding material and segregating populations. Traits include high oil content, early maturity, drought tolerance, foliar fungal disease resistance, large seed size and high shelling. Fresh seed dormancy is identified as key trait in the wake of climate change scenarios. For Magway Division, Virginia or Spanish types maturing in 110–120 days, with high pod yield, large seed size and foliar fungal disease resistance are desirable.
- Enhancing the capacities of human resources at DAR to maintain the groundnut breeding program after the retirement of the leader, Daw Khin Mar Mar Nwe.

There is enormous scope for promoting informal seed systems, i.e. community-based (VSB) and farmer-to-farmer, in Myanmar to enhance adoption of new varieties. Currently only 5–10% of total groundnut area is planted to new, high-yielding varieties and improved productivity and profitability of groundnut cultivation will, to a large extent, depend on farmers adopting new varieties. Farmers save own seed for the next season of planting and this will enable fast dissemination of new varieties. Enhancing groundnut productivity in the country has direct implications for nutritional outcomes as groundnut is used extensively and is a preferred food in daily diets.

There is scope also to introduce and promote mechanisation for groundnut operations. Dry plant threshers that can be used on a custom-hiring basis to separate pods from the plants should prove particularly useful. At the same time, enhancing knowledge and capacities around post-harvest handling of groundnut is needed.

Chickpea

The best yielding Kabuli cultivars were ICCV 07308 and Yezin 11, with 7–9% increased yields compared with the check, Yezin 3 (Table 7.4). Cultivar ICCV 03306 also out-yielded Yezin 3 by 8% but was evaluated in the 2015/16 season only. With the Desi chickpea, ICCV 08106 and ICCV 07118 were the best-performing cultivars, out-yielding the check, Yezin 4 by 19–38%.

Farmers expressed their preference for early maturing chickpea varieties with high yield, large seed size for export quality, and resistance to root rot diseases. Most of the farmers in the Sagaing Region preferred Kabuli ICCV 07308 (Yezin 13, released 2018) and Desi ICCV 07118 (Yezin 12, released 2016) (Table 7.5). In the Magway Region, farmers preferred Yezin 12 because of high yield and short duration. Mandalay farmers preferred Yezin 13 and ICCV 07118 for their early maturity and tolerance to root disease. Yezin 11, released in 2015, was also popular with farmers in the Sagaing and Magway Regions.

The decision was made not to release ICCV 00108 as Yezin 14 because it lacked any improvement over Yezin 12. Although Desi type ICCV 08106 was very high-yielding (38% improvement over the check cultivar Yezin 4), farmers did not like it because of its long duration and dark red seed coat.

Table 7.4. Summary of chickpea grain yield data from the 82 mother and baby Trials across three Divisions of the CDZ during 2014/15 and 2015/16. Values are % of the check cultivars, Yezin 3 (Kabuli) and Yezin 4 (Desi)

Chickpea type	Cultivar	2014/15	2015/16	Average
Kabuli	ICCV 07308 (Yezin 13)	102	112	107
	PCHL 04–34	103	106	105
	ICCV 01309 (Yezin 11)	110	108	109
	ICCV 03306	*	108	108
	Yezin 3 – check (kg/ha)	**1251**	**1517**	**1384**
Desi	ICCV 00108	118	106	112
	ICCV 08106	126	149	138
	ICCV 07118 (Yezin 12)	118	119	119
	CA 02–54	*	108	108
	Yezin 4 – check (kg/ha)	**1250**	**1343**	**1297**

Table 7.5. Cultivars preferred by the farmers in the FPVS during 2014/15 and 2015/16 across 13 Township areas of the CDZ

Chickpea type	Region	Farmers' preferred cultivars	Remarks
Kabuli	Sagaing	Yezin 11	High yield; uniform seed size
	"	Yezin 13	High yield; large (bold) seed size
	Mandalay	Yezin 13	Short duration; drought tolerance
	Magway	Yezin 11	High yield
	"	Yezin 13	High yield; short duration
Desi	Sagaing	ICCV 00108	High yield; short duration
	"	Yezin 12	High yield; short duration
	Mandalay	ICCV 00108	High yield; short duration
	"	Yezin 12	Bold seed size; short duration
	Magway	ICCV 00108	High yield; disease resistance
	"	Yezin 12	High yield; short duration

Seed increase of Yezin 12 was conducted in the Sagaing and Magway Regions during 2016/17 and of Yezin 13 in the Sagaing Region in 2017/18 for distribution to farmers via the VSB system. A total of 4.7 tonnes pure seed of Yezin 12 and 7.8 tonnes of Yezin 13 were distributed.

Data from the 2013/14 and 2014/15 mother-baby trails were aggregated to assess effects of planting date and plant population on grain yield (Fig. 7.3). The total number of trials from which data were used was 86 with 820 observations. The optimum planting date was November through to mid-December. There was no trend between plant population and grain yield, although yields more stable at higher plant populations, i.e. 30–40 plants/m^2. We concluded from these data that farmers should use planting rates of about 1 basket/acre for Desi chickpea and 1.5 baskets/acre for Kabuli chickpea, targeting plant populations of 30 plants/m^2.

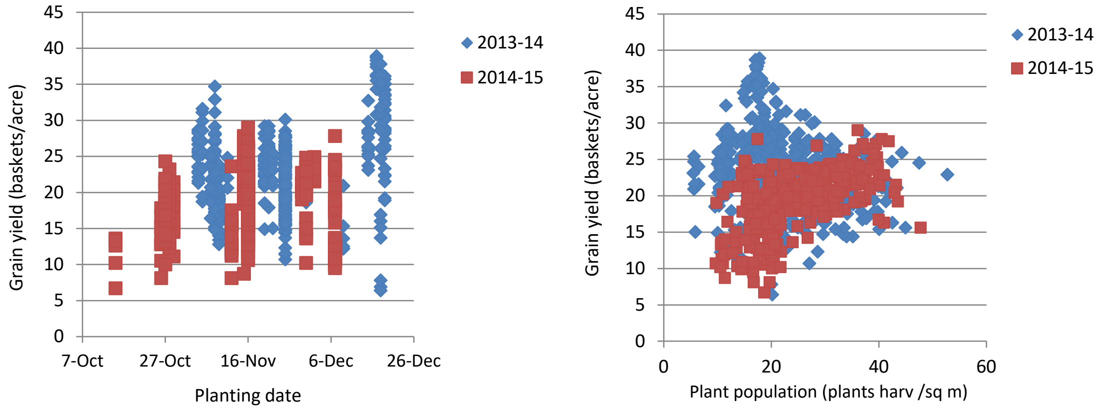


Figure 7.3. Effects of planting date and plant population on grain yield of chickpea. Data from the mother-baby trials in 2013/14 and 2014/15 (n = 820)

Research during 2016/17 included the hybridisation of WR 315 Fusarium wilt resistant germplasm with established high-yielding varieties, including Yezin 3, Yezin 7, Yezin 8, Yezin 11 and Yezin 12 and Yezin 13. Drought tolerant lines were evaluated in multi-site experiments during 2016/17 with Yezin 6 as the check variety. Results indicated similar yields of the genotypes when averaged across the 6 sites, i.e. 97–106% of the yield of Yezin 6 (Table 7.6). Also during 2016/16, 60 genotypes received from ICRISAT in the previous year were seed increased and assessed for yield in observation nurseries at four DAR research farms.

During 2017/18, the 60 genotypes received from ICRISAT in 2015 were more fully assessed for yield at seven DAR research stations. Preliminary observations were made on the 148 lines received from ICRISAT in September 2017 at Zaloke field station (36 machine harvestable lines), Myingyan field station (20 heat-tolerant lines), Myitthar field station (18 high-yielding Kabuli lines), Sebin field station (18 high-yielding Desi lines), Kyaukse field station (18 high-yielding Kabuli lines), Tatkone field station (18 high-yielding Desi lines) and Pangone field station (18 high-yielding Kabuli lines).

Chickpea field days were organised at 18 project sites in concert with DoA and DAR staff and local farmers. Altogether, 1,110 farmers participated in the field days across the three Regions during the 2014–18 chickpea growing season.

The following observations were made in a visit by the ICRISAT project team to Myanmar in December 2016. The observations are relevant to MyPulses achievements and to ongoing and future directions of chickpea improvement in Myanmar.

Chickpea has emerged as an important export crop for Myanmar. There is a need to develop extra-large kabuli varieties for global premium markets and machine-harvestable varieties as part of the mechanisation of chickpea production.

Table 7.6. Evaluation of drought-tolerant germplasm from ICRISAT at six DAR research stations during 2016/17. Values are grain yields (kg/ha)

Chickpea type	Tatkone	Myingyan	Sebin	Zaloke	Myitthar	Kyaukse	Average
				kg/ha			
CA-10-5	2467	1253	2846	1129	2320	2343	**2057**
CA-10-6	2545	1423	2831	1748	2088	2297	**2158**
CA-10-12	2475	1400	3403	1841	1800	1114	**2003**
CA10-21	2939	1253	2815	2057	1702	1825	**2096**
Yezin 6	**2405**	**1315**	**3156**	**1600**	**2552**	**1369**	**2065**

The DAR has limited capacity in chickpea breeding but has been continuously improving under the direction of chickpea breeder Dr Mar Mar Win. The number of crosses made each year and the number of segregating populations and progenies grown for assessment are increasing. ICRISAT has been working closely with the DAR by supplying germplasm and improved breeding lines and providing training in chickpea breeding. This should continue.

The program has a good track record in the release of new, high-yielding varieties which are readily adopted by farmers. Six varieties were released during the period 2009–18 (Yezin 8 to Yezin 13) and an estimated 96% of the chickpea area is planted to improved varieties.

Mandalay and Sagaing Divisions have a short crop season for chickpea. Extra-early (85-90 days) Kabuli chickpea Yezin 3 covers about 75% of the chickpea area in Mandalay Division and 40% of the area in the Sagaing Division. Yezin 4 is the most popular variety in the Magway Division covering over 55% of the chickpea area. The heat-tolerant variety Yezin 6 covers 33% of the area in the Sagaing Division and 13% of the area in the Magway Division.

The major abiotic stresses to chickpea production in CDZ include terminal drought and reproductive stage heat stresses. Among biotic stresses, *Helicoverpa armigera* is the most devastating insect-pest, while *Fusarium* wilt and dry root rot are the major diseases. These are now the current priorities and for the immediate future.

Myanmar researchers remain unconnected to the global chickpea research community. Capacity building of researchers, particularly in modern breeding approaches, continues to be the number one priority for chickpea improvement in Myanmar.

7.1.3 Green gram

Results indicated Yezin 14 producing the highest yields, with an average increase over the check cultivar of 8%. The other tested cultivars were marginally better than the check (1–5% increase) (Table 7.7).

Table 7.7. Summary of green gram yield data from the mother and baby Trials in the CDZ during 2014/15 and 2015/16. Values are % of the local check cultivar

Cultivar	2014/15	2015/16	Average
YM 03-2-5	108	103	**105**
YM 03-4-21	97	106	**101**
Yezin 11	90	111	**101**
Yezin 14	95	122	**108**
Local (kg/ha)	**968**	**640**	**800**

Green gram and black gram were part of MyPulses during its first two years only, i.e. 2013–15, until a new project focussed entirely on mungbean – CIM/2014/079 ‘Establishing the International Mungbean Improvement Network’ – commenced in 2016. That project involved the DAR mungbean breeding group with collaborators from the World Vegetable Centre, the Queensland DPI and scientist in Bangladesh and India. It should be noted that the World Vegetable Centre’s involvement in CIM/2014/079 was from its node at ICRISAT.

7.1.4 Village seed bank (VSB) program

During the three years of the VSB program, a total of 1,080 pigeonpea farmers, 390 chickpea farmers and 122 groundnut farmers (grand total of 1,592 farmers) from about 500 different villages associated with 104 townships across the CDZ obtained good quality seeds of Monywa Shwedinga pigeonpea, Yezin 4, 6 and 12 chickpea and Sinpadetha 11 groundnut directly from the DoA (Fig. 7.4). The amount of seed distributed by the DoA was 5.1 tonnes in 2015/16, 18.6 tonnes in 2016/17 and 26.0 tonnes in 2017/18, for a total of 50 tonnes during the three years. Areas planted by the VSB farmers were 200 ha (2015/16), 510 ha (2016/17) and 705 ha (2017/18) for a grand total of 1,410 ha (2015–18).

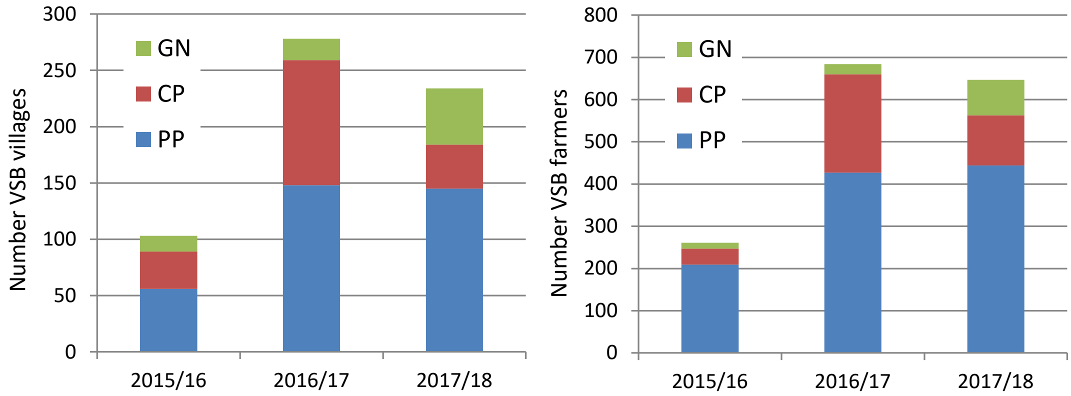


Figure 7.4. Expansion of the VSB program involving new, high-yielding cultivars of pigeonpea, chickpea and groundnut in the CDZ during 2015–18 Note that the total number of villages (615) includes villages that were provided with seed in more than year.

The data describing the expansion of VSB scheme were carefully recorded by staff in the DoA Township offices. What weren’t recorded by the DoA were the benefits and problems of the scheme from the point of view of the participating farmers and the fate of the seed that they produced. Therefore, in 2017 a study was conducted to quantify the formal and informal distribution of the new, improved VSB cultivars in the target areas and to examine the extent to which the VSB program was successful in facilitating spread and adoption of the improved legume cultivars as well as the productivity and economic benefits of those cultivars. Because it would have been impossible to get feedback about the program from all 1,592 VSB farmers, a cohort of 182 VSB farmers from 41 villages were selected at random for the survey.

On average, the surveyed VSB farmers used about 50% of their land for legume cultivation. Their access to information, adequate seed storage facilities and inputs was generally poor due to distance from DoA and DAR support and from seed dealers and markets. The most common method of on-farm seed storage was bag or basket, but the absence of good quality on-farm storage facilities was generally problematic. Pest infestation and moisture losses were common issues as was damage by rats and declining seed viability.

The average production figures for the surveyed VSB farmers was 1.28 tonnes chickpea seed per farmer, 0.71 tonnes pigeonpea seed per farmer and 0.57 tonnes groundnut seed in pod per farmer. From these figures, we calculate total seed production from the VSB scheme increased from 205 tonnes in 2015/16 to 614 tonnes in 2016/17 and 515 tonnes in 2017/18 for a grand total of 1,334 tonnes for 2015–18 (Table 7.8). That final figure was made up of 766 tonnes pigeonpea, 500 tonnes chickpea and 70 tonnes groundnut.

Table 7.8. Outputs (tonnes seed) of the VSB scheme during 2015–18

Legume	2015/16		2016/17		2017/18		Total (2015–18)	
	No. farmers	Prodn (tonnes)	No. farmers	Prodn (tonnes)	No. farmers	Prodn (tonnes)	No. farmers	Prodn (tonnes)
Pigeonpea	209	148	427	303	444	315	1080	**766**
Chickpea	38	49	233	298	119	152	390	**498**
Groundnut	14	8	24	14	84	48	122	**70**
Total	261	**205**	684	**614**	647	**515**	1,592	**1,334**

Only a fraction (3–16%) of the seed produced in the VSBs was returned to the DoA for them to direct to new VSB farmers in the same village/township or, more often, in new villages/townships (Table 7.9). What was not sent back to the DoA was either consumed (0–2%), kept as seed for own use (2–24%), procured by private seed companies (0–14%), sold to fellow farmers in the same village or distant villages through informal networks (6–34%), or sold as grain (24–76%).

Table 7.9. Fate of improved-cultivar seed produced by the surveyed VSB farmers during 2017-18

VSB farmer type	Average output per farmer	Consumed*	Kept as seed	Given back to DoA	Sold as seed to other farmers	Sold to private companies	Other uses, including sold as grain
				Kg seed			
Pigeonpea	710	0 (0%)	16 (2%)	20 (3%)	42 (6%)	100 (14%)	537 (76%)
Chickpea	1,280	16 (1%)	100 (8%)	140 (11%)	350 (27%)	6 (0%)	665 (52%)
Groundnut	570	11 (2%)	137 (24%)	90 (16%)	194 (34%)	2 (0%)	137 (24%)

** includes payment of in-kind wages*

Further analysis of the informal farmer-to-farmer networks revealed that, on average, seed was sold by the VSB farmers to 8 (pigeonpea), 10 (chickpea) or 3 (groundnut) other farmers (Table 7.10). Assuming there was no further spread of the improved VSB cultivars, an estimated 8,640 pigeonpea farmers, 3,900 chickpea farmers and 366 groundnut farmers (total 12, 910 farmers) purchased the VSB-produced seed (Table 7.11).

If, however, the farmers purchasing the VSB-produced seed then onsold some of the seed that they produced to other farmers, then potential recipients of the improved cultivar seed would have been much greater. Assuming the seed-producing farmers sell to 4 (pigeonpea), 5 (chickpea) and 2 (groundnut) other farmers, the potential informal (farmer-to-farmer) distribution of the improved cultivars during 2016–19 via the VSB program would involve about 83,500 farmers (Table 7.11). Note that this number does not include the 1,592 farmers who originally received the seed from the DoA.

Reported benefits of the VSB program for the surveyed farmers ranged from the access to better quality seed and improved crop and seed production knowledge to increased productivity and profitability. Grain yields of improved VSB cultivars were 34% and 43% higher for sole and intercropped pigeonpea, 55% higher for groundnut and 52% higher for chickpea. The yield benefits translated into reduced unit (basket) costs and improved net margins of A$212/ha and A$207/ha for sole and intercropped pigeonpea, A$440/ha for groundnut and A$650/ha for chickpea.

Table 7.10. Magnitude of farmer-to-farmer seed distribution of improved cultivar seed for the surveyed VSB farmers

VSB farmer type	Average no. farmers receiving seed from each VSB farmer	Breakdown of the no. farmers receiving seed from the VSB farmers and % of VSB famers in each category
Pigeonpea (n = 135)	8	None : 8% 1–5 : 38% 6–10 : 43% > 10 : 11%
Chickpea (n=23)	10	None : 4% 1–5 : 30% 6–10 : 48% > 10 :18%
Groundnut (n=24)	3	None : 8% 1–5 : 92% 6–10 : 0% > 10 : 0%

Table 7.11. Potential impact of farmer-to-farmer informal seed distribution in the VSB scheme in Myanmar's CDZ

VSB farmer type	Year seed obtained by VSB farmers	No. of VSB farmers	No. farmers receiving improved seed informally			
			2016-17	2017-18	2018-19	Grand total
Pigeonpea	2015-16	209	**1,672**	6,688	26,752	
	2016-17	427	-	**3,416**	13,664	**55,744**
	2017-18	444	-	-	**3,552**	**(8,640)**
Chickpea	2015-16	38	**380**	1,900	9,500	
	2016-17	233	-	**2,330**	11,650	**26,950**
	2017-18	119	-	-	**1,190**	**(3,900)**
Groundnut	2015-16	14	**42**	84	168	
	2016-17	24	-	**72**	144	**762**
	2017-18	84	-	-	**252**	**(366)**
Grand total		**1,592**	**2,094**	**14,490**	**66,872**	**83,456 (12,906)**

Feedback from the surveyed farmers also indicated a need for strengthening of infrastructure for seed storage at DoA township offices and for cost-effective on-farm storage methods to be demonstrated and scaled-up over time (as stated previously). As with most of the other issues raised by the farmers, there was consensus across the three legumes that farmers involved in the VSB program need to be well trained in seed production and seed systems generally. All the VSB farmers were expecting a continuous pipeline of improved cultivars for sustaining their long-term interest in the scheme. An impressive 87% of the surveyed VSB farmers indicated willingness to continue in the program.

7.2 Nutrient management of the legume-based farming systems of the CDZ, particularly P, N, B, S, K and Zn

Adoption of proper crop management practices, including application of fertilisers for nutrient supply, is required to fully realise the genetic potential of improved varieties. In the development phase of MyPulses, nutrient management was identified as a priority area for research because there was good evidence that nutrient supply was sub optimal in Myanmar agriculture and was severely limiting productivity of the legume crops, and, to a larger extent, rice, other cereals and oilseeds.

7.2.1 Defining extent of P, B, S, K and Zn deficiencies in the cropping areas of the CDZ and updating recommendations for farmers to address those deficiencies

Soil survey: 2013

The soils of the CDZ are mostly alluvial in origin, classified as luvisols, vertisols, gleysols and nitisols. Data from the MyPulses soil survey indicated that the majority of CDZ surface soils were near neutral to alkaline (pH_{water} range 5.0–9.7, average 7.7) and low to very low in organic carbon (C) (range 0.05–1.6%, average 0.45%), clay contents (range 2–69%, average 11%), and plant nutrients (Table 7.12).

Table 7.12. Average and ranges of values for 319 surface (0–10 cm) soils sampled in 2013 from farmer fields across the Sagaing, Mandalay and Magway Regions of the CDZ and adjacent Nay Pyi Taw Union Territory

Soil test	Average	Standard deviation	Range
pH_{water}	7.7	0.77	5.0 – 9.7
Organic C (%)	0.45	0.34	0.05 – 1.61
% sand	76	17	11 – 97
% silt	13	11	1 – 59
% clay	11	9	2 – 69
EC (dS/m)	0.10	0.11	0.01 – 0.80
Available (alkaline $KMnO_4$)-N (mg/kg)	42.9	18.4	12.0 – 99.0
Available (Olsen)-P (mg/kg)	6.5	5.1	0.1 – 31.6
Exchangeable K (cmol/kg)	0.27	0.25	0.02 – 2.71
Exchangeable Na (cmol/kg)	0.48	0.73	0.01 – 4.28
Exchangeable Ca (cmol/kg)	8.8	7.9	0.2 – 71.0
Exchangeable Mg (cmol/kg)	4.5	4.7	0.2 – 19.6
ECEC (cmol/kg)	14.1	11.4	0.6 – 72.8
Water-extractable S (mg/kg)	10.3	30.6	0.4 – 315
DTPA-extractable Zn	0.68	1.51	0.0 – 25.4
DTPA-extractable Fe	9.9	6.2	0.2 – 35.5
Hot water-extractable B	1.2	1.1	0.1 – 7.2

For key macronutrients, Guppy et al. (2017) reported that 61, 35 and 48% of the surface soils had less than the critical values for P, S and K, respectively. Multiple deficiencies (P, S and K) were recorded for 18% of soils. Sodicity did not appear to be a problem; however, 28% of soils had pH values >8.3, suggesting potential for sodicity deeper in the profile. Notwithstanding the generally impoverished nature of the surveyed CDZ soils, very high values for the various soil measures were recorded for individual fields suggesting luxury application rates for organic and/or mineral fertilisers by some farmers.

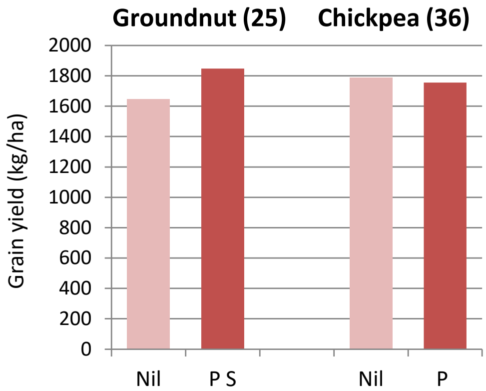
More than half the surface soils had <10% clay, indicating the coarse-textured nature of most CDZ soils. The average clay content of the soils increased with increasing latitude, from an average of 4% clay in the Magway township area, Magway Region (latitude 20.13° N), to 24% clay in the Butalin township area, Sagaing Region (latitude 22.38° N), a distance of ca. 240 km to the north of Magway. This may have implications for soil fertility and crop productivity with regression analysis indicating positive relationships between % clay and available N and P, exchangeable Na and Mg ($P<0.01$). It also has implications for crop choice, for it is on these higher clay soils in the Sagaing Region that chickpea is widely grown after rice on stored soil moisture (Guppy et al. 2017).

Less is known of the nutrient status of the CDZ soils below the surface 10 cm. Deeper soils may contribute to plant nutrition, particularly if soluble nutrients are leached during the episodic drainage events identified by Cornish et al. (2018). Preliminary data from the southern part of the Magway Region indicated generally increasing clay content of soils with increasing depth, from average 6% clay at the surface to 21% clay at 80–100 cm depth (see FPCB results). Clay in the subsoil may hold nutrients leached from the surface to be accessed by the deeper roots of growing crops.

The physical state of the soil has the potential to impact crop productivity (e.g. Lal 1995; Alakukkua et al. 2003; Vaughan and Levine 2015), although the evidence for soil degradation in the CDZ is mainly observational rather than empirical. Tun et al. (2015) reported modelled erosion losses of 0–114 t/ha/yr but noted that the data required to make such assessments were scant. Further research is needed to provide empirical evidence of erosion rates.

Fertiliser trials: 2014–18

The first season of trials (2014–15) revealed minimal response to applied P or S fertiliser in on-farm demonstration plots at a range of sites throughout the CDZ (Fig. 7.5). The 25 groundnut plots and 36 chickpea plots revealed minimal increase in yield as a result of broadcast, at-sowing nutrient application. In contrast, more carefully established trials for chickpea in the Sagaing region identified responses to nutrient application when basal nutrients were applied (Fig. 7.5).



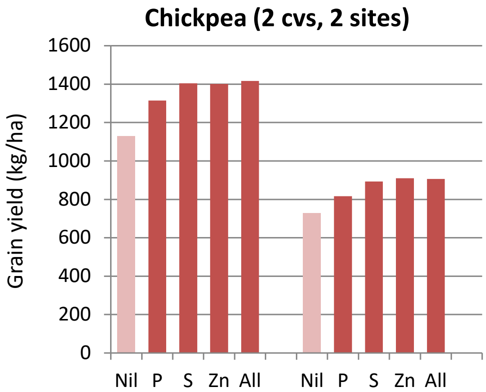


Figure 7.5. Effect of P or S applied as a broadcast, pre-sowing fertiliser at 61 low fertility sites throughout the CDZ of Myanmar (left-hand graph). Effects of inputs of P, S and Zn, either alone or in combination, on chickpea yields at two sites at Sagaing in the northern CDZ (right-hand graph).

Results from the first trial season resulted in consideration of the importance of basal fertiliser application to ensure other nutritional factors were not limiting yield. However, across 21 sites in the CDZ in the second 2015–16 season, inconsistent yield responses to the application of nutrients were again observed, even though soil test values were considered low. Average yields for groundnut ranged 0.52–1.52 t/ha at 9 sites, and from 0.78–2.35 t/ha for chickpea at 9 sites. Treatment effects to fertiliser were negligible at most sites, with the exception of significant responses to S and B in an earlier-sown green gram crop at Magway (Fig. 7.6). Although one groundnut crop did respond to basal nutrient addition, and combined P and K addition (Fig. 7.6), the response in most fields demonstrated that either farmer treatments, or nil fertiliser application out-yielded fertiliser addition. In fact, biomass cuts 45 DAS revealed applied nutrients were not being recovered by plant tops, with negative fertiliser recovery values at most sites (data not shown).

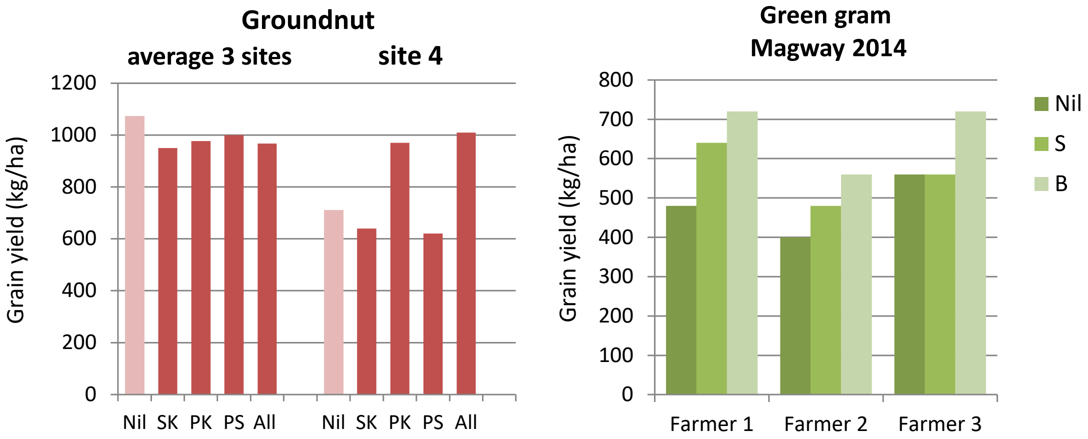


Figure 7.6. Response of groundnut to basal addition of P, K and S in factorial combinations at 4 sites in the southern CDZ of Myanmar. Yield response of green gram to S and B application at three sites in the CDZ

In 85% of the 2015–16 trials, groundnut and chickpea yields failed to reach 50% of benchmark expected yields for the sites. Theoretical water-limited yields of 2.7 t/ha for groundnut pods and 3.0 t/ha for chickpea can be achieved in the CDZ when no other factors are limiting. The further lack of response to applied nutrients prompted a change in strategy within the project.

In the 2016–17 monsoon and post-monsoon seasons, research on nutrient management was done in the context of the farmer participatory crop benchmarking (FPCB) in the Magway Township area, as previously described. The N+P+K+S (N for sesame only) fertiliser was given to 33 farmers to try to achieve the water-limited yield potential. However, the yields from these strips either were similar to farmer-practice yields or unable to be measured, or the data that was collected were unreliable. Problems with the data included difficulties in getting yield data from the small areas (0.1–0.2 ha) when harvested by contract labour and the large variation in area treated (between 50% and 200% of the recommended area).

However, the strips still performed two useful functions. For the fertiliser trials, the lack of response to increased nutrient inputs, and the amount of time spent in the field inspecting the trial sites and surrounding crops, led to the recognition of the potential impact of nutrient leaching and the importance of split applications. It also alerted the team to widespread S deficiencies in sesame crops. Farmers had been assuming that the crops were N deficient and were treating them with urea or compound fertilisers, with poor outcomes.

In the second year (2017–18) of benchmarking, the potential of nutrient leaching was addressed in a network of trials in which all fertiliser was applied at planting or applied in two or three split applications. In 7 of 9 sesame fields, grain yields more than doubled relative to the control treatments when fertiliser application was split. In 6 of 9 fields, split application increased sesame yields over a basal application by at least 70%. Encouragingly, in all fields, the application of fertiliser resulted in yield increases in sesame (Fig. 7.7).

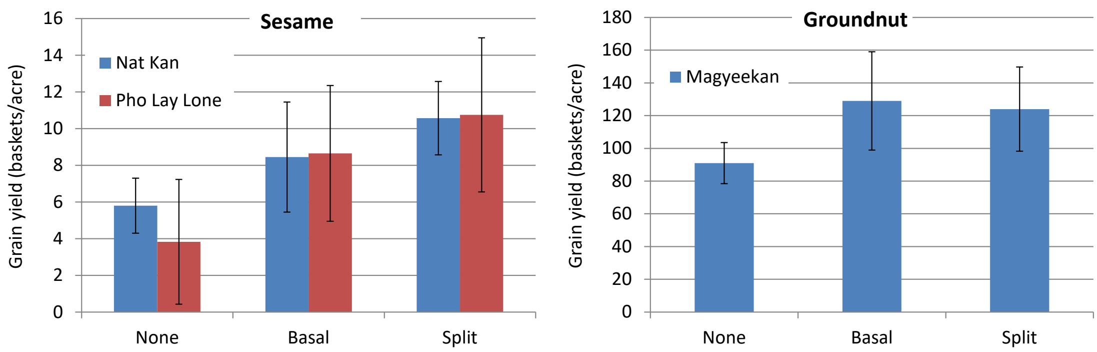


Figure 7.7. Response of sesame at 9 sites in Nat Kan and Phoe Lay Lone villages, Magway Township area (left-hand graph) and groundnut at 3 sites in Magyeekan village, Magway Township area (right-hand graph) either to basal addition of P, K and S at sowing, or split application of P, K and S during the monsoon season of 2017–18. Bars are the SDs

The groundnut trials were less consistent, due to the inherently higher soil fertility of Magyeekan village and drier early season rainfall patterns that reduced the timing and leaching differences between basal and split fertiliser applications to 10 days. Yields in all three fields were close to benchmarked expectations. The only field lower than expected, still doubled groundnut yield to nearly 3.30 t/ha when nutrients were applied. However, there were no differences to whether the nutrients were applied up-front or split over the season, as indicated above.

7.2.2 Enhancing capacity at DAR, Yezin, for soil and plant analysis through revision of protocols and infrastructure development and expanding demand for soil testing by farmers, extension & technology transfer groups

Laboratory structural improvements achieved during the term of MyPulses and paid for either by the project or by DAR included:

- Air-conditioning (DAR)
- Maintenance (roof repairs/painting) (DAR)
- Fume hood repair (DAR)
- Centrifuge
- Centrifuge tubes and racks
- Pipettes x 10 (Gilson and Eppendorf)
- Bottle-top dispensers
- Soil tumblers
- ASPAC standards
- Pot trial benches

New methods introduced through project activities included:

- Olsen P by malachite green colour reagent
- Phosphorus Buffer Index (PBI)
- Plant and soil Si analysis
- Hot water-extractable B
- $CaCl_2$-extractable sulfate

Throughput of soil samples analysed by the DAR soil chemistry laboratory doubled in the 5 years from 2012 to 2017 (Fig. 7.8). Plant samples also increased in number until 2016 when they were interrupted by fume hood repairs. Increases in the number of individual analyses were much higher as each soil and plant sample was analysed for a greater range of properties and nutrient concentrations.

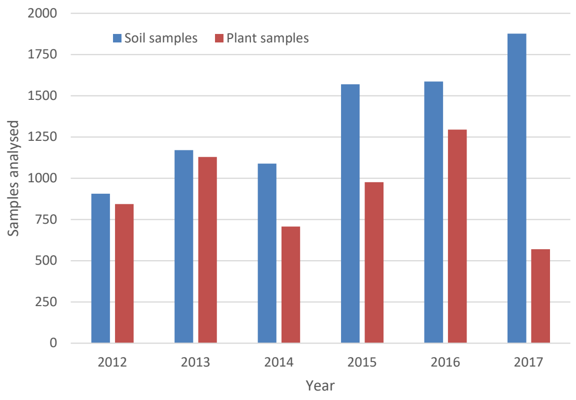


Figure 7.8. Soil and plant sample throughput at the DAR Soil Chemistry laboratory, Yezin, during 2012–17

We can conclude that laboratory output is now limited by demand rather than capacity constraints. However, quality control remains a work in progress.

7.2.3 Enhancing capacity at DAR, Yezin, for soil and plant nutrient RD&E

Fertiliser trials established, sown, harvested, compiled and evaluated. This objective was partially achieved. Inconsistent results from the 2014/15 and 2015/16 seasons (see Figs 7.5 and 7.6 above) resulted in implementation of FPCB methodology during 2016–18 with simple fertiliser strip interventions in 33 groundnut and sesame fields in 2016/17 and the nutrient leaching experiment on 12 farms across three of the benchmarking villages in 2017/18 (see Fig. 7.7).

Organic resource management trials established, sown, harvested, compiled and evaluated. Original trial designed, but farmer implementation withheld as farmers did not believe that it was useful or sensible to increase manure density in furrows due to inability to manage increased weed density. With the adoption of FPCB in early 2016 came a different focus of the role of FYM in crop nutrition.

Other activities relating to enhanced capacity for soil and plant nutrient RD&E can be found in Section 7.4.

Production of a Manual on Crop Nutrition and Fertilisers for Upland Cropping in the CDZ was a milestone of MyPulses which was not achieved during the life of the project. Depending on the level enthusiasm by the DAR and DoA to complete this milestone, it may still materialise.

7.2.4 Expanding production of quality legume inoculants at DAR, Yezin

During 2013–14, peat was sourced from HeHo, Shan State, dried and ground at DAR, Yezin. It was then compared with Australian peat in a laboratory-based production and storage experiment which also aimed to evaluate DAR-maintained cultures and Australian commercial freeze-dried cultures of chickpea rhizobia and effects of dilution of the rhizobial cultures on numbers in the peats.

Results, shown in Fig. 7.9, indicate no differences in counts at 90 days storage amongst the four treatments. This meant that the HeHo peat could be used with confidence for inoculant production in Myanmar and that Australian commercial freeze-dried cultures could be used as a source of pure rhizobial cells for inoculating peats. In theory a small vial of freeze-dried rhizobia could be used to inject 5–10 thousand peat packets.

A substantial amount of time and effort was devoted to enhancement of the DAR Rhizobium Inoculants Laboratory and on-site and formal training of DAR laboratory staff (and others from YAU). Refurbishment of the DAR Rhizobium Inoculants Laboratory was completed during the latter half of MyPulses and included partitioning of space in the laboratory to make smaller more functional rooms, inserting doorways to link spaces, installation of air conditioning, repair of ceilings and relocation of the temperature-controlled plant growth room from an adjacent building to the main laboratory. The outcomes of the refurbishment were improved efficiency and sterility control.

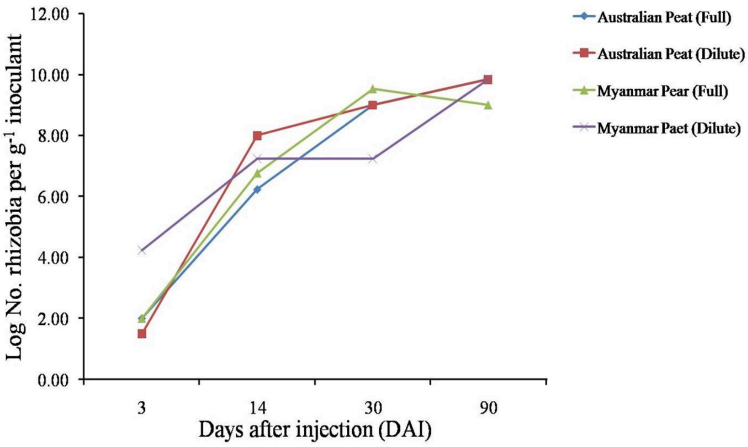


Figure 7.9. Changes in chickpea rhizobial numbers with time of storage after injection. Treatments were Australian and Heho peats and the use of undiluted or diluted rhizobial broths for injection.

There were two training workshops during 2017. The first at the YAU, Yezin, in July 2017 was a 15-day Rhizobium inoculants training workshop, conducted by Greg Gemell and Elizabeth Hartley, ex NSW DPI, Australia, and involving 18 participants (13 female; 5 male). The workshop focussed on the isolation of rhizobia from nodules and culture of the rhizobia on Petri plates and in peat, the authentication of the rhizobia using serology, plate counting, Gram staining and plant-infection testing (Fig. 7.10). The course highlighted aseptic techniques and participants were involved in all aspects of materials preparation. In an exit survey, 87% found the course to be very useful (highest category). All participants felt that the trainers were very effective and 87% of participants considered it very likely that they would use some of the course information during the next 12 months. The workshop was co-funded by MyPulses and the Crawford Fund (Sth Australia). A comprehensive 63-page training manual was produced for the workshop (Section 10.2.5. Hartley and Gemell 2017a) and a 14-page report on the workshop produced for the Crawford Fund (Section 10.2.6 Gemell, Hartley and Denton 2017).

Figure 7.10. Plant-infection testing and counting of rhizobia in broths and peats – a key technique to authenticate and ensure inoculant quality. Images from the October workshop at the refurbished DAR Rhizobium Inoculants Laboratory, Yezin.

The second workshop was conducted at DAR, Yezin, in October 2017. The 11-day workshop involved 10 participants (8 female; 2 male) and was designed to extend the basic microbiological training of the first workshop. In this workshop, participants were tasked with producing 20 white clover and 675 soybean peat-based inoculants and subjecting samples from the batches to quality testing. The soybean inoculants were of high quality and suitable for use by Myanmar farmers. A comprehensive 61-page training manual was produced for the workshop (Section 10.2.5. Hartley and Gemell 2017b).

7.2.5 Expanding demand by farmers for legume inoculants through understanding the nature of rhizobia in Myanmar soils and replicated and demonstration field trials

Rhizobial populations in the 20 chickpea-growing fields in the CDZ were generally low with estimated numbers ranging from $\log_{10}$ 0.7–4.5/g soil (equivalent to 5–32,000/g soil). At 17 of the 20 sites, the chickpea rhizobial populations were sufficiently small that increased grain yields would be expected as a result of inoculation.

The 2014/15 inoculation *x* fertiliser field experiments were conducted at the DAR Zaloke, Pankone, Kyauk Sae and Tatkone farms and on 16 farmers' fields (Fig. 7.11). Results were inconclusive with variable plant populations, nodulation and dry matter production. Plant disease were apparent across the experimental sites.

Figure 7.11. Field experiments to determine effects of rhizobial inoculation and fertiliser P on nodulation, N_2 fixation and yield of chickpea in the Sagaing region. Replicated experiments were conducted on DAR farms and unreplicated experiments on farmers' fields.

Results from the 2015/16 replicated experiments on the DAR Zaloke, Pankone, Myittha, Myingyan, Tatkone and Sebin farms were again inconclusive with very marginal treatment effects on nodulation, but very large site effects (Fig. 7.12).

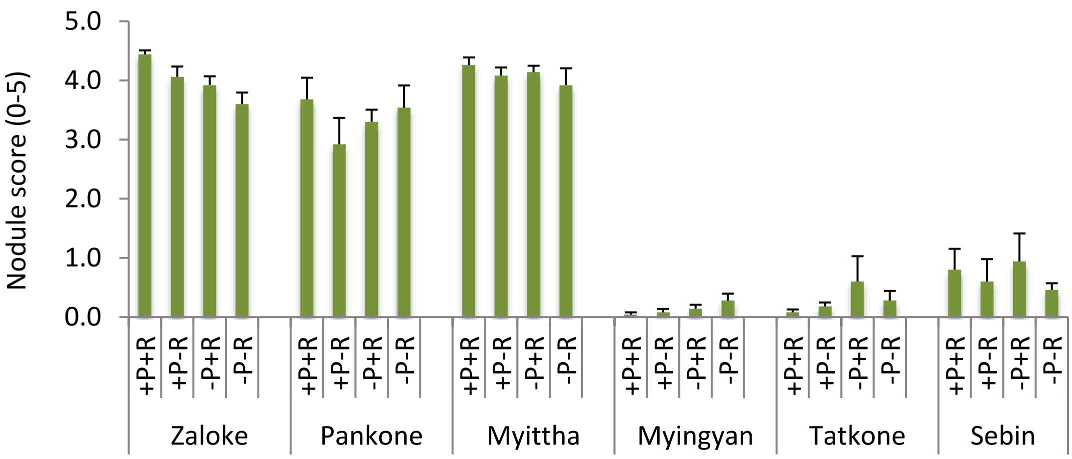


Figure 7.12. Effects of rhizobial inoculation and fertiliser P on nodulation of chickpea at 6 DAR farms in 2015/16

Grain yield was increased by both fertiliser P and inoculation, but not their interaction (Fig. 7.13). At Zaloke, Pankone and Myittha, P and inoculation increased yield, while at Myingyan there was only a response to fertiliser P. There was no influence of either inoculation or P on grain yield at the Tatkone and Sebin sites.

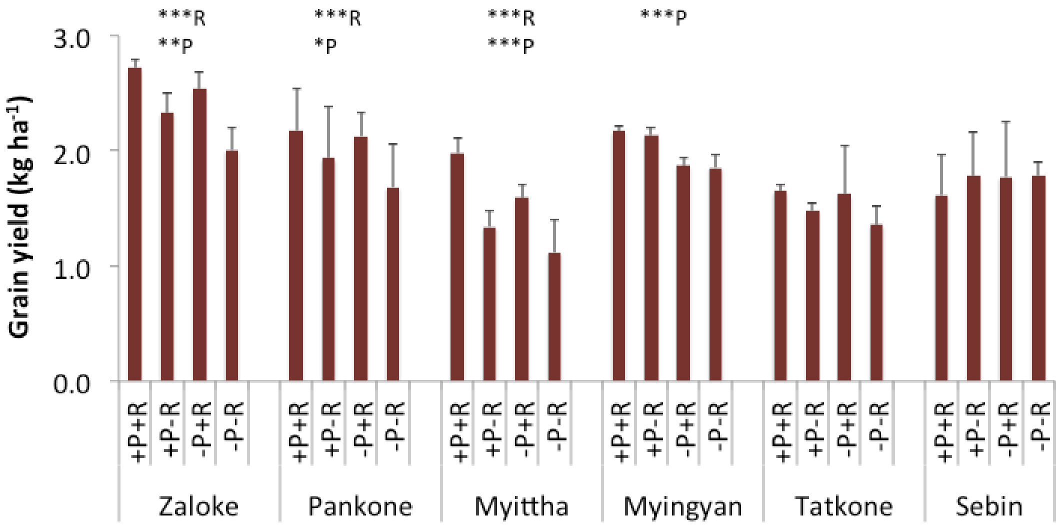


Figure 7.13. Effects of rhizobial inoculation and fertiliser P on grain yield of chickpea at 6 DAR farms in 2015/16

Nitrogen fixation was assessed at the Myittha DAR farm site only. The proportion of nitrogen fixed (%Ndfa) at Myittha indicated a strong differentiation between $\delta^{15}N$ from chickpea relative to that of reference plants (data not shown). The calculated %Ndfa values varied between 82–83%. There were, however, no treatment effects from either fertiliser P or inoculation. These values are greater than those estimated as the global average by Herridge et al. (2008) of 63% and within the range of 41-90% Ndfa reported by Unkovich et al. (2010). Our values indicate that chickpea at the site were highly dependent on N_2 fixation and it was likely that they did not have access to significant mineral N, which can reduce these values.

In the following 2016/17 season, the inoculation *x* P experiment was repeated at the Myingyan, Tatkone and Sebin farms. Although nodulation was substantially improved from the previous 2015/16 season with nodule scores of 1.5–2.0 for Myingyan, 2.0–3.5 for Tatkone and 2.5–3.0 for Sebin, there were only inconsistent treatment effects. Similarly, grain yield was unaffected by treatment. Yields varied 1.5–2.5 t/ha.

7.2.6 Analysis of fertiliser quality in the CDZ and rapid assessment using NIR

Poor fertiliser quality had been recognised as a potential problem for farmers in Myanmar for a number of years. Two years of multi-location experiments across the CDZ revealed little response to P, K and S fertilisers (see Section 7.2.1) and, in some cases, apparently negative fertiliser recovery. The objective in this work was to test fertilisers sourced in the market and, as an alternative to standard laboratory analysis, to develop a rapid test based on near infrared (NIR) technology for distinguishing counterfeit from legitimate fertilisers.

There was generally good agreement between the labelled P and N contents and that determined by standard analytical methods (Fig. 7.14).

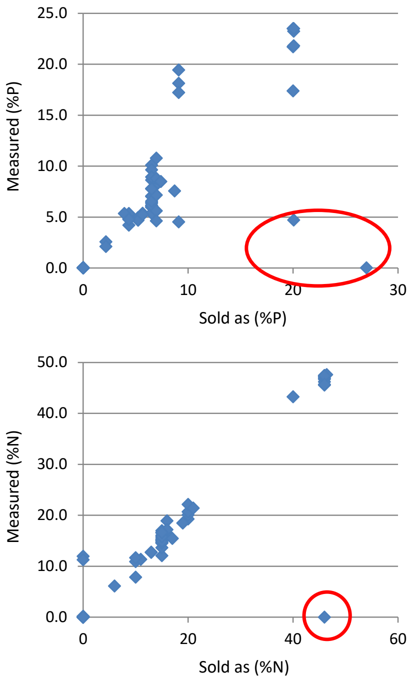


Figure 7.14. A total of 78 fertiliser samples were sourced at the market in Myanmar's CDZ and analysed for labelled nutrients and heavy metal contaminants. Results indicated P concentrations as per the label in 97% samples and N concentrations as per the label in 99% samples. No heavy metal contamination was detected in any of the samples.

An analysis of nitrogen in fertiliser samples indicated very good agreement between N in fertiliser predicted by standard chemistry methods and that using the MicroNIR (r^2 >0.98) (Fig. 7.15). Whilst the prediction of %N as accurate to within 0.8% when scanning the fertilisers directly, scanning through vials did not manifestly reduce accuracy.

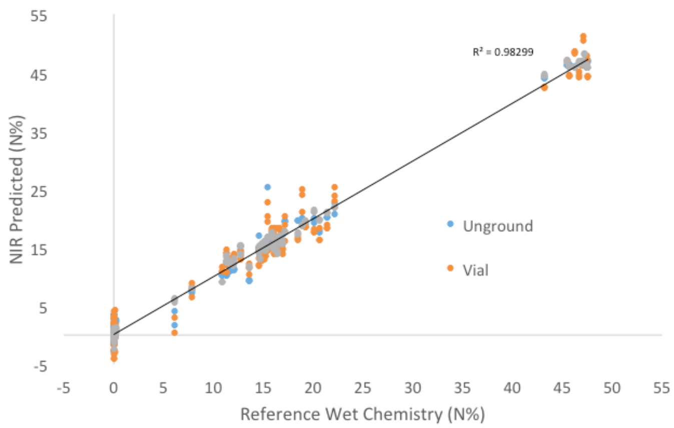


Figure 7.15. Relationship between %N values of market-sourced fertilisers using standard wet chemistry and a novel NIR-based methodology (data from Denton et al. 2017 (see Section 10.2.3)).

The MicroNIR technology to assess fertiliser quality was effective for rapid testing. NIR spectroscopy had already shown promise in the analysis of blended fertilisers in South Africa. This technology shows significant promise for use in Myanmar and has the potential to be adapted by importers and resellers to initially screen and assess fertiliser quality. Although counterfeit compound fertiliser was identified, 97–99% of fertiliser samples were true to label, so there does not appear to be a widespread quality problem. Caution is warranted however, as this screening trial only sourced material from the CDZ and did not aim to identify the extent of counterfeit fertilisers in all regions of Myanmar.

7.3 Agronomic management of the legume-based farming systems of the CDZ through increased system water use and integration of new technologies

7.3.1 Research on practices affecting crop yield and water use

The 2012 PRA of 260 farmers indicated that 75% of them aimed to conserve soil moisture by cultivation to open soil and control weeds. Other less popular strategies were adding clay to sandy soils, adding farmyard manure and windbreaks. The use of mulching (retention of crop residues) and cover crops were considered by just 2% of farmers as moisture conservation practices. Not surprisingly, crop WUE in the CDZ is low because of loss of soil water through evaporation, runoff and weeds coupled with low yields because of low fertility and pests/diseases reducing crop water use.

Figure 7.16. Craig Birchall conducting a soil sampling workshop for DAR, Yezin, staff. Images to the right-hand side are the soil cores laid out before packaging for weighing and drying.

Key to project research on retention and conservation of soil water was the purchase in 2013 by Craig Birchall to DAR of hand-operated soil coring equipment that made it possible to core to depths of about 1.5 m (Fig. 7.16). Delivery of the equipment coincided with soil water seminars, soil coring and sample processing training and demonstrations to about 240 DAR, DoA and YAU staff and students. In project research, the soil cores were used for both water and nutrient (P, S, K etc) analyses.

During 2013–16, a total of 22 replicated field trials examined a range of management practices on grain yield and crop water use. Field experiments were conducted at the DAR Magway, Tatkone and Nyaung Oo farms and evaluated effects of crop residues, windbreaks, cover cropping, reduced tillage, mechanical planting and agronomic management (planting rates, plant populations, planting dates) on yield and water use.

Results from the residue *x* fertiliser P, N trial at the DAR Magway farm showed responses to residues and fertiliser, albeit at low yield levels. One of the replicates at this site was an old laneway and had a substantially increased level of fertility. Yields in this replicate were 3–5 fold the yields in the other two replicates, highlighting the generally low level of fertility in the Magway soils. Results of the windbreak trial at the DAR Nyaung Oo farm were inconclusive, although effects of the *Gliricidia* windbreaks on productivity of pigeonpea and mungbean were minimal suggesting that the practice may have merit. More work needed, particularly assessing the economic value of the by-products of the windbreaks, i.e. organic residues, fodder, building materials and fuel.

In two years of sowing method trials (2013/14 and 2014/15) at the DAR Tatkone farm, grain yields of chickpea sown after corn increased with increasing sowing rate with no effect of sowing method, i.e. cultivated vs zero tillage (Fig. 7.17). This was a positive result suggesting chickpeas can be sown after corn without the labour cost and loss of soil water associated with cultivation, as practiced currently.

Figure 7.17. Chickpea was successfully grown at the DAR Tatykone farm with no-tillage and retention of the previous crop's residues.

Shortage of labour is a major issue affecting timeliness of farming operations and crop use of water. The 2012 PRA survey indicated 43% of farmers had a labour problem, with labour scarce at land preparation (31% of respondents), sowing (43%), weeding (41%) and harvest (51%). The solution to the labour problem is mechanisation. In September 2015, Craig Birchall purchased 4 small hand-guided mechanical planters and located them at the DAR farms at Tatkone, Magway, Nyaung Oo and Monywa (Zaloke). This was combined with demonstrations of their operation for 150 farmers and DoA staff (Fig. 7.18). These machines offered a means of potentially improved crop productivity through timeliness of farming operations, increased fertiliser efficiency, increased soil moisture conservation and the pathway to residue retention with the elimination of draft animals. The machines were used subsequently in field experiments at the DAR farms and loaned out to nearby farmers to use.

Figure 7.18. Mechanisation, in conjunction with residue retention, may lead to increased grain yields, improved farm profitability and enhanced sustainability through timeliness of farming operations, redressing labour shortages at critical times, improved fertiliser-use efficiency and moisture conservation.

In the 2017–18 post-monsoon season, experiments were conducted at the DAR Tatkone, Nyaung Oo and Zaloke farms to compare chickpea and groundnut production under conventional methods of draft animal power and manual labour and the replacement where possible of traditional methods with the Golgi mechanical planter. Results from the Tatkone site indicated 20–50% reductions in the labour costs of sowing, weeding and harvesting of chickpea and a more than doubling of grain yield. Data from the other two sites could not be interpreted. However, the Farm Managers at all three sites were enthusiastic about the Golgi planters, principally because of the labour savings.

The PhD program of U Aung Kyaw Thu at the YAU investigated effects of crop residues as mulches on soil water capture and retention and biomass and grain production in five different crop sequences – sesame-green gram, sesame-groundnut, groundnut-groundnut, groundnut-green gram and groundnut-sorghum. The experimental site was at the DAR Magway farm. Results, summarised in Table 7.13, indicated 6–29% (average 17%) increase in seasonal plant-available soil water, 21–53% (average 36%) increase in grain yield and 18–45% (average 35%) increase in WUE. Note the very low soil water values for the 2014/15 post-monsoon season, reflecting the drought conditions at that time. Rainfall was just 362 mm in 2014 compared with 927 mm in 2015.

Table 7.13. Effects of mulching of crop residues on seasonal plant-available soil water (mm), grain yield (t/ha), crop water use (mm) and crop water-use efficiency (WUE; kg/mm). Values are the means for the five crop sequences

Soil test	2014/15		2015/16	
	Monsoon	Post-monsoon	Monsoon	Post-monsoon
Plant-available soil water (mm)				
- residues	87	45	125	120
+residues	104	58	132	133
	<0.001	<0.001	<0.05	<0.01
Grain yield (t/ha)				
- residues	1.17	0.19	1.05	0.76
+residues	1.53	0.29	1.45	0.92
	<0.05	<0.001	<0.001	<0.01
Crop water use (mm)				
- residues	292	93	466	337
+residues	283	93	478	339
	ns	ns	ns	ns
Crop water-use efficiency (kg/mm)				
- residues	4.0	2.2	2.1	2.2
+residues	5.4	3.2	3.0	2.6
	<0.01	<0.01	<0.001	<0.01

These were very positive results and showed clearly the benefits of mulches, but more importantly the potential benefits of retaining crop residues *in situ* to enhance soil water storage and retention and more effective conversion of that additional soil water into grain and profit for the farmer. The impediment to broad adoption of *in situ* residue retention is that the residues have another purpose and that is as feed for draft animals. Replacement of draft animals with mechanised implements will need to happen before residues can be used to directly nourish and protect the soil.

7.3.2 Farmer participatory crop benchmarking (FPCB)

Soil testing the farmers' fields for key nutrients, soil organic C, texture and EC (salinity)

The objective of this sampling and analysis was to test relationships for the farmers' field soils between nutrient levels, soil pH, soil organic matter, soil texture, EC and grain yield. A total of 139 farmers' benchmarking fields in the four villages were sampled for surface soil, i.e. 0–10 cm, at the start of the 2016 monsoon season. The soils were then analysed at the DAR Soil Chemistry laboratory, Yezin. Data, i.e. average values (±SD) for each village, are summarised in Table 7.14.

All soils were close to neutral and salinity (EC) levels were very low. We conclude that there are no problems with soil pH or salinity, at least in the surface soil. Soil P and K levels were generally low with a small number in the medium range. Sulfur levels were a little higher, in the low-medium range. Lowest levels of P, K and S were in the Pho Lay Lone soils with the other three villages similar to each other. Analysis of all the data indicated that soil with higher levels of P tended to also have higher levels of K and S ($P<0.05$). There were also positive relationships between the amount of clay in the soil and K ($P<0.0.001$), Organic C ($P<0.05$) and EC ($P<0.01$) levels.

Table 7.14. Average (±SD) values for 139 surface (0–10 cm) soils sampled in the 2016 monsoon season from benchmarked fields at Nat Kan, Magyeekan, Aung Myay Kone and Pho Lay Lone villages in the Magway Township area of the CDZ

Soil property	Nat Kan	Magyeekan	Aung Myay Kone	Pho Lay Lone	Range of values across all 4 villages
pH_{water}	7.7 (0.43)	6.9 (0.30)	7.0 (0.42)	7.5 (0.52)	6.2 – 8.8
Organic C (%)	0.33 (0.25)	0.57 (0.21)	0.63 (0.26)	0.53 (0.25)	0.06 – 1.15
% clay	5.9 (0.9)	6.3 (0.7)	7.5 (3.3)	7.2 (2.7)	3.9 – 23.1
EC (dS/m)	0.04 (0.02)	0.03 (0.01)	0.05 (0.05)	0.06 (0.03)	0.01 – 0.26
Available (Olsen)-P (mg/kg)	5.5 (2.2)	5.4 (3.0)	6.6 (5.7)	4.2 (2.4)	0.1 – 28.5
Exchangeable K (cmol/kg)	0.18 (0.03)	0.19 (0.08)	0.20 (0.11)	0.12 (0.04)	0.07 – 0.74
Exchangeable Ca (cmol/kg)	2.1 (1.05)	1.6 (0.32)	2.1 (1.54)	5.3 (5.65)	0.3 – 32.5
Water-extractable S (mg/kg)	8.1 (1.4)	10.2 (2.8)	7.0 (2.5)	3.7 (1.5)	1.0 – 21.2
Hot water-extractable B	0.6 (0.16)	0.7 (0.49)	0.6 (0.10)	0.7 (0.12)	0.4 – 2.8

As was the case with the previous, larger 319-field soil survey in 2013, individual fields had reasonable nutrient levels. We concluded, however, that the low generally soil fertility means that farmers need to apply substantial inputs of FYM and/or mineral fertiliser to attain good yields from most fields.

Soil testing the farmers' fields to depth

The data in Table 7.14 relates to surface, i.e. 0–10 cm, soil. Sesame grain and groundnut pod yield data from the 2017/18 leaching trials on 13 farmers' fields in Nat Kan, Magyeekan and Pho Lay Lone villages were presented in Section 7.2.1. Soils were sampled down to 1.8 m depth from the same fields and analysed for P, K, S, Ca, Mg, EC, pH and texture. Part of that data were combined with soil data from benchmarked fields during the 2016 post-monsoon season and are presented in Fig. 7.19. As indicated in Table 7.14, soil clay content at the surface is very low at about 6% but does gradually increase with depth to about 20% clay below 1 m depth.

This trend in clay levels varied with field and village, with some increasing substantially with depth, while others only increased a little. The importance of the increasing clay levels with depth was evident in some fields where areas of crop which were always unproductive were found to have very little clay in the top 80 cm, compared to better performing areas where the clay levels did increase with depth.

The lack of clay has implications for the leaching of nutrients, particularly the soluble nutrients N, K, S. The generally low levels of clay in the Magway soils means that the mobile (soluble) nutrients are prone to being leached beyond the depth of the crop roots by the 800–1,000 mm monsoon rainfall. To investigate leaching of the key nutrients, P, K and S, soils from one of the benchmarked fields of groundnut in Pho Lay Lone village were sampled in mid-October 2016, approximately 60 days after applying fertilisers.

Concentrations of the nutrients at the various depths in the soil are shown in Fig. 7.19. With P, the fertiliser had leached to a depth of approximately 50 cm, but still in that part of the soil profile containing the roots of the groundnut. There appeared to be no leaching of P beyond the root zone.

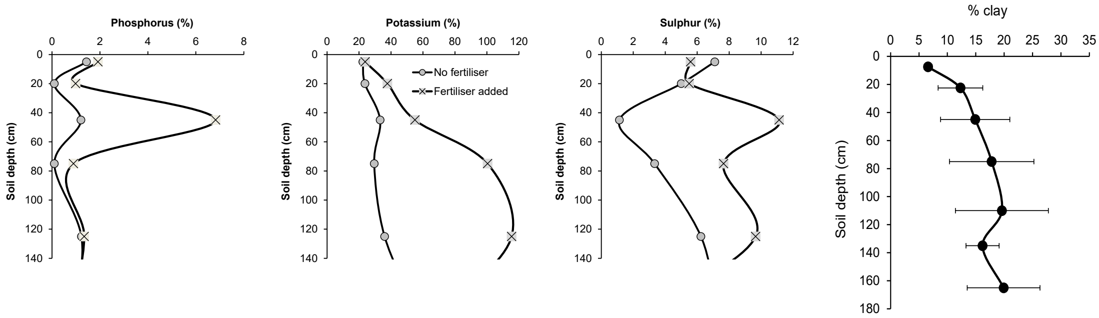


Fig. 7.19. Data from the 2016 post-monsoon fertiliser experiment and the 2017 monsoon leaching experiment showing leaching of fertilizer P, K and S applied at planting and general increases in clay content with increasing depth

The K and S fertilisers had been leached deeper into the soil profile during the same time frame with some of the K and S beyond the reach of the groundnut roots. These are results from just one sampling of one field but they did highlight the risk of losing nutrients out of the bottom of the root zone. The solution to this problem was to split the fertiliser applications (see Fig. 7.7 from the 2017 leaching experiments).

Testing samples of FYM from the benchmarking villages for N, P, K and S

In order to understand the contribution of FYM to nutrient supply in these systems, it was necessary to quantify the concentrations of the nutrients in the FYM. Therefore, 16 samples of FYM were collected from the 4 benchmarking villages in early 2017 and analysed for P, K and S. The results are summarized in Fig. 7.20. There are some differences amongst the villages in the nutrient concentrations of the FYMs with Pho Lay Lone having the highest P and K levels. For S, highest levels were found in FYM from Aung Myay Kone and Magyeekan.

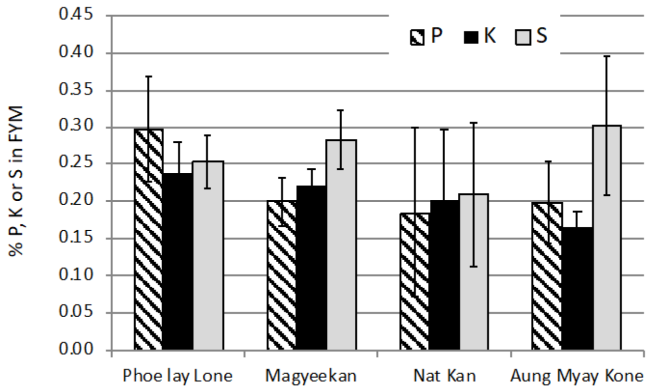


Figure 7.20. Concentrations of P, K and S in FYM sampled from the four benchmarking villages. The vertical bars are the SDs

FYM concentrations used when calculating nutrient inputs were 0.57% for N (data from other DAR analyses), 0.20 for P, 0.20 for K and 0.25 for S (see Table 5.9).

Groundnut – benchmarking pod yields, agronomy and fertiliser inputs

Pod yields of the 210 benchmarked groundnut crops from the 4 villages are shown in Fig 7.21. Data are for monsoon (81 fields) and post-monsoon groundnut (129 fields). Yields varied substantially from 6 baskets/acre to 110 baskets/acre. Variations for each of the villages were: 35–78 baskets/acre for Aung Myay Kone; 20–110 baskets/acre for Magyeekan; 6–83 baskets/acre for Nat Kan; 7–80 baskets/acre for Pho Lay Lone.

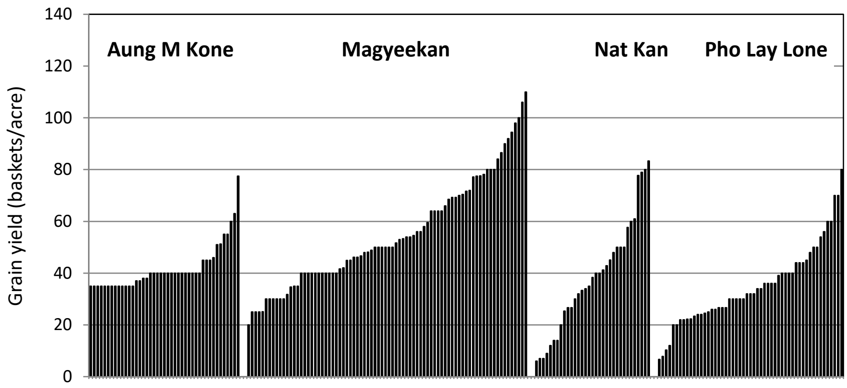


Figure 7.21. Pod yields of groundnut for each of the 4 benchmarking villages indicated large variability. The highest yield was 110 baskets/acre (equivalent to 3.1 t/ha)

Average yields were higher for Magyeekan at 55 baskets/acre than for the other three villages (35–42 baskets/acre). Magyeekan farmers cultivate relatively more of their groundnut crops in the monsoon season than the other villages, so it was not surprising that their crops were higher yielding. The overall average monsoon groundnut yield (59 baskets/acre, all villages) was higher than the average post-monsoon yield (36 baskets/acre, all villages) (Fig. 7.22). Respective lengths of the growing seasons might be a major factor. The post-monsoon season is often shorter than the monsoon season with pod filling truncated by soil water deficits as stored soil water is exhausted and rainfall ceases (see water modelling in Section 7.3.3).

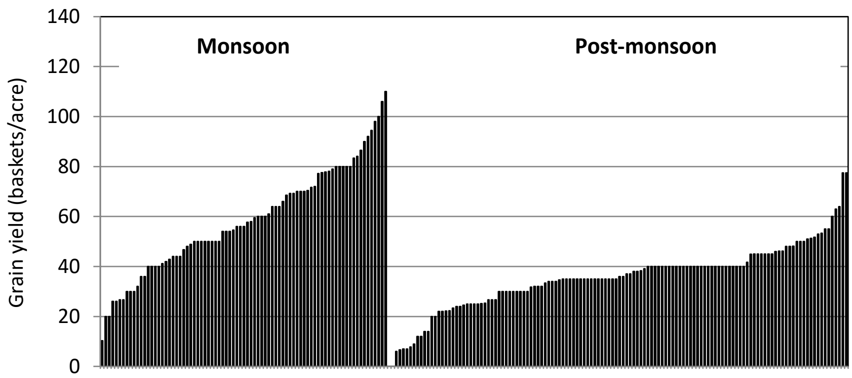


Figure 7.22. Pod yields were generally higher for the monsoon groundnut than for post-monsoon groundnut

There were very large differences in the amounts of FYM and mineral-fertiliser that the farmers of the benchmarked fields applied (Fig. 7.23). Simple correlation and regression analyses can inform us of the strength of the relationships of the nutrient inputs and pod yields. A more powerful analysis is frontier or boundary analysis. The basis of this approach is the assumption that in the absence of other limiting factors, a bivariate relationship between a single limiting factor or 'independent' variable (e.g. fertiliser P), and the 'dependent' variable (e.g. pod yield) exists (Farquharson and Baldock 2008). Boundary line Analysis (BLA) considers only the outer envelope of a data scatter rather than fitting a regression line through the total scatter of data.

Relationships between total inputs of N, P, K and S and groundnut pod yield are shown in Fig. 7.23. For each nutrient, there is a large scatter of data. The boundary lines shown on the graphs in blue were defined by eye with the ends of the lines indicating the points of inflection beyond which there were no further increases in yield. It is at those points that the values for the independent variables (inputs of N, P, K and S) relate to maximum pod yield and become non-limiting. The non-limiting value for P was estimated to be 16 kg/ha, and for K and S was 30 kg/ha.

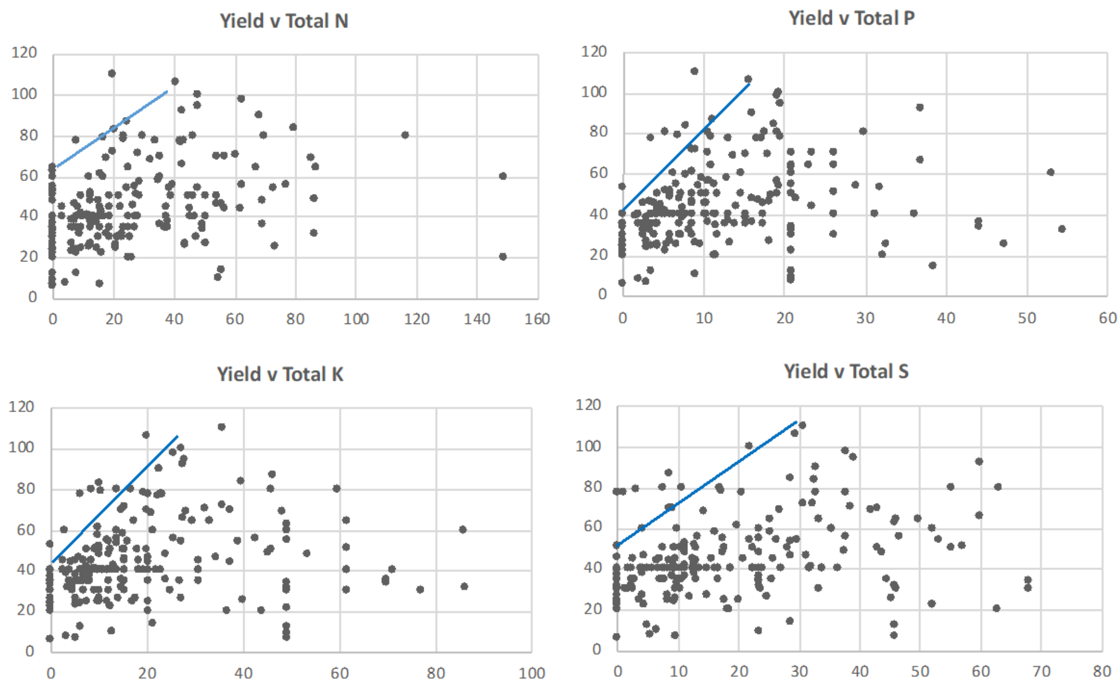


Figure 7.23. Relationships between total inputs of N, P, K and S, i.e. from FYM applied pre-sowing and mineral fertilisers applied at sowing or in-crop (kg/ha), and groundnut pod yield (baskets/acre). Data are from 210 benchmarked crops grown in 4 villages in the Magway Township area during 2016 and 2017. The boundary lines, drawn by eye, define at the end point the level of P, K and S required for maximum yield.

According to the graph for N, the non-limiting value for was 40 kg/ha. Groundnut is a legume that fixes its own N and does not need fertiliser N. Therefore, the apparent response to inputs of N were more likely to have been responses to the other nutrients, i.e. P, K and S, in the FYM (applied pre-sowing) and compound fertilisers (applied at sowing and in-crop) that delivered the N. The applied N does not cause any harm, except it costs the farmer money. There may also be a benefit, however, with some of the added N boosting seedling growth and aiding plant establishment. The amount required, however, would be in the order of 5–10 kg/ha, substantially less than the 40 kg/ha indicated on the graph (Fig. 7.23).

As well as providing values for nutrient inputs associated with maximum yields, the data highlighted the large variations in N, P, K and S inputs across the 210 groundnut fields. Some farmers applied far too little FYM and mineral fertilisers, some about right and some far too much. With P, 51% of the fields received 0–10 kg/ha (too little), 31% received 11–20 kg/ha (about right) and 18% received 20+ kg/ha (too much). It was much the same story with K and S. For both, 60% of fields received 0–20 kg/ha (too little), 25% received 21–40 kg/ha (about right) and 15% received 40+ kg/ha (too much).

Other nutrient-input benchmarking data indicate the benefit of applying gypsum (S) in-crop, i.e. 30–40 days after planting and the complementarity of FYM and mineral fertilisers in supplying nutrients (data not shown).

The benchmarking data indicated another important relationship – the 1 basket/acre decline in pod yields of the post-monsoon crop for every day planting was delayed beyond the 17 August (Fig. 7.24, left-hand graph). In many instances farmers have little option as to when they plant a crop, so in the event that they cannot ensure a relatively early planting of the post-monsoon crop, they can adjust seeding rates. Figure 7.24, right-hand graph) indicates the strong effect of plant population on pod yield and the fact that plant populations for the post-monsoon crop need to substantially more than those of the monsoon crop to achieve equivalent yields.

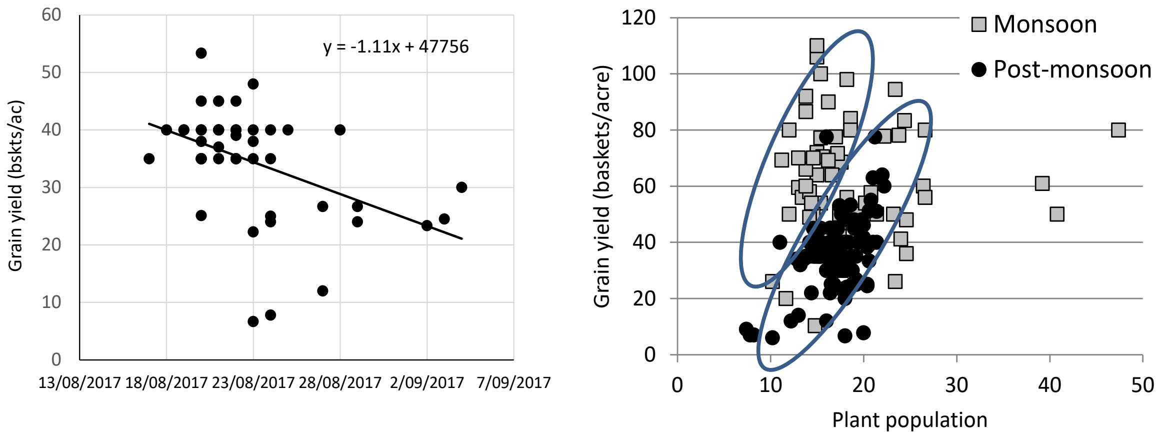


Figure 7.24. Relationships between planting date and grain (pod) yield of post-monsoon groundnut (left-hand graph) and plant population and grain (pod) yield for monsoon and post-monsoon groundnut (right-hand graph)

The data in Figs 7.21–7.24 provide benchmarks for a target pod yield of about 100 baskets/acre for N, P, K and S inputs, plant population and time of sowing (for post-monsoon groundnut only). Another approach is to use as benchmarks the best yields and associated nutrient and agronomic factors, i.e. use as benchmarks the most highly-productive crops. Table 7.15 summarises inputs for the top 5% of farmer crops yielding 98–110 (average 104) baskets/acre in the monsoon season and 55–78 (average 66) baskets/acre in the post-monsoon season. Values are presented using both local Myanmar (baskets, acre) and international (tonnes, hectare) units. Values for P and K are also presented as P_2O_5 and K_2O.

Table 7.15. Yields, plant populations and nutrient inputs for the top 5% of farmer monsoon and post-monsoon groundnut crops. Values shown as local and international units.

Pod yield	Plant pop	FYM	Fert N	Fert P	Fert P_2O_5	Fert K	Fert K_2O	Fert S
Local	/10 ft row	bskts/ac	kg/acre	kg/acre	kg/acre	kg/acre	kg/acre	kg/acre
Monsoon (100 baskets/ac)	16	83	8	3	7	5	7	8
Post-monsoon (65 baskets/ac)	20	0	5	6	14	14	17	9
International	/m^2	t/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Monsoon (2.8 t/ha)	16	4 t/ha	20	8	18	13	16	21
Post-monsoon (1.8 t/ha)	20	0	13	15	34	34	41	22

For monsoon crops, plant populations should target 15–20 plants/10 ft row with nutrient inputs as shown in the table. For post-monsoon crops, plant populations should target 20+ plants/10 ft row (m^2). Planting should be, if possible, before 20 August. Note that FYM is normally not applied to the post-monsoon crop, which instead relies on residual benefits from the earlier pre-monsoon crop application. Farmers may have compensated for this by applying higher rates of mineral fertilisers. Note that the top 5% yielding post-monsoon crops received about double the inputs of mineral P and K as the top-yielding monsoon crops.

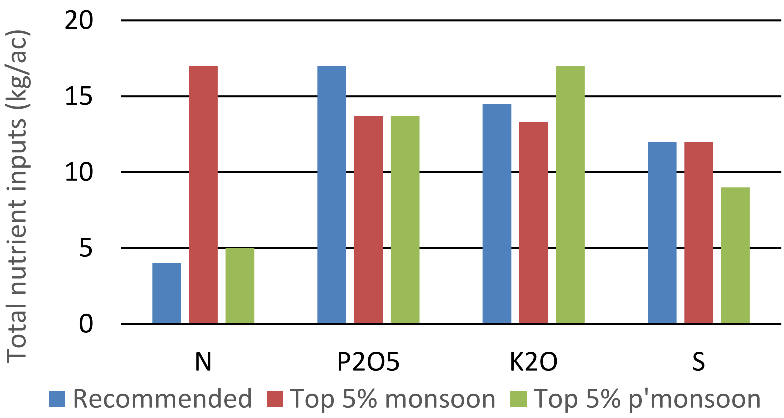


Figure 7.25. Comparing total nutrient inputs, i.e. FYM + mineral fertilisers, applied to the top 5% of monsoon and post-monsoon groundnut crops to recommended rates

There was good agreement between interpretation of the boundary layer graphs describing nutrient inputs, plant populations and pod yield (Figs 7.23 and 7.24) and how the top 5% of crops were managed (Table 7.15). However, the best managed monsoon groundnut crops received too much N (from FYM) and the post-monsoon crops too little S (Fig. 7.25).

Sesame – benchmarking grain yields, agronomy and fertiliser inputs

Grain yields for 188 benchmarked sesame crops from the 4 villages from the 2016 and 2017 monsoon seasons are shown in Fig 7.26. Yields varied substantially from 1 to 20 baskets/acre with an overall average of 9.3 baskets/acre (equivalent to 0.56 t/ha). As was the case with groundnut, average yields were substantially higher for Magyeekan at 13 baskets/acre than for the other three villages (7.2–9.0 baskets/acre). There was a large spread of yields for each of the four villages.

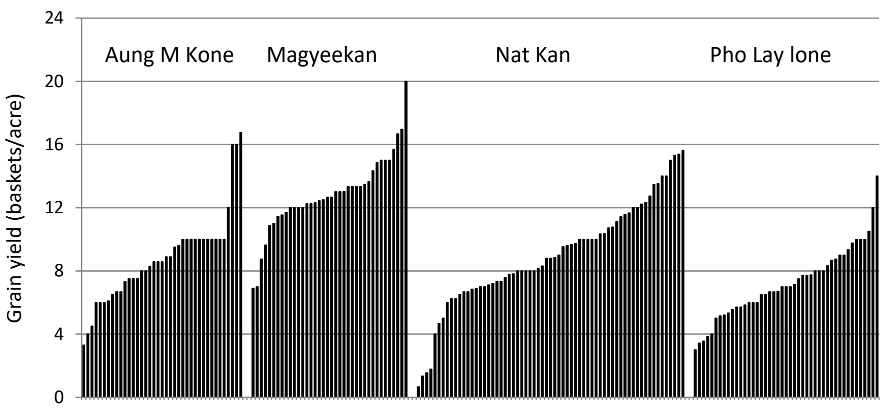


Figure 7.26. Grain yields of sesame for each of the 4 benchmarking villages, Magway Township, indicated large variability. The highest yield was 20 baskets/acre (equivalent to 1.2 t/ha). All crops were grown in the monsoon season

Simple correlation analysis revealed significant ($P<0.05$) relationships between grain yield and plant population, fertiliser P and fertiliser S. The boundary analysis approach was again used to interrogate the data and to determine the points at which values for the nutrient input and agronomic variables coincided with maximum grain yield. For example, the value for plant population was 20 plants/10 ft row (m^2) (Fig. 7.27).

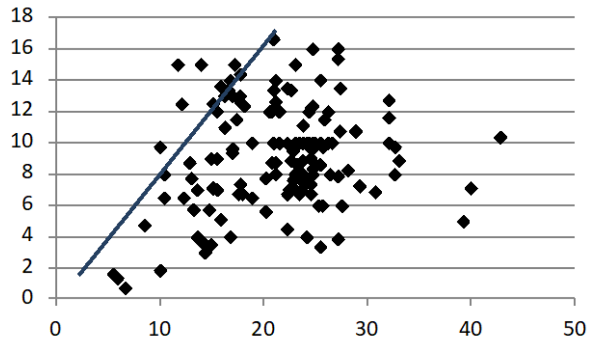


Figure 7.27. Relationship between plant population and grain yield of sesame. Data from the 2016 and 2017 benchmarking, Magway Township area. Highest yields coincided with a population of 20 plants/10 ft row (m^2).

Benchmark values for total, i.e. FYM + mineral fertilisers, nutrient inputs were 60 kg N/ha, 14 kg P/ha, 20 kg K/ha and 20 kg S/ha.

Table 7.16. Yields, plant populations and nutrient inputs for the top 5% of farmer sesame crops. Values shown as local and international units.

Pod yield	Plant pop	FYM	Fert N	Fert P	Fert P_2O_5	Fert K	Fert K_2O	Fert S
Local	/10 ft row	bskts/ac	kg/acre	kg/acre	kg/acre	kg/acre	kg/acre	kg/acre
Monsoon (9.3 baskets/ac)	25	90	12	3	7	6	7	2
International	/m^2	t/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Monsoon (0.56 t/ha)	25	4.5 t/ha	29	8	18	14	17	5

Agreement between the recommended benchmark values and inputs for the top 5% of crops (Table 7.16) was again very good. Our interpretation of the benchmarking data suggests the top 5% of crops may have received the correct amount of N, slightly too much P and K but too little S. (Fig. 7.28).

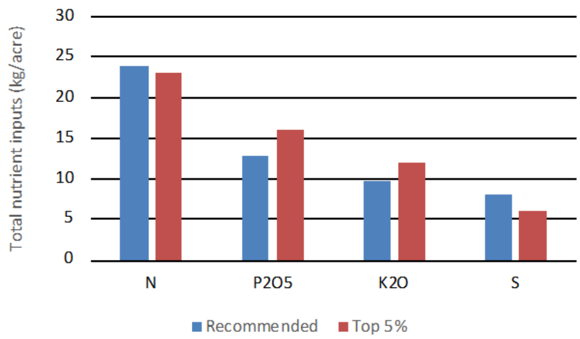


Figure 7.28. Comparing total nutrient inputs, i.e. FYM + mineral fertilisers, applied to the top 5% of monsoon and post-monsoon groundnut crops to recommended rates

Higher yields equate to improved farmer incomes

The derivation of the benchmarks for yield and nutrient input and agronomic management factors has all been directed at the highest yield levels, but does that necessarily equate to highest profits for the farmer? Are farmers who are reluctant to spend money on inputs being financially prudent or are they in fact wasting opportunity to increase profits?

Using data from the two years of benchmarking combined with information on costs and prices from the DoA and from other sources (e.g. Myint et al. 2017; Kumara Charyulu et al. 2018), net margins were calculated for sesame and groundnut. Prices were assumed to be 35,000 kyats/basket for sesame and 12,000 kyats/basket for groundnut. Assumed costs, including the cost of family labour, were 29,000 kyats/basket for sesame at a yield level of 10 baskets/acre and 12,000 kyat/basket for groundnut at yield of 48 baskets/acre.

Costs, on a per basket basis, for yields higher and lower than those were adjusted to account for the inflexibility of some of the costs.

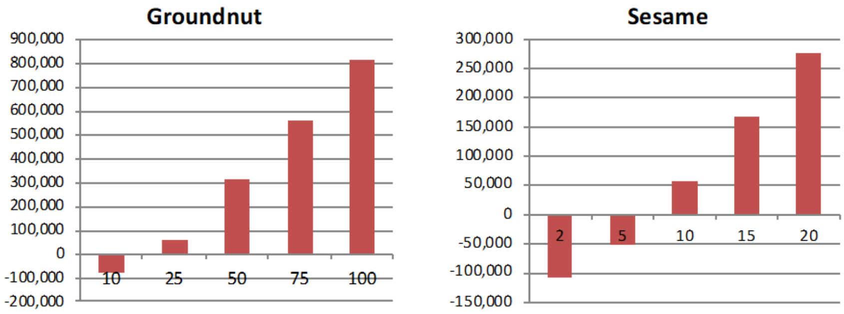


Figure 7.29. Net margins of groundnut and sesame production in the CDZ

For both sesame and groundnut, the major costs were labour, accounting for 55% of total costs for groundnut and 66% of total costs for sesame (Fig. 7.30). The obvious solution to the high cost of labour is mechanisation.

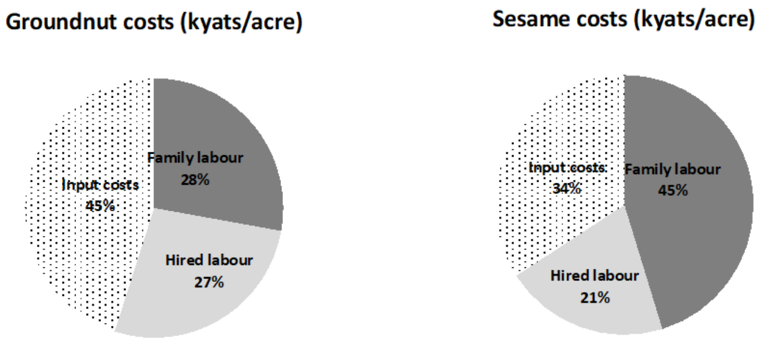


Figure 7.30. Breakdown of costs for groundnut and sesame production in the CDZ. Labour costs equate to 55 and 66% of total costs for groundnut and sesame, respectively

Inputs costs are mainly associated with fertilisers. Nutrient inputs are essential for high yields and potentially high profits so FYM and mineral fertilisers need to be applied. There are differences in the unit cost of nutrients in the fertilisers and in the efficiencies with which the nutrients are used by the growing crops. For example, the unit cost of P in triple superphosphate is much lower than in compound (e.g. 15:15:15) fertilisers. Likewise, the unit costs of N and K are much less in urea and potash, respectively, than in a compound. With careful use of single element mineral fertilisers (TSP, urea, potash), fertiliser costs can be reduced by 30–50% (see Fertiliser DS tool, next section and Birchall et al. 2017). Data from the 2017 multi-site leaching trials at Nat Kan, Magyeekan and Pho Lay Lone villages indicated higher efficiency of crop use of mineral fertiliser use with split applications, compared with a single basal application.

Putting it all together – a simple decision support tool to help CDZ farmers make decisions about fertilisers for groundnut and sesame

A simple Excel-based decision-support (DS) tool was developed to help farmers negotiate the decisions and choices around nutrient management. It was based on the outcomes of the 2 years of crop benchmarking, soil analyses and associated fertiliser experiments in the four benchmarking villages during 2016 and 2017. The current version of the fertiliser DS tool does not calculate the optimum rates of N, P, K and S inputs as such, rather it is:

- a spreadsheet for adjusting mineral-N, P, K and S fertiliser inputs to complement those elements in the FYM that the farmer had already applied pre-planting
- a spreadsheet for pricing the different fertiliser options for sourcing the N, P, K and S. The options are many including TSP for P, gypsum for S, potash for K, urea for N and an infinite number of compounds for all 4 elements.

The DS tool (Fig. 7.31) needs further tweaking to include an adjustment for grain yield - the current spreadsheet outputs are calibrated for high yielding crops, i.e. 80+ baskets/ac for groundnut and 15+ baskets for sesame.

Fertiliser options for 15+ bskts (sesame) or 80-100 baskets (groundnut)/ac

			Using single element fertilisers			Using compound fertiliser		
Crop	FYM (baskets/acre)	Nutrient	Fertiliser	Rate (kg/ac)	Cost (kyats/ac)	Fertiliser	Rate (kg/ac)	Cost (kyats/ac)
						buffalo 15:15:15:2	43	32,180
Sesame	74	**N**	Urea	34	14,008	Urea	20	8,215
		P_2O_5	TSP	14	5,721	TSP	0	-
		K_2O	Potash	10	4,738	Potash	-1	-
		S	Gypsum	24	5,542	Gypsum	19	4,436
				Total cost	**30,008**		**Total cost**	**44,831**
						buffalo 15:15:15:2	74	55,760
Groundnut	68	**N**	Urea	-8	-	Urea	-32	-
		P_2O_5	TSP	25	9,913	TSP	0	-
		K_2O	Potash	19	8,802	Potash	0	66
		S	Gypsum	48	11,084	Gypsum	40	9,168
				Total cost	**29,799**		**Total cost**	**64,994**

Rate (kg/ac)		
Planting	**20 DAS**	**45 DAS**
14	10	10
14		
4	3	3
10	7	7

negative values in fert rate show that the manure or compound fertiliser have applied more nutrient than necessary for the crop.
remember to apply the N and S as split application - ###
and P (as TSP or compound) should be applied at sowing, and if split, in the first 2 weeks

if P rate is supplied by manure, then what abut starter P ??

***Insert own fertiliser costs if different from those shown**

Fertiliser	Weight bag (kg)	Cost of bag (kyats)
Urea	50	**20,700**
TSP	50	**20,000**
Potash	50	**23,500**
Gypsum	25	**5,800**

***Insert details for the compound fertiliser you want to use**

	Fertiliser name	Weight bag (kg)	Cost of bag (kyats)	
	buffalo	50	**37,500**	
nutrient	**N**	**P_2O_5**	**K_2O**	**S**
concentration	15	15	15	2

These numbers are on the bag. You may have to read the fine print for the sulfur concentration.

Figure 7.31. Output of the fertiliser DS tool produced for groundnut and sesame in the coarse-textured soils of the southern CDZ

The DS tool was introduced to the benchmarking farmers in the final meeting in June 2018. The response was positive with many of the farmers downloading a copy onto their mobile phones.

Changing practices – farmer action plans

In February 2017, the 2016 monsoon and post-monsoon benchmarking data were presented to the farmer groups in workshops in each of the four villages. The data were discussed and debated amongst researchers, extension workers and farmers, and at the end of the workshop, farmers (men and women) were asked to create their own written action plans for the coming 2017 cropping seasons. To some extent, the action plans reflected the topics that were highlighted in those meetings, but they were generally consistent with what the FPCB research team considered to be important to increasing yields (Fig. 7.32).

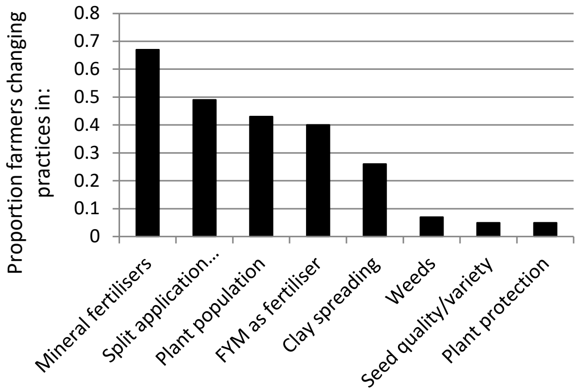


Figure 7.32. Farmers' intended practice changes, as reported in farmer action plans in February 2017, according to the practice (n = 94)

There was a high degree of farmer interest (about 68%) in changing practice in their monsoon 2017 crop with respect to mineral fertiliser application. This was followed by splitting applications of mobile nutrients like S and N because of leaching, more care with plant establishment and plant populations, FYM as a fertiliser and clay spreading. The other categories for which farmers indicated they would change, or would like to change, practices were related to weed management, seed quality and crop varieties and plant protection. Their interest levels in the latter three topics were, however, at a low level.

Farmers were also asked at the February 2017 meetings if they would like to continue the crop benchmarking during 2017. For each of the 4 villages, the response was an overwhelming yes. As a result, the FPCB continued into the 2017 monsoon and post-monsoon seasons with more crop monitoring and a network of multi-site nutrient leaching experiments.

Reflections of the FPCB research team

During the course of the FPCB, the team held a number of reflection meetings both in Australia amongst Australian team members and within Myanmar with Australian and Myanmar colleagues. The purpose of these meetings was for the team to learn where things were working well, and where and how the team needed to modify approaches or activities. Effective reflection sessions guided the benchmarking workshops in the villages to be more about farmer (group) participatory learning rather than a workshop/lecture on crop nutrition or other technical topics. It was a gradual learning process in finding the balance between delivering technical content to the farmers, while also ensuring that farmers had the opportunity to share their knowledge. The time available to schedule the workshops was limited to about 3 hours, so the tight timeframes presented a significant challenge.

For example, in August 2016 the project team met in Magway to reflect on how well the crop benchmarking and farmer group meetings were progressing and what needed to be improved.

A summary of points from the first of these team reflection meetings of things that went well are: good technical content, provided new knowledge, good farmer interest indicated by questions and farmer attentiveness.

On what did not go so well in the workshop: too much content, minimal participation by farmers with too much of standard lecturing, planning for the coming post-monsoon season benchmarking too rushed, the process did not really engage the women in the group, benchmarking team not fully engaged, timing of the workshop problematic, lack of clarity around the purpose of the meeting – benchmarking or fertiliser workshop?

The learning for future workshops was to restructure the program so that it is more about farmer (group) participatory crop benchmarking rather than a technical workshop/lecture on crop nutrition.

Evaluation of the FPCB

A formal evaluation of the FPCB in the four villages of the Magway Township area was conducted by Michelle Carnegie and Myanmar colleagues in September 2017 as part of xProject C2016/021 ‘Undertaking research on engaging women and men farmers in participatory research and extension in Myanmar (Farmer Participatory Crop Benchmarking – FPCB)’ activities. Full details of C2016/021 and the evaluation of the FPCB can be found in the project’s Final Report (see Carnegie et al. (2018) in Section 10.2.6).

Briefly, the evaluation aimed to quantify changes to farmer decision making and practice and to understand the extent of farmer involvement in the crop benchmarking process and its usefulness to them. The project team collected evaluative field data from farmers in all four participating villages. The evaluation methods included a survey and focus group discussions. Total numbers completing the survey were 72 farmers. Seven focus group discussions (FGDs) were conducted, with each having 5–9 participants (total of 49 farmers involved in the focus groups). Some farmers participated in both the survey and FGDs. All farmers were recruited on a voluntary basis.

Regarding the farmers' attendance at the FPCB meetings, 70% of the surveyed farmers reported attendance at most project workshops and other events hosted by the project, with <1% reported attending not many. About 70% of the surveyed farmers also reported learning a large amount of information from the FPCB activities.

About 80% of farmers reported that their new knowledge from the benchmarking workshops was very important, and likewise the same percentage reported it was very important to be a member of a farmer group (Fig. 7.33).

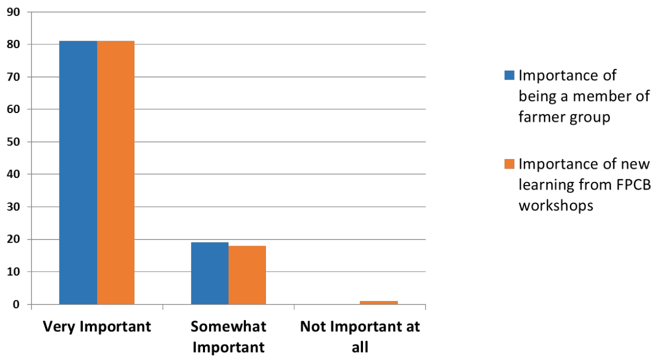


Figure 7.33. Farmers' perceptions about being a member of a benchmarking group and the value of the new knowledge acquired from being involved in the FPCB activities

Six out of seven focus groups identified the need to split fertiliser applications amongst the top three things they learned from the project. This was a key recommendation that arose from the project field trials and benchmarking data. Another key recommendation identified as a top learning by four focus groups was FYM/compost application, and particularly the need to balance FYM/compost and mineral fertilisers.

More than 90% of the surveyed farmers indicated that they made practice change(s) as a result of the FPCB activities. Practice change(s) mainly related to timing, amounts and formulations of fertilisers. The existing practices had been to apply mostly compound fertilisers at planting, with sometimes 1–2 repeat applications in the next 25–30 days. Urea and gypsum (groundnut) or just urea (sesame) were also applied by some farmers with the compound fertilisers. There were several problems with this practice, including:

- Compound fertilisers not supplying the nutrients (particularly N, K and S) required at particular growth stages, or applying P too late to established crops
- Supplying most of the N, K and S during early growth, with significant leaching losses during large rainfall events, and deficiencies occurring later in crop growth
- Not supplying sufficient P, K, and N and S (sesame) or S (groundnut) in many fields.

The practice changes are consistent with action plans from benchmarking workshops in February 2017 (see earlier discussion) and the fertiliser recommendations delivered to the DoA in April 2017 (see Section 10.2.6) and subsequently discussed with the farmers in the benchmarking meetings in May 2017 (all based on 2016 benchmarking data). It was also verified by benchmarking results from 2017. In October 2017, after the monsoon crop and at the end of the post-monsoon crop, farmers said the 2017 crops looked as good or better than normal with the changed fertiliser program.

Substituting compound fertiliser with gypsum or urea can reduce input costs (see earlier discussion, Birchall et al. 2017). Nearly half of LIFT (2012) survey respondents cited fertiliser availability and cost as constraining productivity. Changing fertiliser practices to include more single-element fertilisers also allowed particular elements to be applied at the most appropriate times and rates, potentially increasing yields.

Engagement of women in the farmer participatory crop benchmarking (FPCB) and the role of women in farming decisions

This section is also taken from the Final Report of the xProject C2016/021 'Undertaking research on engaging women and men farmers in participatory research and extension in Myanmar (Farmer Participatory Crop Benchmarking – FPCB)' and is included because it is highly relevant to how this action learning approach of the FPCB might be implemented in the future.

In separate male and female focus group discussions, the decision-making processes of husbands and wives in participating households was examined. Most respondents, both male and female, stated that they made the decisions to change practice together with their spouse. This proved a challenging topic to explore in greater depth and is discussed in greater detail in the Final report of C2016/021.

A key finding of the focus groups' discussions was that women's control of household budgets plays a substantial role in purchase of fertilisers and therefore practice change. The following quotes, from participating farmers in Aung Myay Kone village, indicate the value in having both husbands and wives attend workshops where each of them has access to new agricultural knowledge and learning.

> *Previously I didn't use gypsum much. Although I wanted to, my wife didn't agree because it is too costly, and she controls the household budget. But now we have both attended the farmer workshop and learnt how important gypsum is, my wife also accepts that we use it* ***Male farmer, Aung Myay Kone village***

> *Before, we used 25 kg of urea at the one time. But we learned that the plant can't consume all, and the rest will be leaching. Now we change to apply 10 kg per time over 2 applications. It is more efficient and less costly. Formerly men didn't know about this and after attending the meeting I can also understand and I can negotiate with my husband. He also agreed. F****emale farmer, Aung Myay Kone village***

The gender analysis also highlighted that while many agricultural decisions are jointly made by women and men, if there is a disagreement or difference of opinion, final decisions default to the male household head. This also reflects DoA extension staff perceptions that overall crop management decisions are the responsibility of men, which reflects their default targeting of men for extension service delivery.

Both men and women said that decisions about the use of fertiliser are made by men but, as stated above, making decisions related to the use of inputs are necessarily linked to the women's influence over household budgets. It can be speculated that if women and men both have the same level of access to agricultural knowledge and learning, then deciding to change farming practice is more likely to be done together, as both have the knowledge and the evidence base to decide if and when practice change is a wise investment.

Final comments on FPCB as a research and extension methodology to develop and have adopted improved practices and technologies

Note that the following is an edited version from Section 7.9 of the Final Report of the xProject C2016/021 (see Carnegie et al. 2018 in Section 10.2.6 of this report).

A new and unfamiliar approach to research and extension (R&E)

Not surprisingly, the whole FPCB team, including farmers, scientists and extension officers, were on a very steep learning curve throughout the duration of this work. The FPCB approach represented an R&E methodology for Myanmar that was new and unfamiliar. Previously, i.e. during 2013–16, the MyPulses team had worked with CDZ farmers at a distance in the crop nutrition research, designing simple on-farm unreplicated experiments, for instance on fertiliser responses, and dispatching fertilisers from DAR Yezin with instructions to farmers as to how they would implement the experiments at the multiple sites. Replicated experiments were also conducted on DAR farms, but with little or no input from farmers. In this way, 84 experiments were conducted during 2014–16.

By contrast, the researchers in the FPCB worked closely with farmers, in groups, at just four locations with the work in each village conducted at greater depth than what had been done before. During the two years of the benchmarking, comprehensive information was gathered on a range of factors potentially effecting yield of almost 400 sesame and groundnut crops. The FPCB study was therefore designed to capture multiple factors affecting yield by more intensively examining a greater range of soil, water and agronomic conditions across multiple farmer fields.

As well as taking the novel approach of including farmers as active participants in the research, the FPCB approach involved multiple professionals from different disciplines, i.e. biophysical as well as social scientists, who needed to operate inter-dependently if the project was to succeed. The approach also sought to undertake R&E concurrently across several Myanmar Government agencies. The biophysical and socioeconomic issues monitored were in themselves quite complex, demanding a high level of expertise that needed to be enhanced as the project progressed.

Moreover, the FPCB approach was open to easy dismissal by senior management. It is an unfamiliar approach in that it offers farmers the opportunity to be active learners rather than passive observers of demonstrations. The project also depended on participants engaging in reflection on how things were progressing, which most people practice rarely in day-to-day life – for most people it is something to be learnt through practice.

Moving beyond the traditional understanding of the extension officer/researcher as technical expert and teacher (as per the TOT approach) has been a substantial challenge. With an emphasis on learning, one of the most challenging aspects for all of the team was to transition from teacher/expert to co-learner. Finally, the project purposefully engaged women as farmers, which broke with conventional extension delivery in Myanmar.

Agronomic data collection: delays, data quality and field challenges

The FPCB study did not work entirely as the team had envisaged in the first 12 months, i.e. during the 2016 seasons. The Australia-based project staff had good engagement with farmers in the farmer groups and the eight DoA extension staff. However, gathering data in the Myanmar context from nearly 100 farming families, while ensuring quality control, was challenging. The benchmarking approach required enrolling a minimum number of farmers into the project, to ensure that there were sufficient farmer fields to meet statistical significance requirements for the aggregated data set. The number of treatment interventions was also over-ambitious in the first 2016 season, given project resource constraints and staff capacity. Part of the challenge was distance, as Australian team members, though visiting Myanmar frequently, were not on the ground throughout the growing seasons and were relying on DoA extension staff. Working across English and Myanmar languages added to the complexity.

The crop yield and soil nutrient dataset was large and complicated, and there was a great deal of uncertainty over the veracity of elements of the initial data set, so much so that it was difficult to draw conclusions. Data quality issues identified in 2016 and corrected for 2017 included:

- Baskets and bullock cart sizes were not standard across the four villages, which created problems in recalculating local volume-based data into international weight-based values
- Calculations made of baskets per acre and baskets per field were confused, when fields were of different sizes and this was not taken into account
- Fertiliser strips were smaller than the nominated 0.5 acre size. The correct measurements were later obtained from farmers by using the number of rows and Google Earth to measure plot lengths
- Uncertainty about fertiliser types (brands) and nutrient contents.

Analysis of soil samples revealed the need for greater control over soil sampling, better custody and prompt transport of samples to the laboratory, and improved laboratory procedures, in particular the rigorous use of reliable standards for quality assurance.

Re-checking and cleaning data before undertaking re-analysis of farmer field data was a long process. Following this, the data showed a number of clear trends and key messages could be developed.

The benchmarking methodology relies on dynamic, timely, information that is fed back to farmers in the action learning cycle in a short time frame, so that they can make action plans and decisions on what they will do differently for the next crop. With data from the 2016 monsoon season only becoming available in February 2017, when it had been anticipated it would be available in August 2016, meant that the anticipated immediate feedback from farmers with respect to what was happening on their fields was also delayed. Some of the anticipated momentum for farmer learning and practice change was also subsequently slower than anticipated.

In February 2017, the team reflected on the process of data collection from farmers' fields during 2016. Four key points raised by DoA staff in the reflection meeting were:

- The numerous data quality issues meant the DoA extension staff had to repeatedly question farmers to get clarification. This caused some friction between DoA staff and farmers and an uncomfortable feeling for the DoA staff
- Better communication between non-Magway based project team members and those in Magway, including the Township Manager was flagged as necessary
- DoA extension staff needed extra money for motorbike fuel
- Farmers wanted recommendations.

In response, the project leaders agreed to improve communications by more-systematically informing the Township manager of upcoming activities and allowing him adequate time to arrange staffing requirements. They also agreed to pay the DoA staff for extra fuel needed to collect data.

With respect to the data quality issues, going forward in 2017 the team were much more aware of how to ensure quality control and how to ensure the integrity of the data. This meant that DoA extension staff had less need to ask farmers questions many times, which became a key concern of DoA extension staff in 2016.

Staff turnover and capacity

Loss to the benchmarking of Myanmar DoA extension staff, and the unavailability of other key DoA and DAR staff at critical times impacted project activities. For example, during the two years of FPCB, three of the eight assigned extension staff resigned from DoA to take up positions in the private sector. At times, it was difficult to ensure sufficient Myanmar project personnel to participate in the village benchmarking planning and meetings. This necessitated using DoA and DAR staff from other MyPulses research who were, at least initially, unfamiliar with the benchmarking. All staff had competing obligations and responsibilities. The heavy regular workload of staff in the three key Myanmar partner organisations of DoA, DAR and YAU was notable, as was the increasing demands on their time from various international development agencies.

In addition, the ability to carry forward the work of engaging and advising farmers in the absence of the Australian experts was limited, and further diluted anticipated impacts. This was due not only to the workload of DoA Magway staff, but also to limited technical knowledge and skills in the relevant areas.

Finally, time-demands on Magway DoA extension staff to collect the agronomic data were substantial. In 2016 this became the focus of their work during the monsoon and post monsoon cropping seasons. It meant there was less opportunity to further build capacity to manage farmer groups than anticipated.

7.3.3 Soil water modelling, analyses of climate and climate change

To better understand the opportunities and risks of rainfed cropping on the CDZ, long-term climate data was analysed in combination with soil water modelling to estimate the average length of the growing season and its variability (see Cornish et al. (2018), Section 10.2.1). Taking Magway Township area in the southern part of the CDZ with its sand/sandy loam soils as an example, the average growing season was sufficient for two short-duration crops such as sesame and groundnut (total of 177 days), or an intercrop system combining the two short-duration crops with the long-duration and deeper-rooted pigeonpea (total of 200 days). These findings provided agro-ecological support for the cropping systems in widespread use, but also brought into focus the importance of managing variability around the 'average' growing season.

Rainfall variability can lead to water stress at any time during the growing season, but the greatest risk identified by the study was associated with variable growing season length and the risk of terminal drought, especially with the second crop in a double-crop system. The risk of terminal water stress was of greater concern than the risk of establishment failure of the first crop early in the wet season, provided farmers had the resources to re-plant.

Water balance modelling also revealed the magnitude of deep drainage as a component of the annual water balance. Deep drainage averaged about 10% of the growing-season rainfall and occurred in 60% of years, albeit with large inter-annual variation. Deep drainage was most likely to occur later in the monsoon and be significant for the second crop (termed post-monsoon by local farmers) or at the time of flowering of pigeonpea. The agronomic challenge of deep drainage in sandy soils is leaching of soluble nutrients, most notably N, K and S. The overall conclusion of the modelling was that water use efficiency of both individual crops and cropping systems could be substantially and sustainably increased, but there were significant challenges to doing so.

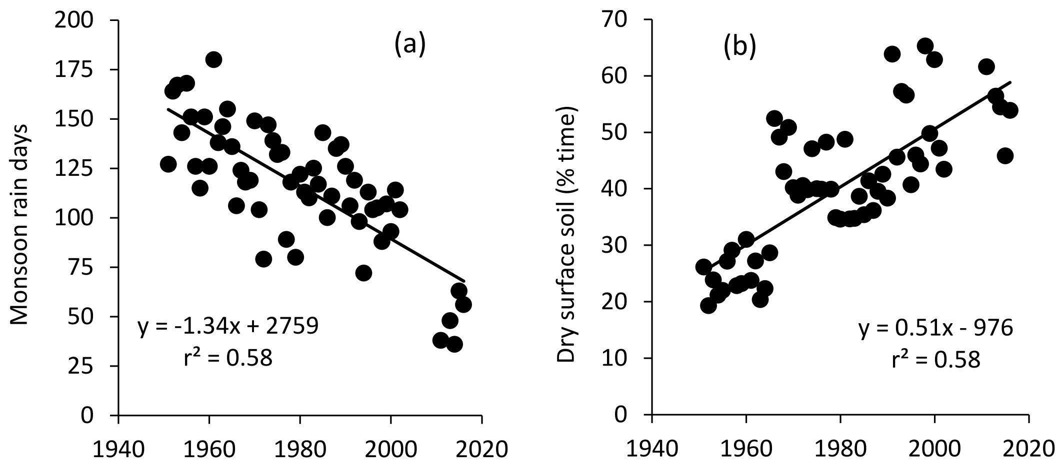


Figure 7.34. The changing frequency of (a) rainy days during the monsoon and (b) its effect on surface soil water. Data for Magway Township in the southern part of Myanmar's CDZ, 1951 to 2016 (Cornish et al. 2018).

Several authors had already documented climate change in Myanmar noting that temperatures were generally increasing as was the frequency of heavy (extreme) and sometimes untimely rainfall events. Analyses of climate change in the CDZ indicated increasing temperatures and increasingly erratic rainfall with some reports suggesting significant declines in total amount (e.g. FAO 2014; ADB 2016). While the decline in rainfall at Magway since the early 1950's had been small and non-significant, the fall in June-July rainfall had been substantial (Cornish et al. 2018). This is the critical period for first crop establishment and may be far more important than a small decline in total rainfall. A further aspect of the changing climate was a sharp decline in the number of rainy days in the growing season, with fewer but larger rainfall events (Figure 7.34a). The immediate consequence of this is an increase in the period of time the soil surface is dry (Figure 7.34b), with implications for organic matter breakdown and crop nutrient uptake as well as for crop establishment.

Predictions of future climate in the CDZ vary although there is universal agreement that temperatures will continue to increase (e.g. ADB 2016). At the same time modelling indicates little change in annual rainfall (ADB 2016) but higher rainfall in the shortening monsoon with reduced rainfall in the dry seasons. The possibility of an increase in extreme rainfall events and flooding in the wet season and more and prolonged droughts in the dry season will create further challenges for the CDZ farmers in an already challenging environment.

7.3.4 Survey of farmers in the CDZ about changes to cropping patterns, fertiliser use, mechanisation and climate

There is a sense that this is a time of substantial change for farmers and their families in the CDZ. In attempting to capture those changes, a survey of 190 famers from 33 villages across the CDZ was conducted during July 2017, organised by project staff in DAR with assistance from extension and management staff in DoA. The survey consisted of questions related to current cropping, 10-year changes in cropping, 10-year changes in the use of draft animals and mechanical implements, 10-year changes in fertiliser use and type and 40–50 year changes in climate and effects on crops. Eight associated focus group meetings were conducted concurrently with the survey.

Data on cropping systems and crop yields for the surveyed farmers were consistent with currently-available data for the CDZ as a whole. Just 18% of farms were fully irrigated, with the remainder relying on rainfall alone (63%) or rainfall plus supplementary irrigation (18%). For the upland systems, crops in descending order of sown areas were groundnut, sesame, pigeonpea, chickpea and green gram. In the irrigated and mixed irrigated/areas, rice dominated with sesame the next widely-grown crop. Average rice yields as reported by the farmers were high, ca. 4.0 t/ha, compared with average sesame, groundnut and pulse yields which were much lower, ca. 0.5–1.1 t/ha.

The survey confirmed that labour shortages are driving mechanisation. Many (75%) of the surveyed farmers now own or rent tractors for primary cultivation and are looking for other tasks that can be mechanised, e.g. planting, weeding and harvesting. Many farmers are also starting to use herbicides for the same reason. However, they have concerns about the long-term effects of the herbicides on the soil and are conscious that they and essentially everybody else in the country know little about the effective and safe use of herbicides.

Use of draft animals remains strong, however, with 93% of the surveyed famers either owning cattle or hiring them. However, as farmers in the CDZ progressively replace draft cattle with tractors, one of the consequences will be the loss of their supply of FYM. The survey confirmed this with farmers are reducing their reliance on FYM for crop nutrient supply and replacing it with mineral fertilisers (Fig. 7.35).

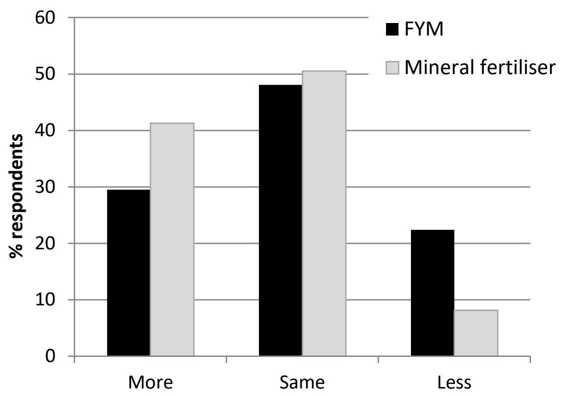


Figure 7.35. Farmers in the CDZ are now using relatively more mineral fertilisers and less FYM that 5–10 years ago.

Clearly as herbicide and mineral fertiliser use increases, there will be an ever-increasing need for expertise about their use and guidance for farmers. This was emphasised in the farmer group meetings time and time again. In the survey, the majority of farmers (58%) considered that they had sufficient information on mineral fertilisers to make good choices about which fertiliser to buy and use. However, that left 42% of respondents either unsure about the adequacy of information or certain that they did not have the necessary information. When asked what information they were looking for, 46% wanted recommendations (application rates etc.) and guidelines for use, 31% wanted market and other relevant economic information, while 17% wanted information on the quality of the fertilisers. Only three farmers wanted information on the nutrient status of their soil.

Dry rot and collar rots of the pulses (incl. groundnut) are an issue, particularly in the heavier clay soils. This is not surprising, given the lack of crop diversity in the CDZ. Pulse (and sesame) yield losses to disease could be substantial in some cases. Yellow mosaic virus is a major problem of black gram in the rice systems.

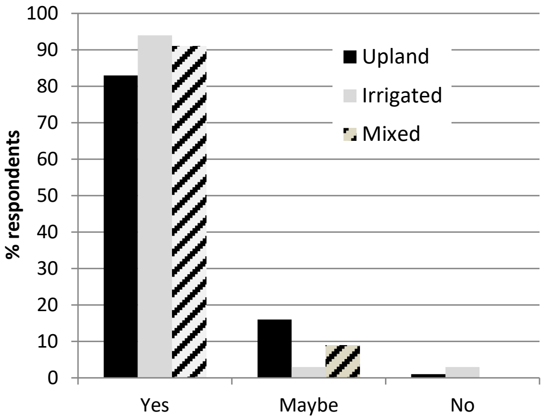


Figure 7.36. Farmers in Myanmar's CDZ, irrespective as to whether they had access to irrigation or not, overwhelmingly believed that the climate was changing and affecting the way they grew their crops.

The majority of farmers (80–90%) that were interviewed in the CDZ think that the climate is changing and the changes are detrimental to their crops (Fig. 7.36). They think it is becoming hotter, there are more droughts (dry spells), less rainfall and the rain when it falls is heavier. They (80%) believe the growing seasons are becoming shorter and there is more yield variation. Some also believe the changing climate is exacerbating insect pressure on their crops. Note that the farmer perceptions and the outcomes of the soil water modelling and climate analysis (seed above and Cornish et al. 2018, Section 10.2.1) are consistent.

7.4 Capacity building for RD&E in Myanmar

During the project, there were 15 individual training activities involving overseas travel for 31 DAR and DoA staff (32% men, 68% women) (Table 7.17). Training ranged from 7 days (conference participation by Dr Mar Mar Win in Morocco) to 4 years (PhD training of U Myint Zaw, Daw Kyin Kyin Htwe and Daw Khin Lay Kyu in Australia). ICRISAT hosted 20 DAR and DoA staff in 5 short-term training activities focussed on legume breeding and seed-production technologies.

Table 7.17. Summary of training, involving overseas travel, of Myanmar scientists and technicians during 2013–18

Details of training, capacity building	Location of training	No. or name of trainees	Institut-ion	Year and time of training	No. participants		
					Men	Women	Total
Conference, laboratory techniques	New Zealand, Australia (UNE)	Dr Su Su Win	DAR	2013/14, 12 days	0	1	1
Pre-breeding crop legume improvement	India (ICRISAT)	U Aung Kyaw Moe, U Kyaw Zin Htun, U San Htun	DAR	2013/14, 11 days	3	0	3
Post-graduate training – PhD	Australia (UNE) and Myanmar	Daw Hla Myo Thwe	*	2013–15	0	1	1
Legume breeding, seed production technologies	India (ICRISAT)	Daw Su Htwe Nge, Daw Thida Aung, Daw Ei Han Kyaw	DAR	2014/15, 19 days	0	3	3
Post-graduate training – PhD	Australia (UNE)	Daw Kyin Kyin Htwe	DAR	2016–19, 4 years	0	1	1
Post-graduate training – MSc	Australia (UNE)	Daw Khin Myo Thant	DAR	2016–18, 2 years	0	1	1
Legume breeding, seed production technologies	India (ICRISAT)	U Kyaw Myo Aung, U Ye Min Thu, U Aye Zaw, U Win Soe	DAR	2015/16, 21 days	4	0	4
Post-graduate training – PhD	Australia (U Adelaide)	U Myint Zaw	YAU	2016–20, 4 years	1	0	1
Laboratory techniques	Australia (UNE)	Daw Thuzar Win	DAR	2017, 28 days	0	1	1
Legume breeding, seed production technologies	India (ICRISAT)	Daw Pyae Phyo Thi, Daw Su Htwe Nge, Daw May Myat Thu	DAR	2017–18, 4 months	0	3	3
Seed production technologies	India (ICRISAT)	Daw Zun Zar Hlaing, Daw Aye Aye Khaing, U Htun Aung Kyaw, U Nay Myo Aung, Daw Tin Mar Win, Daw Nwe Nwe Lay, Daw Aye Aye	DoA	2017, 1 month	2	5	7
Rhizobium inoculant technology	Australia (U Adelaide)	Dr Maw Maw Than, Daw Nilar	DAR	2017, 13 days	0	2	2
Post-graduate training – PhD	Australia (U Western Australia)	Daw Khin Lay Kyu	DAR	2017–21, 4 years	0	1	1
Post-graduate training – MSc	Australia (UNE)	Daw Thuzar Win	DAR	2018–21, 3 years	0	1	1
Conference participation	Morocco	Dr Mar Mar Win	DAR	2018, 7 days	0	1	1

During 2013–18, the 15 training and workshop activities in Myanmar involved a total of 1,920 staff and students from DAR, DoA and YAU (32% men and 68% women) (Table 7.18). The training covered a wide range of topics including chemistry laboratory analytical procedures, rhizobial inoculants production and QA, soil water measurement, IPM and village seed bank production and storage.

Table 7.18. Summary of on-site, i.e. in Myanmar, training of Myanmar scientists and technicians during 2013–18

Details of training, capacity building	Location	No. or name of trainees	Trainer, institution	Year and time of training	No. participants		
					Men	Women	**Total**
Soil chemistry laboratory – analytical procedures	DAR, Yezin	5 staff from DAR	Ms Gabrielle Ray, UNE	2013/14, 13 days	0	5	**5**
Soil chemistry laboratory – analytical procedures	DAR, Yezin	7 staff from DAR	Ms Gabrielle Ray, UNE	2014/15, 11 days	0	7	**7**
Soil chemistry laboratory – analytical procedures	DAR, Yezin	4 staff from DAR	Ms Gabrielle Ray, UNE	2014/15, 12 days	0	4	**4**
Soil chemistry laboratory – analytical procedures (x10)	DAR, Yezin	4–8 staff from DAR	Dr Chris Guppy, UNE	2012–18, 50 days	0	8	**8**
Soil Rhizobium laboratory (x10)	DAR, Yezin	2–5 staff from DAR	Dr Matt Denton, U Adelaide	2012–18, 50 days	1	4	**5**
Post-graduate training – PhD	Myanmar (YAU)	U Aung Kyaw Thu	Dr Khin Mar Htay, Mr Craig Birchall, YAU	2013–16	1	0	**1**
Nutrient management, nutrient deficiencies of crops in the CDZ (x6)	DAR, Yezin; YAU, Yezin; Magway, Nyaung Oo	450 staff from DAR, DoA and YAU	Dr Chris Guppy (UNE)		100	350	**450**
Soil water measurement, agronomy (x6)	DAR stations at Yezin, Nyaung Oo and Magway	70 staff from DAR and DoA	Mr Craig Birchall, UNE	2014/15	80	160	**240**
Legume technologies, including breeding, insect management, pathology	DAR, Yezin	70 staff from DAR and DoA	ICRISAT, UNE, U Adelaide	2015/16	25	45	**70**
Village seed bank – scheme, production, storage etc	Magway, Mandalay, Sagaing Regions, Nay Pyi Taw UT, Yangon	566 staff from D0A, NGOs, private seed companies, DAR	Dr San San Yi, DoA	2015–18	266	300	**566**
IPM	DAR, Yezin	42 staff from DAR and DoA	Dr GV Ranga Rao, ICRISAT	2016, 2 days	4	38	**42**
Training seminar-workshops on IPM (x5)	Yangon, Myingyan, Magway, Monywa, Yezin	151 staff from DoA, DAR	Dr GV Ranga Rao, ICRISAT	2017, 1 day	80	150	**230**
Rhizobial inoculants techniques, strain maintenance	YAU, Yezin	18 students, staff from DAR and YAU	Ms E Hartley, Mr G Gemell, Australia	2017, 12 days	5	13	**18**
Rhizobial inoculants, production and QA	DAR, Yezin	10 students, staff from DAR and YAU	Ms E Hartley, Mr G Gemell, Australia	2017, 11 days	2	8	**10**
Crop benchmarking, crop nutrients, fertilisers (x3)	DoA, Magway DAR, Yezin	255 staff from DoA, DAR	Mr Craig Birchall and colleagues, UNE	2017–18	55	200	**255**

A total of 30 small projects including PhD and MSc projects were funded at YAU during 2015–18, including 9 from YAU Agronomy, 14 from Soil and Water Management and 7 from Plant Pathology (Rhizobiology). A total of 43 academics and students were involved in the projects, 33 (77%) of which were women and 10 men (23%). Seven of the funded projects were for post-graduate students (6 MSc and 1 PhD).

During the term of MyPulses including the pre-project scoping missions, there was a total of 131 individual site visits to Myanmar by Australian (83 visits) and ICRISAT scientists (48 visits) (Table 7.19). The travel was evenly spread across the 7 years.

Table 7.19 Travel to Myanmar by Australian and ICRISAT scientists during 2011–18. Note 2011–13 travel associated with project development and implementation.

Names	Role	2011–14	2014/15	2015/16	2016/17	2017/18	Total
Australian							
Herridge	Project leader	7	3	2	3	4	**19**
Birchall	Agronomy, crop benchmarking	5	3	4	5	4	**21**
Denton	Legume inoculants	6	2	4	3	4	**19**
Guppy	Nutrient management	6	2	2	2	3	**15**
Ray	Soil chemistry laboratory, training	1	2	*	*	*	**3**
Cornish	Crop benchmarking	*	*	1	1	*	**2**
Gemell/Hartley	Rhizobium laboratory, training	*	*	*	*	4	**4**
ICRISAT							
Gaur	Chickpea breeding	2	*	2	3	2	**9**
Ranga Rao	Coordination, IPM	3	3	2	1	1	**10**
Saxena	Pigeonpea breeding	1	*	*	*	*	**1**
Sameer Kumar	Pigeonpea breeding	*	2	1	1	*	**4**
Hingane	Pigeonpea breeding	*	*	*	*	2	**2**
Upadhyaya	Groundnut breeding	1	1	1	*	*	**3**
Janila	Groundnut breeding	*	*	*	1	2	**3**
Charyulu	Economics	*	2	1	2	3	**8**
Whitbread	ICRISAT management	*	*	*	2	*	**2**
Rao/Gosh/Reddy	Various	2	4	*	*	*	**6**
Grand Total		**34**	**24**	**20**	**24**	**29**	**131**

Even though the training and capacity building activities were substantial in number and scope, 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.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project's scientific impacts included:

- An improved understanding of effects of rainfall patterns of the CDZ on cropping, particularly related to nutrient acquisition. Soil texture analysis combined with climate analysis and soil water modelling determined the potential for quarantining of immobile P in the drying surface soil and leaching of mobile N, K and S deep into the profile beyond the root zone (see Section 7.3.3 and Cornish et al. 2018. Section 10.2.1)
- An improved understanding of the major constraints to productivity and sustainability of cropping in Myanmar's CDZ. Analysis of data from the MyPulses participatory rural appraisal (PRA) in 2012, a 319-field soil survey in 2013, comprehensive surface and deep soil sampling during FPCB activities in 2016–18 and a 190-farmer survey of changes to cropping in the CDZ conducted in 2017, together with published knowledge and information about the CDZ, were used to draw conclusions. The study, conditionally accepted for publication in Agricultural Systems (see Herridge et al. (2018) in Section 10.2.1) concluded that the CDZ was fragile and that farming practices were changing through necessity, principally because of declining labour availability, climate change and the volatile nature of grain markets. As a consequence, the study recommended widespread adoption of conservation agriculture practices, embracing the basic elements of crop diversity, effective weed control, *in situ* retention of crop residues, optimised crop nutrition and minimal-to-zero soil disturbance.
- Highlighting the benefits of crop residue retention on water storage and availability in soils (average 17% increase over traditional residue management) , resulting in an average 35% increase in crop WUE and 36% increase in crop yields (see Thu et al. 2016, Section 10.2.1 and Thu PhD thesis (2016) in 10.2.2)
- Development of farmer participatory crop benchmarking (FPCB) as an effective research-extension methodology for Myanmar. The 2-year program was conducted in the Magway Township area of the southern CDZ, involving 94 farming families. The FPCB was intensive with 36 farmer group meetings as well as numerous field inspections. At the same time, it proved effective as a vehicle for on-farm nutrition experiments as well as identifying best agronomic and nutrient management practices and previously unidentified constraints to crop productivity. The latter included leaching of mobile nutrients beyond the root zone, widespread S deficiency in sesame and groundnut because of poor timing of fertilisers combined with low rates of application, and the potential problem of hollow heart of groundnut because of boron (B) deficiency (see Carnegie et al. 2019 (submitted) in Section 10.2.1; series of refereed conference papers in Section 10.2.3).
- Revision of recommendations for major nutrient inputs (N, P, K and S) for groundnut and sesame, based on the 400-field data from the Magway Township area FPCB. A prototype decision support (DS)-tool for FYM and mineral fertiliser management, to be used by farmers and extension officers, was developed from the data set. To increase the potential impact of the tool, the aim is to transition it to a web-based product that can be readily accessed on mobile devices by farmers and extension officers.

8.2 Capacity impacts – now and in 5 years

A major focus of MyPulses was to build scientific capacity in Myanmar at the DAR and the YAU, Yezin, and extension capacity at DoA using expertise in Australia and at ICRISAT. Throughout the 5 years of the project, there has been a strong emphasis on post-graduate and short-term training, the physical capacity building of the DAR soil chemistry and microbiology laboratories and purchase of key resources using project funds. Impacts of the capacity building activities are difficult to quantify in the short-term and some of the activities are ongoing, but it may be instructive to summarise the activities themselves.

Since 2013, formal post-graduate and short-term training has been conducted in Australia and at ICRISAT for 31 DAR, DoA and YAU staff (see Table 7.17). There have also been in-country training workshops, seminars, demonstrations and on-site training for DAR, DoA and YAU staff and for other non-Government personnel by Australian and ICRISAT scientists as well as by the Myanmar project team. These activities, summarised in Table 7.18 involved a total of 1,920 persons. A summary of capacity building activities:

- Twenty persons from DAR and DoA received short-term training at ICRISAT in legume breeding and seed production during 2013–18
- Four persons received short-term training in soil chemistry and rhizobiology in Australia during 2013 and 2017.
- Two PhDs, Aung Kyaw Thu (2016) and Hla Myo Thwe (2016), and one MSc, Khin Myo Thant (2018) awarded
- Three PhDs, Daw Kyin Kyin Htwe, U Myint Zaw, Daw Khin Lay Kyu and one MSc, Daw Thuzar Win, currently at Australian universities.
- 30 small projects including PhD (x1) and MSc projects (x6) were funded at YAU in agronomy, soil and water management and rhizobiology
- Dr Mar Mar Win participated in the Int. Food Legumes Conference, Morocco, in May 2018
- More than 50 training activities, including workshops, on-site training etc. conducted during 2013–2018 on Rhizobiology, IPM, crop nutrition, soil water, plant and soil nutrient analysis, pulse technology, participatory crop benchmarking and village seed bank technologies
- About 180 field days and farmer meetings involving 7,870 farmer participants, NGOs and DoA/DAR extension staff, conducted during 2013–2018 (Table 8.2)

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

The estimated 1.2 million CDZ farmers cultivate 3.3 Mha land to grow 5.5 Mha grain crops. The cropping is principally upland (75%) with major crop types the 2.5 Mha pulse (e.g. chickpea, pigeonpea) and oilseed legumes (groundnut) and 1.5 Mha of the non-legume oilseed crops, sesame and sunflower. The gross annual value of upland cropping is estimated at about A$2 billion. It was anticipated that potential economic impacts of MyPulses would result from increased productivity through improved varieties, improved soil nutrient, fertiliser and agronomic management as well as from increased areas of upland cropping.

One example of realised economic benefits of MyPulses was captured in the impact assessment of the VSB program (see Kumara Charyulu et al. (2018) in Section 10.2.6). The VSB program was initiated in 2015 by the DoA for production, distribution and adoption of pure, high-quality seed of improved cultivars of pigeonpea, groundnut and chickpea by farmers in the CDZ. The improved cultivars had all been bred, evaluated and released as part of MyPulses and its predecessor SMCN/2006/013. The impact assessment of the 3-year program, conducted in December 2017, indicated that almost 1,600 farmers from 500 villages received seed directly from the DoA and an additional 83,000 farmers potentially received seeds produced in the VSBs via informal (farmer-to-farmer) distributions. Benefits of the VSB program included access by farmers to better quality seed and improved crop and seed production knowledge, resulting in increased grain yields and profitability. Grain yields of improved VSB cultivars were, on average, 39–55% higher than yields of the farmer cultivars. The yield benefits combined with the potentially large number of farmers accessing the improved VSB cultivars equated to a potential economic impact of A$33 million during the 3 years of the program (Table 8.1).

It is also worth noting that the MyPulses VSB program was a catalyst for implementation of a number of other seed production and distribution programs in Myanmar and was used as a model for those programs. Included were DoA regional, state and national seed programs for rice and oilseed crops (principally sesame) and Myanmar private sector rice and pulse seed programs. Dr San San Yi, DoA, led the VSB program for this project and her advice on how the DoA and private sector groups might set up similar programs has been widely sought.

Table 8.1. Potential impact (annual A$ benefit) of the VSB scheme in Myanmar's CDZ during 2016–19

Crop	No. farmers reached	Improvement in Net Margin (A$/ha)	Area target legume planted (ha)	% of legume area as improved cultivar	Benefit (A$/year)
Pigeonpea	55,744	210	1.66	38	**8,800,000**
Chickpea	26,950	650	2.15	65	**24,500,000**
Groundnut	762	440	0.97	28	**90,600**

Finally, there is strong interest from commercial companies/NGOs, such as the Awba Group and Syngenta Foundation for Sustainable Agriculture (SFSA), in producing, distributing and marketing improved varieties of a range of crops in the CDZ including the pulses and oilseed legumes. A new and well-funded Awba-LIFT program commenced in early 2018 with objectives to produce, store, distribute and sell seeds of about 10 crop species in the CDZ, essentially as a commercial enterprise. The consortium intend being involved in extension and training and will set up a network of farmers for seed production. They don't intend to get heavily involved in research but may conduct farmer demonstration activities. They want to take seed production and distribution to a much larger level than could be achieved by MyPulses, through their expertise, networks and financial resources. They are keen to establish strong links with the now well-established pulse and oilseeds breeding programs at DAR, Yezin, and to use DAR-produced material. They are also keen to work with the DoA to utilise their extension and farmer networks in conjunction with their own. The principals of the new Awba-LIFT consortium are generous in their praise of the breeding and seed distribution activities of MyPulses and consider this new initiative an impact of the project.

8.3.2 Social impacts

Potential social benefits of this project could be as significant as the economic impacts. Direct impacts are likely to be improved livelihoods for farming families and improved food supply and quality of food for rural households, critical in reducing malnutrition and enhancing well-being. Also, when food is deficient there is a tendency for men to seek work off-farm, isolating them from their families and, at the same time, intensifying the workload of the women left behind. Thus, increased availability of food legumes and other crops will ensure a more balanced and protein-enriched diet for men, women and children, as well as reducing the pressure for men to seek off-farm work. Increasing legume and farming system productivity with the projected economic benefits should also have a flow-on effect for children's education.

A second gender-specific impact was the opportunity for women to be involved in the Village Seed Bank (VSB) and the Farmer Participatory Crop Benchmarking (FPCB) programs. The 3-year VSB directly involved 1,592 farmers from about 500 villages and indirectly involved, through farmer-to-farmer seed trading, an additional 83,000 farmers. No specific gender analysis was done on the role of women in the VSB scheme, but we can note that about 30% of participants in the VSB field and farmer days on the VSBs organised by the DoA were women (See Table 8.2).

On the other hand, impact analysis of the 2-year FPCB program in the Magway Township area indicated a very positive outcome for women, and for the family as a whole. For the first time, women were accessing new technology at the same time as their farmer husbands with the result that decisions about adoption of the new technologies were made jointly with both parties being well informed of the options. According to the evaluation, this had a positive effect on the decision (see Section 7.3.2. about the engagement of women in the FPCB and the role of women in farming decisions; see also Carnegie et al. (2019) in Section 10.2.1, and Carnegie et al. (2018) in Section 10.2.6). Traditionally in Myanmar farming, tasks are well defined with the male farmer the custodian of the farming knowledge and technologies and the female partner managing the family finances. Thus, adoption of new and potentially income generating practices were often stalled because of the lack of common ground for discussion and decision making.

8.3.3 Environmental impacts

This project should impact positively on the environment through improved crop productivity leading to potentially greater inputs of organic matter to the soil, coupled with reduced erosion. Enhancement of soil organic matter, being a food for microorganisms, improves availability and efficiency of use of N, P, S and other plant nutrients for crop growth, thereby reducing the requirements for synthetic fertilisers. With biologically-fixed N from the pulse and oilseed legumes bound into organic residues and slowly released into the soil system, the potential for leaching of N from the root zone into the subsoil and ground water is minimised, thereby increasing efficiency of usage and reducing pollution. Nitrate in ground water has serious consequences for human health. With increased adoption of efficient crop management options, the inputs of plant protection chemicals may decrease, thereby benefitting the communities through supply of residue-free products and protection of natural resources. Any negative impact from introducing farmers to new pesticides is to be managed by developing and making available farmer courses on safe effective use of pesticides.

Concerns were raised by farmers at a number of the group benchmarking meetings about the quality of fertilisers that they were purchasing in the local markets. They were concerned that the fertilisers did not contain nutrients at the levels claimed on the bags. Results indicated that from the 75 samples, there were just three that did not meet label requirements. Significantly and just as important, no heavy metal contamination was detected in any of the samples. This was a very positive result and proved to be consistent with fertiliser analysis for heavy-metal contamination conducted independently by other groups, e.g. University of Melbourne, at about the same time.

8.4 Communication and dissemination activities

Extension and outreach activities of MyPulses are summarised in the Table 8.2. Note numbers of participants are the recipients of the training and extension activities and do not include the numbers of project scientists involved in the activity. A total of 180 MyPulses outreach/extension activities were conducted involving 7,870 farmers.

Note also that the DoA also distributed 210,000 copies of extension pamphlets related to MyPulses during 2015–18. Topics included:

- Pigeonpea cultural practices & characteristics of new varieties
- Chickpea cultural practices & characteristics of new varieties
- Groundnut cultural practices & characteristics of new varieties
- Green Gram cultural practices & characteristics of new varieties
- Black Gram cultural practices & characteristics of new varieties
- Village Seed Bank system

- Pulses post-harvest handling

Table 8.2. Summary of extension and outreach activities of MyPulses during 2014–18

Type of activity	Details	Venue	Dates	No. participants		
				Men	Women	Total
Field days (100)	Village seed bank – scheme, cultivars, production, storage etc	Magway, Mandalay, Sagaing Regions	2015/16 2016/17 2017/18	2,880	1,480	4,360
Field days (10)	Pigeonpea varieties and specific traits, e.g. drought tolerance	Magway, Mandalay, Sagaing Regions	2014/15 2015/16 2016/17 2017/18	400	200	600
Field days (8)	Groundnut varieties and specific traits, e.g. drought tolerance	Magway, Mandalay, Sagaing Regions, Nay Pyi Taw UT	2014/15 2015/16 2016/17 2017/18	400	150	550
Field days (18)	Chickpea varieties and specific traits, e.g. drought tolerance	Magway, Mandalay, Sagaing Regions	2014–18	800	310	1,110
Field days, farmer and DAR/DoA demonstrations (x4)	Mechanical planters	Tatkone, Magway, Nyaung Oo and Zaloke DAR farms	March 2016	105	45	150
Field days, training workshops (x2)	Trichoderma and fungicides	Myaing	April , May 2017	160	100	260
Field days, farmer workshops (x3)	Legume inoculants	Mandalay, Sagaing Regions	Jan 2016	75	45	120
Farmer meetings, field days (x36)	Crop benchmarking, crop nutrients, fertilisers	Magway	May 2016–July 2018	500	220	720

9 Conclusions and recommendations

9.1 Conclusions

Notwithstanding the efforts of SMCN/2011/047 (MyPulses), detailed in Sections 4–8 of this report, there remains considerable scope to improve the productivity of CDZ cropping systems. Our data from >1,200 observations indicate average crop yields are 42 and 50% of the best-farmer yields for chickpea and rice in rice-based lowland systems and 30–35% for sesame, groundnut, pigeonpea and green gram in upland systems. Analysis of the long-term soil water balance supports this conclusion, suggesting a large increase in average yields should be possible in the upland monsoon crops and in post monsoon crops with the economic risks being managed through an opportunistic approach to inputs (Cornish et al. 2018). However, there are significant barriers to realising this.

9.1.1 Breeding and release of high-yielding varieties of pigeonpea, groundnut and chickpea

The spread of improved varieties of the major legume crops across the CDZ is mixed. About 96% of the estimated 275,000 ha chickpea crops are recently-released, high-yielding varieties compared with about 30% of the 530,000 ha pigeonpea and just 5–10% of the 570,000 ha groundnut crops. For pigeonpea, groundnut (and the 580,000 ha green gram) it means that 70–90% of the crops grown are local landraces and old varieties. Not surprisingly, farmers in the CDZ consider lack of access to new, high-yielding varieties as a major constraint to farm productivity and profitability.

The Food Legume and Oilseed sections of the DAR, supported by ICRISAT (and the World Vegetable Centre), have maintained active breeding/crop improvement programs for pigeonpea, groundnut, chickpea (and green gram) for many years now with new varieties regularly released. For example, new high-yielding varieties of chickpea were released in 2016 (Yezin 12) and 2018 (Yezin 13). Likewise, groundnut variety Sinpadetha 11 was released in 2010, Sinpadetha 12 released in 2013 and Sinpadetha 13 (YZG-98017) released in 2015. Sinpadetha 14 (YZG-08075) and Sinpadetha 15 (YZG-04123) were scheduled for release in 2018, but that decision has been delayed. In the crop improvement themes of MyPulses and its predecessor, SMCN/2006/013, the mother-baby trial design was successfully used as part of farmer participatory varietal selection (FPVS). The methodology engaged about 4,200 farmers across both projects in the evaluation and final selection of genotypes for commercial release and in their promotion. Partnering farmers in varietal selection also showed its value with the non-release of the very high-yielding chickpea genotype, ICCV 08106, because it’s long duration and red seed coat were not acceptable to the farmers.

Clearly, well adapted, high yielding varieties of the major legume crops are being produced in Myanmar by the DAR. The breeding and genotype selection must continue to produce future varieties with even higher yields and with particular traits such as disease resistance, oil content, seed size, maturity types etc., that impart agronomic advantages and meet market requirements. It is imperative also that ICRISAT continue to support pigeonpea, groundnut and chickpea improvement in Myanmar with supply of relevant, elite germplasm and with high-quality training in crop breeding, disease screening and seed production technologies for DAR and DoA personnel.

9.1.2 Farmer access to high-yielding varieties of pigeonpea, groundnut and chickpea

There are about 1 million farmers in the CDZ currently cultivating pigeonpea, groundnut and chickpea as part of their farming systems. The majority of these farmers, however, do not have access to the new, high-yielding DAR varieties referred to above. They are part of Myanmar's informal seed system in which seed is saved by the individual farmer from one year (season) to be used in the next year (season), purchased from or exchanged with other farmers or purchased from the local grain market. One estimate is that the informal seed system accounts for about 95% of the seed planted by farmers (van den Broek et al. 2015). By difference, just 5% of planted seed are part of the intermediary or formal seed systems. It follows, therefore, that until the new, improved varieties become part of the large, informal seed system, they will not be accessed and used by the majority of farmers. Of course, this may change as the intermediary and formal seed systems expand but that expansion may take some time to occur.

In an effort to introduce good-quality seeds of new, improved varieties into the informal seed system, the village seed bank (VSB) scheme was implemented by the DoA in 2015 and managed as part of MyPulses for the next three years. It was highly successful, with a potential reach of 83,000 farmers (see Section 7.1.4) and having a potential economic impact of A$33 million (Section 8.3.1). As stated previously, Dr San San Yi, DoA, managed this program and her advice on how the DoA and private sector groups might set up similar programs for other crops and localities has been widely sought. Significantly, the new OFID-ICRISAT project that will continue the collaboration of the DAR groundnut improvement group with ICRISAT breeders will use the VSB model to disseminate improved varieties.

9.1.3 Soil organic matter, crop nutrition and fertilisers

Crop nutrient deficiencies are widespread across the CDZ and a major productivity constraint (Guppy et al. 2017). The soils are nutritionally deficient (Tables 7.12, 7.14) and nutrient inputs from FYM and mineral fertilisers are also generally low (Gregory 2015; MOALI 2016; Birchall et al. 2017). However, FYM provides the foundation for crop nutrition for most farmers at present. Efficient use of rainfall is not possible with low nutrient inputs, especially as soil organic matter is already low and provides little nutrient buffering. Not only is the system less productive than it need be, but it is ultimately unsustainable.

One reason for low soil organic matter is that farmers commonly remove all above-ground crop residues with the harvested grain, using the residues for animal feed and returning only a fraction in FYM. This compromises the efficient recycling of nutrients between crops, and organic C inputs to soil are reduced. Because crop residues and soil organic C help to protect the soil from physical damage, the removal of crop residues increases the risk of erosion and the further loss of crop nutrients associated with soil loss (Tilman et al. 2002; Tun et al. 2015). Therefore, in terms of both soil fertility and erosion management, there is a compelling argument in favour of greater *in situ* crop residue retention, *albeit* with implications for animal nutrition.

Mechanisation and reduced ownership of draft animals will result in an inevitable decline in the availability of FYM and farmers will have to rely more and more on mineral fertilisers. The transition from organic fertilisers, providing a slow release source of relatively balanced nutrition, to more labile mineral fertilisers will require skill on the part of the farmer to deliver effective crop nutrition. The 2017 MyPulses survey indicated that farmers are generally using more mineral fertilisers than 5–10 years ago (Fig. 7.35) but they also recognise that they lack the knowledge of how to optimise crop fertiliser use and, in many cases, the funds to buy them. MyPulses research into the complementary use of FYM and mineral fertilisers and into fertiliser strategies such as split-application that potentially improve fertiliser-use efficiency by reduce leaching losses is a start to addressing those issues (see section 7.3.2, also Birchall et al. 2017; Cornish et al. 2018). There is a need for further research with the outcomes to be incorporated into effective extension programs that translates research outcomes to farmer practice.

9.1.4 Cropping system agronomy and climate change

There is a lack of crop diversity in the upland (and lowland) systems of the CDZ that renders the crops to soil-borne diseases. The ratio of broadleaf (groundnut, sesame and the pulses) and cereal crops is currently ca. 10:1 in the upland systems (75% of CDZ cropping). Data from the 2017 CDZ farmer survey (Section 7.3.4) confirmed the ratio of broadleaf crops to cereals to be not only large but indicated that it was slowly increasing, driven by market forces, climate change, reduced demand for cereal-based animal feed and labour shortages.

Predictably, the CDZ farmers identified root and collar rots of the pulses, groundnut and sesame as major issues which, in extreme cases, can result in a total loss of yield. All are soil-borne diseases with the causal agents transmitted via crop residues. Removing crop residues from the fields may provide some relief by reducing disease inoculum levels (Veena et al. 2014). However, rotating different crops in the sequence to reduce disease inoculum levels is universally recognised as the most effective means of managing the problem (e.g. Kirkegaard et al. 2008).

The shortage of labour at critical times, such as sowing, weeding and harvesting, is a constraint to crop productivity in the CDZ (e.g. LIFT 2014) and is largely responsible for the drive for mechanisation (Section 7.3.4. The farmers' perceptions of climate change as a constraint broadly agree with published reports based on weather data and modelling (Fig. 7.36; Cornish et al. 2018). About 90% of the surveyed CDZ farmers, irrespective of whether their cropped land was rainfed or irrigated, considered the climate to be warming with rainfall occurring in fewer but larger and sometimes unseasonal events. MyPulses climate analysis and soil water modelling indicated also that rainfall is declining in the June or June-July period, a critical time for crop establishment in the upland systems (Cornish et al. 2018). At this stage, the upland farmers are partially adapting to the changing climate by planting later and being prepared to replant if seedlings perish in the absence of follow-up rainfall. As the climate continues to change, more system changes will be necessary.

9.1.5 Threats to sustainability of cropping in the CDZ

Because the majority of cropping in the CDZ is currently low input, low productivity and based on cultivation and crop residue removal, the threats of surface soil degradation and loss may be more critical than other sustainability issues such as pollution from soil nutrients, pesticides and fertilisers leached into groundwater and surface waters. This will change over time. For example, as the use of mineral fertilisers continues to increase, the potential for leaching of N, K and S, as well as other mobile elements, into groundwater resources will also increase. Soil degradation and loss are also likely to be greater in the upland systems of the CDZ than in the irrigated and rainfed lowland (rice-based) systems. Bunded rice paddies are somewhat protected from erosive forces in contrast to the upland areas that are more sloped and exposed to the weather (Vaughan and Levine 2015).

Quantifying the scale of soil degradation and loss in the cropping systems of the CDZ is problematic. The results of modelling indicating potentially high rates of erosion in Myanmar (Tun et al. 2015) may be misleading because of the scanty data available for the research. The rainfall analysis of Cornish et al. (2018) in the Magway region showed that the average growing season rainfall of 668 mm falls on an average of 177 days, resulting in an average daily rainfall of merely 4 mm. They found that since 1950, only one-third of years have had even a single rainfall event (day) of more than 50 mm of rain. This does not suggest a generally high risk of erosion, rather erosion restricted to high-risk areas such as steeper slopes or soils with impeded drainage. What is also important is that rain appears to be falling in fewer, bigger events, so the risk of erosion is likely to be increasing.

9.1.6 Farmer participatory crop benchmarking (FPCB)

In response to the recommendations of Prof Peter Cornish and Dr John Ba Maw in MyPulses 2015 mid-term review, FPCB was implemented in early 2016 in partnership with 94 farming families from four villages in the Magway Township area. The subsequent two years of crop benchmarking indicated 10-fold differences in yields amongst farmers' fields receiving similar rainfall, with some fields approaching the water-limited potential. There would appear to be scope for the farmers managing the lower-yielding fields to greatly improve yield with current technology. The research confirmed the generally low fertility status of soils in the southern CDZ, found a wide range of nutrient application rates from too little to large excess, provided guidelines and a draft DS tool for choosing appropriate fertiliser rates, and found evidence that leaching of mobile nutrients may be a key factor limiting yields. The implementation of FPCB was critical to progressing our understanding of the previously (2014–16) puzzling, variable responses to fertiliser (nutrient) inputs.

A thorough analysis of the successes and shortcomings of the MyPulses FPCB activities was undertaken by Dr Michelle Carnegie in the xProject C2016/021 and details of that analysis can be found in Carnegie et al. (2018) in Section 10.2.6. Perhaps the key finding was that it was a radical departure for the DoA and DAR in how they have traditionally conducted research and extension. The MyPulses FPCB embraced the concepts of farmers as partners in research leading to action rather than passive learning, of working with groups of farmers, rather than individuals, and of including women in the group activities. It tried, with varying degrees of success, to move away from the traditional one-way transfer of technology (TOT) model to a co-learning model whereby farmers and researchers/extension agents gained new knowledge and solve problems together.

Evaluation of the two years of FPCB also indicated that farmers were happy to participate in the benchmarking, that they modified their fertiliser practices as a result of the participation and that the fertiliser changes had a positive impact on yields and profits (see details of the evaluation in Carnegie et al. 2018). Significantly, 70% of the surveyed farmers reported attendance at most of the (36 in total, 9–10/village) meetings, workshops and other FPCB events, with <1% reported attending not many. About 70% of the surveyed farmers also reported learning a large amount of information from the FPCB activities. About 80% of farmers reported it was very important to be a member of a farmer group. Overwhelmingly, the benchmarking farmers were keen to continue with the program.

9.1.7 Engagement of women in technology transfer in the FPCB activities and the role of women in farming decisions

Another key objective of the xProject was to examine the engagement of women as farmers in the FPCB and subsequent farm decision making. According to the report by Carnegie et al. (2018) (see Sections 10.2.1 and 10.2.6), women participated well, but said there were barriers to their full participation in meetings and other project activities because of them having to fulfil household duties. Overall, women gained access to new knowledge from which they would ordinarily have been excluded. The project evaluation demonstrated that participating female farmer's understanding of the key project messages based on scientific learnings was similar to that of male farmer participants.

Given the short timeframe of the FPCB, it was too early to assess whether women had a greater role in decision making for farm related matters. One emerging finding, however, was that women's influence over family financial matters was clearly related to their influence over farm related matters. Men are the main decision makers for the type and amount of agricultural inputs to purchase. At the same time, women have more responsibility for, and influence over, household budgets, and men may have to convince their wives when they want to change household expenditure priorities. The FPCB evaluation indicated that involving women farmers was beneficial for joint agricultural decision making with their husbands on issues that required investing household funds.

9.1.8 Conservation agriculture: the way forward?

Widespread adoption of best-practice conservation agriculture principles by CDZ farmers should have environmental, economic and social benefits. In conservation agriculture, adequate crop nutrients are supplied with high efficiency and tillage and residue-management practices are implemented that retain biopores for good macrostructure and drainage, protect the soil surface from physical damage, and return sufficient organic matter to foster efficient cycling of nutrients and healthy soil biota. Conservation agriculture systems include a variety of broadleaf and cereal crops to reduce disease and weeds and insect pests are managed efficiently.

To make it happen, farmers need high-quality technical advice from Government and commercial scientists, advisers and technical experts about modern farming practices and the efficacious use of mineral fertilisers, herbicides and pesticides. Although the general principles of conservation agriculture are well known, there is a need in Myanmar for research into the application of those principles to the unique biophysical and socio-economic environment of the country. To that end, the post-graduate study of Dr Aung Kyaw Thu was ground-breaking in highlighting the substantial benefits of crop residues on soil water capture and storage (average 17% increase), grain yield (average 35% increase) and crop WUE (average 35% increase) (see Thu 2016, Section 10.2.2).

A participatory approach to this research, as used in the FPCB, should effectively address the challenge of modifying entrenched thinking and long-established practices. Until changes occur, however, productivity of cropping in the CDZ will remain low and may even decline further.

9.2 Recommendations

Recommendation 1 – Continuation of the breeding and genotype selection of the pulses and oilseed legumes by DAR to produce future high-yielding varieties with particular traits such as disease resistance, oil content, seed size, maturity types, mechanical harvestability etc., that impart agronomic advantages and meet market requirements. It is imperative also that ICRISAT continue to support pigeonpea, groundnut and chickpea improvement in Myanmar with supply of relevant, elite germplasm and with high-quality training in crop breeding, disease screening and seed production technologies. At the policy level, Government policies and procedures for plant breeding, variety release and seed production may need to be reviewed and updated to support the benefits of the participatory breeding and Village Seed Bank (VSB) systems and partnering with private enterprise.

Recommendation 2 – Continuation of the VSB program. With about 1 million CDZ farmers cultivating legumes and with currently low uptake of improved varieties for groundnut, pigeonpea and green gram, there is considerable potential to expand the VSB program beyond what was achieved by MyPulses to facilitate spread of new, improved varieties. Significantly, the new OFID-ICRISAT project will continue the collaboration of the DAR groundnut breeders with ICRISAT breeders and will use the VSB model for varietal dissemination.

Recommendation 3 – While much was done to improve recommendations for nutrient (FYM and mineral fertilisers) management in the Magway Township area, unresolved issues remain. These include nutrient management across the remainder of the CDZ with their different cropping patterns and soils, and the potential for micronutrient (B, Zn and perhaps Mn, Cu and Mo) deficiencies in the coarse-textured soils of the southern CDZ and finer-textured soils of the northern CDZ, respectively,

Recommendation 4 – Improve and finalise the fertiliser decision-support tool, including the development of a smart phone version. If this is not possible in the final days of MyPulses, this activity could be built into the new project. The prototype of a nutrient decision support tool was well received by leading farmers, and many of younger ones requested that it be available on a smart phone platform.

Recommendation 5 – DAR develop a succession plan to transition leadership of the soil chemistry laboratory by identifying and training of a replacement. ACIAR could consider supporting the incumbent, Dr Su Su Win, to ensure thorough upskilling of her successor as she transitions to retirement, possibly through the sister soil and land management project (SMCN/2014/44).

Recommendation 6 – Capacity for production of quality-assured, efficacious legume inoculants in sufficiently-large volumes to meet potential demand remains inadequate and needs to be developed. The potential for inoculant use on chickpea and soybean could be in the order of 500,000 packets annually. Expertise in Australia should be tapped to provide technical guidance and partnerships with Myanmar's private sector developed.

Recommendation 7 – Production of a training package (in English and Myanmar language) on the theory and processes of the farmer participatory crop benchmarking (FPCB) and assist DoA extension staff through training to apply the methodology in their villages. The MyPulses FPCB proved to be a highly informative and effective platform for research and extension, leading to practice changes by farmers. However, further investment is required to ensure DoA staff have the skills and experience to rapidly out-scale this program to other villages.

Recommendation 8 – A follow-up project using the FPCB process developed by My Pulses as a basis to better understand the key crop management practices that make the top 5-10% of farmers so profitable, and to promote adoption of these practices through farmer-to-farmer communication. A new project should also have as key objectives the introduction of conservation agriculture into CDZ cropping, as discussed throughout this document, linked to mechanisation.

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11 Appendixes