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Final report

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1 Acknowledgments

HORT/2003/045 should, in the words of the February 2009 project review team, "be counted a success". The reason for this high level of success comes down to the efforts made by the Cambodian project teams at the Cambodian Agricultural Research and Development Institute (CARDI) and the General Directorate of Agriculture (GDA). Throughout the project all team members displayed a high level of dedication to achieving project objectives, resulting in high praise from the external review team, and plaudits from the farmers they collaborate with. The application to learning new skills in areas such as postharvest research and plant pathology was impressive, and the future for vegetable research in Cambodia looks bright.

In particular I would like to thank the respective project team leaders at CARDI, Ms Sakhan Sophany, and GDA, Mr Heng Chhun Hy for their leadership and support throughout the project.

The involvement of the team from AVRDC World Vegetable Centre in Taiwan enhanced the project significantly. Drs Peter Hanson, Paul Gniffke and Katinka Weinberger provided expert advice and germplasm willingly, and were a pleasure to work with throughout the duration of the project.

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Drs Ben Stodart and Gavin Ash from Charles Sturt University, Wagga Wagga have also provided great leadership for the plant pathology component, and their expertise has been a major boost to the project over the past 12 months.

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The project team listed overpage, are worthy of mention here as all have contributed to the project's success.

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2 Executive summary

The unique nature and recent history of the Cambodian vegetable industry necessitated a whole of system response by ACIAR project HORT/2003/045 *Improvement of vegetable production and postharvest systems in Cambodia and Australia*. The shortage of expertise in Cambodia in new disciplines such as postharvest research required a systems approach be adopted to address needs along the whole of the production and supply chain. This required intervention from the project team from "seed to plate", and for this reason, two commodities, tomatoes and chillies were chosen as initial target crops.

Industry & Investment NSW partnered with the two main Cambodian agricultural institutions - the Cambodian Agricultural Research and Development Institute (CARDI) and the General Directorate of Agriculture (GDA) in addition to the AVRDC World Vegetable Centre in Taiwan. Charles Sturt University (CSU) joined the project in June 2008, managing the plant pathology component.

The project commenced with the 1st planning workshop in October 2005, and concluded in June 2009. The first 2 years of the project focussed on research station and laboratory based research, incorporating practical training and capacity building across a wide range of disciplines, including cultivar evaluation, pest and disease identification and management, production research, postharvest research, research trial management and biometrics.

Following a process of selecting the best performing cultivars and production practices from replicated trials on research facilities, the final 20 months of the project saw an expansion of on-farm trials and demonstrations. Farmers from four provinces Kandal, Kompong Cham, Siem Reap and Takeo participated in testing and evaluating cultivars, production practices and new posthharvest management techniques introduced by the project team. To improve seed supply of new cultivars, tomato and chilli seed production screenhouse units were also established at Kbal Koh Vegetable Research Station, Kandal.

Cultivar selections from the tomato and chilli trials were grown on eleven separate farms across three provinces, Kandal, Siem Reap and Kompong Cham. District and provincial staff assisted CARDI and GDA team members in managing the sites, and conducting the field days, which were held in February 2008 and March 2009. AVRDC World Vegetable Centre plant breeders also attended the field days. Farmers participated in assessment of the varieties at the CARDI sites in Siem Reap, and this information fed into the evaluation process.

The top three tomato varieties included in the on farm trials were CLN 2428 (Neang Pich), CLN 2418A (Neang Tamm) and CLN1462A, with these compared with farmers standards at each site. The top yielding tomato variety was Neang Tamm, with marketable yield of 44.5 tonnes per hectare compared with the local variety at 23 tonnes per hectare. The best chilli varieties were CCA 321, 9955-15 and PBC 142. All varieties are open pollinated selections from AVRDC breeding programs. These varieties also featured in the mulching and drip irrigation demonstrations.

The supply chain surveys on tomato and chilli provided an excellent foundation for project research planning. The tomato survey found that fifty six percent of farmers rated colour stage as the most important thing that buyers looked at when they were buying tomatoes, whilst a further 21% rated freedom from blemishes as the most important quality trait. When asked how they decided when to harvest – farmers were relatively evenly split between demand by collector (44%) and when the fruit was at full red colour (39%). Most farmers were harvesting late morning or late afternoon, less than desirable times if the aim is to reduce field heat. The product was also spending a considerable amount of time on farm prior to being sent to market with 42% of tomatoes spending 2-6 hours on farm after harvest, whilst a further 21% remained on farm for 6-12hours.

In the case of chilli, product that is of poor quality or no longer saleable as fresh chilli tends to be dried. Without a dried chilli market product losses would be considerably higher. Losses tend to be higher later in the season and also tend to be realised more at the farm and retail level. The main reasons for chilli being downgraded tend to be postharvest disease and other spoilage and also some sizing issues. In the case of dried chilli insufficient drying seems to be one of the major reasons given for chilli being discounted.

During the final 18 months of the project, production trials also moved on farm, with IDE low-tech drip irrigation and mulching trials in several locations, including Kandal, Kompong Cham, Siem Reap and Takeo. Field days were conducted by the DAALI team at the IDE drip irrigation trial in Kandal, and the mulching / variety trials in Kompong Cham. CARDI also conducted a replicated drip irrigation trial at the CARDI site, while the DAALI team continued their nitrogen rate experiments on chilli at the Dey Eth Research Station.

The establishment of the postharvest laboratory at CARDI is now complete with the installation of the coolroom in April 2008. Supply chain surveys for chillies and tomatoes were also completed.

In an economic impact case study carried out by a related project, AVRDC managed RETA 6208 with a Kandal farmer demonstrated the benefits flowing from this project. Use of improved tomato varieties and production methods (drip irrigation, fertiliser management and trellising) has resulted in an increase in net income for the project farmer from 3 to 4 million riel in 2005/06 to 6 to 7 million riel income in 2007/08. From one small 10m x 5m demonstration of CLN 1462A with drip irrigation, The farmer harvested over 500 kgs of fruit worth in excess of $100 US from this trial.

Three scientists from GDA and three from CARDI participated in a study tour to Australia in March 2007. Nin Charya, from CARDI, conducted a Masters Course at Sydney University under an AusAID scholarship. He completed his major project on tomatoes as part of the Australian component of the project, working with Dr Suzie Newman at the postharvest laboratory at Gosford Horticultural Institute. Ten Cambodian scientists and one farmer joined a seven day study tour of The Dalat and Mekong Delta regions in Vietnam to learning about relevant production and postharvest systems. Several technologies including grafted tomato production have since been tested in Cambodia.

An adjunct to the vegetable development work occurring at GDA was the placement of an Australian Youth Ambassador (AYAD) with the DAALI plant protection team to establish a horticultural pest collection. The AYAD led a team, and provided training for staff in collecting, storage, preservation and mounting of specimens.

In the Australian component, a shortlist of four cherry tomato varieties were selected from an extensive series of varietal assessments conducted in the Sydney Basin and Gosford. Field yields, postharvest assessments, commercial marketability and taste tests were completed as part of the process. Commercial quantities of the three best performing varieties were being grown in the Sydney basin by the completion of the project. The Farmer Field School format, similar to the popular FAO field school program used in Cambodia, was also tested during the 2008 tomato season with Cambodian vegetable growers in Western Sydney.

3 Background

In Cambodia at present, vegetable supplies are erratic, and characterised by seasonal gluts and scarcities of produce which is highly variable in quality. There are several contributing factors, the most significant being the slow recovery from years of war during the 1970's and 80's when Cambodia's agricultural human and physical resources were decimated.

Studies conducted in the early 2000's found that poor seed and production technologies can reduce productivity (10-40% depending on commodity), and inadequate postharvest systems compound these losses (20 -35 % depending on commodity) (AQIP 2002). Inadequate postharvest systems for vegetables significantly contribute to the poor perception/image of domestically produced vegetables in Cambodia, and there was a pressing need to quantify the causes of losses and quality deterioration and to document supply chain deficiencies in order to identify entry points for R & D. The major production districts (eg. Kien Svay) are within 40 kms of the Phnom Penh markets, and as a result over 50% of vegetables reach the market on the back of motorbikes, motorbike trailers and bicycles (AQIP Survey 2002). A high proportion of these are leafy vegetables, unsuited to such transportation, with deterioration during transport as high as 26% for Chinese kale, while losses for cucumbers and tomato are around 14% (AQIP Survey 2002). Once at the market, there is little opportunity to maintain produce quality as the cool chain is non existent.

Despite these challenges, there are good prospects for increasing vegetable production particularly if inputs (seeds, fertilisers and pesticide quality), production technologies and postharvest quality and handling can be improved.

Improvements to production technologies and supply chain management will not only reduce product losses but improve the quality, safety and nutritive value of Cambodian vegetables. Enhanced local production and better marketing have the potential for increasing consumption and farmer incomes as they diversify from rice production, but problems with the inadequacy of current production technologies, supply reliability and quality management are hampering industry development.

To establish a model for improved production and supply chain performance for the Cambodian vegetable industry, this project investigated and implemented changes to the production and postharvest handling and storage of vegetables, commencing with high performing, disease resistant tomato lines being released from the current AVRDC-Cambodia collaboration. Selection of tomato as the initial ‘model’ crop reflects the recognised future importance of this crop to Cambodian producers, maximising benefits from the AVRDC breeding program, and the current quality differential between local and imported produce available in the marketplace. AVRDC lines such as CLN1426A have already been well accepted by growers, but seed supplies are limited. Other important vegetables such as chilli and leafy brassicas were addressed at a later project stage. The overall aim of the project is to improve market demand for and profitability of Cambodian vegetables, and to develop system improvement protocols which can be readily adapted to other commodities and across the transport, storage, processing and export industries.

To clarify how it could best assist in the development of the Cambodian vegetable industry ACIAR commissioned Professor John Spriggs of the University of Canberra to undertake a scoping study, including a visit to Cambodia with project proponents, Mark Hickey of I&I NSW and Peter Hanson of AVRDC World Vegetable Centre in June 2004. The study assessed current status and needs of the industry, made recommendations about how ACIAR could best assist industry development, and advised how this proposal could be framed to best address needs and opportunities The scoping study drew attention to the following:

(a) Status of the industry. The problems hampering the industry were as presented in the AusAID - Agricultural Quality Improvement Project (AQIP) draft policy for fruit and vegetable production and marketing in Cambodia, including high costs of inputs, small-scale of production, lack of postharvest skills, poor competitiveness with imports and informal taxes levied on marketing. There was a clear need for ACIAR support in improving vegetable production and postharvest handling.

(b) Opportunities for ACIAR support. The needs of the Cambodian industry were too extensive to be addressed within just one bilateral ACIAR project, and suggested that ACIAR could also foster improved co-ordination/ synergies amongst the current donor/consultant initiatives. The study endorsed a bilateral project as proposed here in a partnership involving Australian, AVRDC and Cambodian institutions. It also suggested that ACIAR should (in the course of implementing this project) convene a vegetable roundtable in Cambodia, and through this forum, define further initiatives that could follow the initial project.

(c) The project HORT/2003/045 was formulated within a systems context, focussing on development of production and postharvest technologies suited to AVRDC inbred varieties that are being selected in Cambodia (reliable access to these varieties overcomes the first constraint of poor seed). The project aim was to synergise with ongoing AVRDC vegetable germplasm introductions and evaluation work. The report also recommended that participatory methodologies be utilised in multi-institutional partnership to build ownership, trust and foster uptake of project outputs.

A key starting point for improving vegetable production that capitalises on AVRDC/Cambodian progress is to improve access to reliable seed of suitable varieties (starting with tomato). The seed distribution system in Cambodia is ad hoc and the majority of farmers purchase vegetable seed from the local market. Unfortunately, most seed sold through local markets are imported varieties of questionable quality, poorly packaged and often lacking information on variety, description, purity, germination rate or expiry date on the package. (Abedullah et al, 2002). Part of the original project concept included efforts by The AVRDC World Vegetable Centre fostering establishment of the local vegetable seed industry to ensure that locally adapted germplasm (including the AVRDC selections) will be available to farmers in future.

This project brought together the institutional capabilities within Cambodia in partnership with Australian and AVRDC vegetable R & D specialists. Within Cambodia, The Cambodian Agricultural Research and Development Institute (CARDI) is moving from a primary focus on rice research to include other crops. CARDI and GDA had established links with AVRDC through the provision of germplasm and training in plant breeding and other disciplines in vegetable research. CARDI and MAFF- GDA co-lead the project. GDA has key responsibility for facilitating agricultural industry improvement and is also responsible for horticultural field stations which are involved in collaborative research (AVRDC, CIRAD), seed production and farmer education. In the original project, the Department of Planning, Statistics and International Co-operation (DPSI), who have responsibilities for policy, planning and technical improvement in relation to horticultural production and crop protection, were project partners. Within this group, the project worked mainly with the Agricultural Marketing Office (AMO) and the Canadian government funded Cambodian Agricultural Market Information Project (CAMIP).

An Australian component for the project is a prerequisite for the I&I NSW involvement in the project, and helped expose the Cambodian partners to Australian R & D needs and methodologies. The Australian component involved the I&I NSW postharvest group (Dr Suzie Newman and colleagues), with inputs in extension and crop management from the I&I NSW Vegetables Team at Yanco, where the project leader, Mark Hickey was based. Other specialists on the project team included Mr Robert Hoogers (irrigation), Mr Gerard Kelly (intensive vegetable crop agronomy), Dr Sandra McDougall (entomology) and Dr Peter Malcolm (Sydney Basin extension).

The intensive nature of the greenhouse vegetable industry in the Sydney Basin provides complementarities for both research and training endeavours in Cambodia and Australia. The vegetable industry in the Sydney Basin relies on relatively low-tech greenhouses and small scale field production to produce tomatoes, cucumbers and Asian vegetables for the Sydney market. A NSW based supply chain committee comprising representatives from seed companies, growers, wholesalers, supermarkets and other retailers had identified tomato quality (particularly flavour) and supply chain management as areas requiring further research and extension endeavour. The industry in the Sydney Basin also provided a suitable model for optimising agronomic and postharvest handling systems. In additional the vegetable research and extension group at Yanco work closely with the processing tomato industry, and have strong involvement with on farm research and laboratory analysis of tomato quality.

4 Objectives

The overall aim of the project was to improve profitability and quality of Cambodian vegetables for the domestic market and to develop sustainable system improvement protocols which can be readily adapted to other commodities and across the transport, storage, processing and export industries. To achieve this, the project team adopted a systems approach to address key constraints at each stage of the vegetable production/marketing system. The project focus was on improving (1) use of inputs, (2) production efficiency and (3) postharvest storage and quality.

Objective 1– To map supply chains and identify constraints to improvement of the Cambodian vegetable industry.

Objective 2– To develop and demonstrate improved production and postharvest strategies that will underpin quality improvement and industry development. (Cambodia and Australia

- *To optimise vegetable production systems*
- *To optimise postharvest systems*
- *To improve access to reliable germplasm*

Objective 3 - Improve R&D capacity in Cambodia in vegetable research, by ensuring maximum sharing of technology and know-how between Australian, AVRDC and Cambodian partners. (Cambodia, Australia and AVRDC)

- *To undertake training and capacity building*
- *To assess economic and social impacts*

Objective 4 - To transfer plant pathology skills and technology from the Cambodian cereals program to the vegetable program

- *Sub-objective 4.1 Obtain preliminary data for the management of bacterial diseases in rice, including basic treatments and decision tools for advice on sowing retained seed.*
- *Sub-objective 4.2. Provide direct training to new staff with in the Crop Protection*
- *Sub-objective 4.3. Conduct initial disease surveys of vegetables in Kandal province to determine the occurrence of bacterial wilt.*
- *Sub-objective 4.4. Provide a basic laboratory manual consisting of standard operating procedures and protocols to allow staff to confidently and correctly isolate bacteria and perform basic tests to progress with later additional training towards identification to the genus level*
- *Sub-objective 4.5. Initiate surveys of vegetable crops to determine the occurrence and severity of phytopathogenic viruses.*
- *Sub-objective 4.6. Evaluate and modify detection techniques for phytopathogenic viruses to allow preliminary identification at CARDI, with detailed analysis conducted in Australia.*
- *Sub-objective 4.7. Generate data on the prevalence and severity of Sclerotium rolfsii in vegetable cropping systems in Cambodia.*
- *Sub-objective 4.8. Provide laboratory protocols for the detection procedures for*

viruses.

The research strategy was developed following discussions with project partners I&I NSW, AVRDC World Vegetable Centre, Taiwan, CARDI, GDA, Ministry of Agriculture, Forests and Fisheries (MAFF) and other stakeholders including development project personnel from Government and non-Government agencies. The most urgent requirements for vegetable improvement in Cambodia were identified as:

- To develop locally adapted vegetable varieties with characters including disease and pest resistance and heat tolerance, which were suited to local markets.
- To enhance understanding of the current limitations and options for improvement of vegetable supply chains.
- To provide practical and low cost technologies to improve crop yields and quality, postharvest handling and pest and disease management to reduce pesticide residues and provide more effective control measures.

5 Methodology

The project research strategy aimed to;

1) *Assess what feasible improvements to current production and postharvest systems could be made to capitalise on previous AVRDC and other relevant R & D, and foster improvement of the Cambodian vegetable industry.* Surveys of growers, market sellers, government and non-government agencies were used to assess constraints faced by the industry and document baseline information. Supply chains were mapped to identify system improvements and devise appropriate strategies for R & D and industry liaison.

2) *Develop low-tech practical solutions to current production and postharvest system problems*. Research work was targeted to the areas of greatest need, focussing on improving production and postharvest management and access to reliable cultivars. To ensure a sustainable supply of appropriate vegetable seed material is available to Cambodian farmers, the establishment of the vegetable seed distribution system was investigated and preliminary steps taken to instigate a commercial local seed distribution network.

3) *Enhance Cambodian vegetable R&D capacity and extend results to technical personnel, farmers, transporters and market agents.* The project built upon experience of CARDI and GDA staff gained from collaborations with AVRDC and others. At least one CARDI researcher has already received training in tomato breeding. Other ACIAR projects, including *ASEM/2003/012 Marketing of legumes grown in Cambodia (with the Ministry of Commerce), ASEM/2000/109 Farming systems research for crop diversification in Cambodia and Australia and CS1/2003/030 Improving understanding and management of rice pathogens in Cambodia* (with CARDI), provided useful links for this vegetable project. The project also linked with a new AVRDC project funded by the Asia Development bank (ADB), which was led by ACIAR project team member, Dr Katinka Weinberger, *"Poverty reduction, rural economic sustainability and capacity building through vegetable based- based postharvest technologies in Cambodia, Laos and Vietnam"*. In addition, complementary training and survey work was conducted in collaboration with other current ACIAR projects.

The methodologies outlined in the original proposal and variations required as the project progressed are described below according to project objectives.

5.1 Objective 1: *To map supply chains and identify constraints to improvement of the Cambodian vegetable industry.*

5.1.1 Establishment of a postharvest research facility at CARDI

Postharvest management of horticultural crops is a relatively new field to Cambodian research and extension staff. To facilitate development in this area a postharvest laboratory was established at CARDI. Project funds were utilised to purchase equipment including:

- a kitset cool room with drop-in refrigeration unit (2.4 x 2.4 x 2.4 m)

-2 temperature cabinets

-an air-conditioning unit for the laboratory

-an auto-titrator

-a compression firmness tester (for measuring tomato firmness)

-small scale equipment including penetrometers, refractometers (digital and hand-held), impact loggers, temperature and humidity loggers, digital thermometers, low cost evaporative cooler etc.

Figure 1 and 2 Coolroom and laboratory facilities at CARDI

Fig 1. Postharvest laboratory - CARDI

Fig 2. Coolroom - CARDI

In addition to the establishment of this facility at CARDI hands-on training was provided to project research and extension personnel including a 2 day in-country training course in February 2006 and a 10 day Australian study tour and training course in April 2006. The variety evaluation trials provided a useful entry point for project personnel in how to undertake postharvest research trials.

5.1.2 Mapping tomato and chilli supply chains

Tomato supply chain survey

A survey was undertaken of 66 farmers in the 3 major tomato growing districts in Kandal province - Saang, Kien Svay and Muk Kampoul, to gain a better understanding of current production and postharvest practices for tomatoes. A copy of the questionnaire is attached in Appendix x. This built on an earlier supply chain survey undertaken by the ADB RETA 6208 project that focussed on value chain analysis and identifying supply chain constraints. In addition, a further 42 farmers were interviewed using a revised version of the ADB survey and this data provided to the ADB project. Training in survey methodology was undertaken in April 2006 by Katinka Weingberger (AVRDC) and Suzie Newman (NSW DPI), followed by the piloting of the questionnaire. Following refinement of the questionnaire the survey was undertaken between April and July 2006.

Evaluating postharvest losses along the tomato supply chain

Postharvest losses are high (25-40%) for vegetable crops in Cambodia. These losses may be due to:

OUTRIGHT LOSS - in which vegetables are rendered unsaleable due to disease, insect damage or physical damage during harvest, handling and transport operations

POOR QUALITY - in which vegetables of inferior quality receives a lower price in the market due to inferior size, colour and/or flavour.

Monitoring damage and quality losses along the supply chain (from farm to market) is key to understanding where these losses are occurring and developing the means of

overcoming them. To objectively describe the physical environment around the vegetables, temperature and humidity loggers and impact sensors were included in vegetable consignments tracked from farm (Kandal province) to market (Phnom Penh). In addition, damage and quality loss was assessed on a sample of vegetables at the following transfer points in the supply chain:

- At harvest
- After loading into baskets
- Following sorting and/or packaging
- Following transportation to wholesale market

Chilli supply chain survey

In 2007, actors along the chilli supply chain were surveyed to determine: current production, postharvest handling and drying practices; marketing channels for fresh and dried chilli, product losses along the supply chain and where they are occurring; and price information

A total of 202 surveys were undertaken including:

- 32 farmers in Kampong Cham
- 66 farmers in Kampong Chhnang
- 40 retailers
- 25 processors
- 19 collectors
- 20 wholesalers

The survey was piloted in April 2007 and conducted between May and June 2007.

5.1.3 Evaluating the postharvest performance of tomato varieties

In 2006, the postharvest performance of 13 varieties including AVRDC lines, local varieties and a selection of hybrids was evaluated. Fruit was sourced from two replicated trials undertaken at Dey Eth and CARDI research stations. Assessments included fruit quality (firmness, soluble solids, titratable acidity, colour, taste) and shelf life at 20ºC and ambient storage temperatures.

In 2007, the postharvest performance of 5 varieties (CLN1462A, TLCV15, T56, CLN2498A and CLN2418A), sampled from 2 replicated trials (Dey Eth and CARDI) was evaluated in a similar way to the assessments undertaken in 2006.

5.1.4 Improving the postharvest quality of selected vegetables

A series of trials were undertaken in 2007, 2008 and 2009 on Chinese kale and tomato to demonstrate to farmers the benefits of changes in postharvest management (eg. harvest time, maturity, pre-cooling, storage method etc) on the quality and shelf life of their product (Chinese kale, tomato or chilli).

Table 1: Summary the trials undertaken at both Saang and Kien Svay District, Kandal Province. :

Year	Crop	Treatments
2007	Chinese kale	Standard practice; Direct refrigerated storage; Pre-cooling followed by storage in an ice-box; Pre-cooling followed by refrigerated storage x 4 replicates
2008	Chinese kale	As described above for the 2007 trials
2008	Chinese kale	2 harvest times (early (6-7am) or late (12-2 pm)) x 2 pre-cooling treatments (none or pre-cooling in ice slurry) x 3 storage types (ambient storage, evaporative cool storage (jute box) or refrigerated storage (0ºC) x 3 replicates).
2008 and 2009	Tomato	2 harvest times (early (6-7am) or late (12-2pm)) x 2 harvest stages (breaker or 3/4 red) x 3 storage types (ambient storage or evaporative cool storage (jute box) or refrigerated storage (15 ºC) x 3 replicates (replicates were done over time).
2009	Chinese kale	As described above for the 2008 trials

Current packaging methods are also a major cause of postharvest losses, with most packaging materials currently used failing to adequately protect the product leading to impact or compression damage. Ventilation also tends to be lacking in these packaging materials resulting in heat building up around the product and shortening its shelf life.

The objective of this component of the work was to document current packaging and transportation practices and their impact on postharvest loss. Initially an observation study was undertaken to look at existing packaging used by farmers and collectors in Kandal province. A series of discussions were then undertaken with collectors, wholesalers and farmers looking at options for improving current packaging methods. This led to the development of several packaging/transport ideas that included developing a modified frame to go on the back of a motorbike to transport bags of tomatoes. Different options tested included providing extra support and including ventilation holes in the plastic bags. These packaging alternatives were then evaluated by undertaking a series of consignment trials from Kien Svay and Saang district to Deum Kor market.

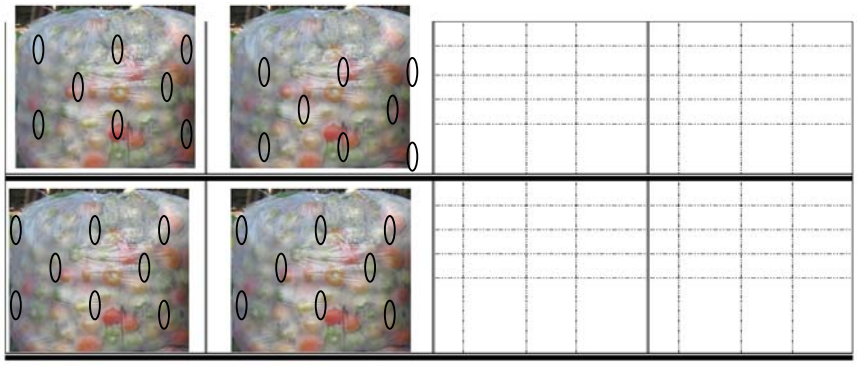


Fig 3 One of the packaging alternatives trialled.

5.2 Objective 2: Develop production and postharvest strategies that improve vegetable quality

This component drew on the findings of supply chain surveys and relevant research in Cambodia, to develop and test improvements for production and postharvest systems and seed supply that will improve the productivity of the Cambodian vegetable industry. AVRDC and Cambodian open pollinated tomato lines were be used as the basis of improvement strategies in Year 1 of the project. Subsequently, chillies were introduced in Year 2, with Chinese Kale varieties examined in the final two seasons.

(i) To optimise vegetable production systems

The project was able to capitalise on ongoing variety screening trials using AVRDC and other germplasm. These trials already based at CARDI, GDA research stations and other sites combined 'best bet' varieties with improved production practices (including irrigation, nutrition and IPM) for agro-ecological systems, shelf life and quality attributes under Cambodian marketing systems. In Year 1 work commenced on tomatoes exclusively.

To enable comparisons with lines from AVRDC, a range of mainly hybrid tomato varieties regarded as suitable for Cambodian conditions from major seed companies (mainly Thai and Vietnamese) were sourced. Local selections were also included. While inbred disease resistant AVRDC tomato lines were the focus in the first year of the project, research on other AVRDC vegetable lines were also be conducted in Years 2, 3 and 4.

Specific trial design for tomato variety evaluations and production research was determined during the October 2005 planning workshop. The design for the variety trials was a randomized block design of at least four replicates, comparing four AVRDC lines with a farmer selection and possibly up to 4 hybrid tomatoes from interested seed companies.

Other trials established in the first year of the project included fertilizer, and irrigation trials (using the IDE low tech drip), which were demonstrations rather than fully replicated trials. In subsequent years, more complex trial designs were introduced to provide further training opportunities. Detailed trial maintenance and assessment guidelines were also developed and agreed to at the planning workshop.

Table 2: Details of the variety evaluations and production trials from each year of the project

Year	Details of production trials - Cambodia
2005/06 Dry season	1 replicated tomato variety trial at CARDI 1 replicated tomato variety trial at Dey Research Station (GDA) 1 replicated on farm tomato variety trial (Mok Ampil/ GDA) 1 non replicated on farm tomato and chilli variety demonstration (Mok Ampil, shared with ADB/ GDA project) 1 replicated tomato nitrogen rate trial (Dey Eth GDA) 1 non-replicated tomato drip irrigation trial (Kbal Koh GDA) 1 replicated processing tomato trial (Australia)
2005/06 Wet season	1 wet season tomato variety evaluation trial at Dey Eth (GDA)

2006/07 Dry season	1 tomato replicated variety trials at CARDI and 1 tomato replicated variety trial at Dey Eth Research Station 1 Tomato on farm demonstration at Rokor Koang (GDA) 1 chilli replicated variety trial at CARDI 1 chillil replicated variety trial at Kbal Koh 1 chilli screening trial for anthracnose resistance at CARDI 1 Chilli replicated on farm trial at Rokor Koang 1 Chilli nitrogen rate fertilizer trials at Dey Eth Research Station 1 Drip irrigation demonstration at Kbal Koh Research Station 1 spring on farm replicated cherry tomato trial (Australia) 1 autumn on farm replicated cherry tomato trial (Australia) 1 autumn greenhouse replicated tomato trial at GHI (Australia)
2007/08 Dry season	I Chinese cabbage demonstration (Dey Eth) 3 On farm tomato demonstrations in Siem Reap (CARDI) 2 on farm tomato demonstrations in Kompong Cham (GDA) 2 on farm chilli demonstrations in Kompong Cham (GDA) 1x on farm chilli IDE drip irrigation trial in Kompong Cham (GDA) 1 on farm tomato IDE drip irrigation trial in Banteay Dek, Kandal (GDA) 1 drip irrigation trial at CARDI 1 tomato screening trial for heat and disease tolerance (CARDI) 1 chilli anthracnose screening trial (CARDI) 1 seed increase plot for Neang Pek and Neang Tamm (CARDI) 1 tomato seed increase plot various varieties at Kbal Koh (GDA) 1 chilli nitrogen rate trial at Dey Eth (GDA) 1 tomato grafting trial at Dey Eth (GDA) 1 spring on farm replicated cherry tomato trial (Australia) 1 autumn on farm replicated cherry tomato trial (Australia)
2008/09 Dry Season	1 Chinese kale replicated variety trial at Dey Eth (GDA) 1 grafted tomato demonstration trial at Dey Eth (GDA) 1 tomato variety screening trial multiple AVRDC lines (CARDI) 1 chilli variety screening trial (CARDI) 1 on farm tomato variety demonstration at Saang District, Kandal(CARDI) 1 drip irrigation x tomato variety demonstration at Tram Kok District, Takeo (GDA) 1 drip irrigation x chilli variety demonstration at Bati District, Takeo (GDA) 1 replicated chilli nitrogen rate fertiliser trial at Bati, Takeo (GDA) 1 chilli variety demonstration at Bati, Takeo (GDA) 2 screenhouse tomato seed replication blocks at Kbal Koh (GDA) 2 screenhouse chilli seed replication blocks at Kbal Koh (GDA)

Trials were designed to assess: crop management, yield, fruit quality, shelf-life, and seasonal variation (dry season vs wet). Subsequently, the best performing varieties from research station trials were then tested on farm across several locations. Two agro-ecological zones were used in the on farm screening stage - the Mekong River levee soils in districts such as Kien Svay, Kandal, and the floodplain soils used for wet season rice production, such as Tram Kok District, Takeo. Trial locations in Kompong Cham and Bati District Takeo were upland transition soils, being of lighter texture than the surrounding heavier rice soils, but only a few meters higher in elevation.

Variety testing was carried out principally on research stations during the first two dry seasons. Dey Eth Research Station and Kbal Koh Vegetable Research Station are located in the Cambodian vegetable industry heartland district of of Kien Svay, on silty loam soils, ideally suited to vegetable production. CARDI trials were carried out on site at CARDI, on silty clay loam soils, river deposits which had been imported from closer to the Mekong River.

In the final two dry seasons, the variety trials and demonstrations went on-farm. Apart from researcher assessments, farmer participatory research principles were used to help

evaluate new varieties, employing methods to help ensure commercial farmer acceptance. The co-operator farmers took an active role in testing and evaluating varieties, production and postharvest techniques

Allied production research further optimised production systems at demonstration sites and in commercial scale trials. On-farm trials were conducted to highlight improvement in yield and quality that can be achieved through modifications to production, including irrigation, nutrition and pest and disease management strategies in tandem with the new varieties. In the course of the trials, a pest and disease audits were carried out to help determine criteria for varietal screening, and suitable management options.

A full description of the CARDI variety trial program can be found in Appendix 1.

(ii) To optimise postharvest systems (Cambodia)

The supply chain studies were used to frame and prioritise postharvest research activities. In the first two years of the project targeted research trials were used to develop technically feasible postharvest management strategies that reduce losses and improve product quality and shelf life. In the final year of the project recommended postharvest strategies will be tested through a 'whole of chain' semi-commercial scale trial. Superior selections of tomato from the AVRDC/Cambodia screening and subsequent project activities will be evaluated for their postharvest performance and consumer acceptance. Specific tasks will include:

Drawing on supply chain assessments, this component introduced and evaluated the effectiveness of simple low cost postharvest technologies on vegetable quality and loss reduction in expectation of introducing production improvements that enhance quality and strategies that enhance supply chain logistics. Specific activities include:

- Compare the postharvest performance of several tomato varieties including AVDRC lines (including CLN1462A), imported and local selections
- Survey consumers to determine preferences and key quality attributes
- Conduct trials to compare different harvest management strategies to reduce losses and optimise quality. These may include modifying current harvesting practices (technique, crop maturity) and the implementation of low-cost cooling systems on farm.
- Conduct trials on tomatoes and leafy vegetables to compare the effectiveness of a selection locally available packaging materials (eg. bags, bamboo, plastic or wooden crates with and without straw packing) to minimise bruising, product damage and reduce water loss. Modifications to current product handling practices will also be evaluated.
- Trial postharvest treatments to extend shelf life.
- In collaboration with the private sector, implement modifications to the supply chain which improve logistics, reduce postharvest losses and present the Cambodian grown product in the marketplace in optimum condition.

In Australia, the focus was on optimising tomato quality (particularly fruit shape size and flavour), productivity (yield) and supply chain management. Ethnic Cambodian, Vietnamese, Chinese and Arabic growers are the dominant groups in the Sydney Basin, and a local R & D committee has identified post-farm gate as an area for improvement.

The Australian component focussed on work with vegetable growers of Cambodian origin in the Sydney basin. A needs analysis at the commencement of the project in 2005 found that there were a range of issues growers faced, but one of more serious was the limited range of cherry tomato varieties available to growers. There were two standard varieties, one determinant type, T30, and another indeterminate type, T38. Little was known of the origins or inherent disease resistance in these varieties, which were supplied by two large

seedling producers. Both varieties had serious limitations in yield, and fruit quality and uniformity was inferior to more recent varietal releases.

The project contacted the seedling growers and seed companies, and gained their support in a varietal testing program which was conducted over two years (or two spring crops and two autumn crops) of the project. Four field trials at Horsley Park, and one greenhouse trial at Gosford Horticultural Institute (GHI) were conducted**.** The first trial failed due to a severe tomato spotted wilt (TSWV) outbreak, but the one TSWV resistant variety survey survived and proved an excellent demonstration of the value of resistant varieties. As the TSWV infection was widespread across the district, a project workshop on management of TSWV was conducted by team member Dr Peter Malcolm.

Four subsequent grower variety field days and a field tour to inspect the Gosford greenhouse trials were conducted. Five of the major seed company representatives were present at most of the field days, and grower interest remained high throughout the two years.

Extensive postharvest evaluations of the new varieties were also conducted at GHI. A summary of the field and postharvest results can be found on pages 55 to 64.

Other activities conducted with the Cambodian growers under the project included two postharvest workshops, a SmartTrain chemical users course, and three grower workshops as part of a abridged farmer field school program (FFS). The FFS program topics included;

- Irrigation, including design, soil moisture monitoring and management
- Nutrition, including fertiliser choice, timing and fertigation management
- Pest and disease identification, use of biocontrols, cultural and integrated pest management

Methods of on-farm evaluation and tomato quality analysis of machine harvested processing tomatoes was also included in the Riverina component. This involved Cambodian scientists participating in the February 2006 study tour of the current system used in on-farm trials and grower participation of evaluation of new varieties combined with laboratory analysis of processing attributes (soluble solids, paste viscosity and colour) at Yanco.

(iii) To improve access to reliable germplasm

In the absence of a commercial vegetable seed company in Cambodia, three tomato and three chilli varieties of the seed breeder lines emerging from the project screening trials were semi - commercially produced and distributed through the Kbal Koh Research Station, providing the Cambodian industry with some wider access to the locally adapted varieties. CARDI also produced limited amounts of seed, mainly for use in on-farm trials.

Linkages were made through projects such as AQIP, and the AQIP Seed company, Kandal. AQIP has been also involved in repackaging imported vegetable seed, using Khmer language labels, for distribution through agencies such as the World Food Program. While such industry linkages may improve farmer access to vegetable seed, there is a need for more stringent evaluation and screening (within the project), to help ensure that the most appropriate varieties are being distributed through industry initiatives.

In Year 1 of the project, a trial batch of 500 x 5 gm packets of CLN1462A with Khmer language labelling was produced by AQIP Seed Company. These trials packets were distributed to various groups including GDA farmer networks and agricultural based NGOs in Kandal, Siem Reap and Prey Veng Provinces. Collaborating farmers and NGOs who tested the variety were impressed with the yield and marketability of the fruit.

Figure 4: A collaborator farmer with a package of the trial seed batch of CLN1462A "Princess Tomato" seed in Siem Reap. The AQIP Seed Company designed and produced the packaging for the seeds.

The development of the vegetable industry Cambodia remains constrained by the lack of a reliable source of high quality seed of varieties suited to its main vegetable production regions. Work is ongoing to assist private enterprise to enter the vegetable seed business, but the decision to do this will ultimately be driven by market forces.

5.3 Objective 3 Improvement of R & D capacity.

(i) R & D training and capacity building. Key activities were to:

- Facilitate effective research planning and extension of results for technical personnel, farmers, transporters and market agents. Learning from the success of the National IPM program in Cambodia and Australian extension approaches, the project team will develop appropriate extension models for vegetable growers in Cambodia, Sydney Basin and Riverina district of NSW.
- Establish/foster postharvest horticulture and production research and supply chain management capacity in Cambodia and train scientists at AVRDC and Australian laboratories and institutes
- Provide practical training in vegetable research trial establishment and management, postharvest storage and handling, and laboratory techniques.
- In Cambodia, conduct supply chain and base line studies to provide key leads for the development of training initiatives.

This approach was complemented by capacity building in research planning and capacity building during project planning meetings.

Technical Training of Cambodian scientists. In February/March 2006, Australian based training of Cambodian counterparts took place at NSWDPI Gosford Postharvest Facility (supply chain management, postharvest and quality assurance), while field and greenhouse production of tomatoes and other vegetables will be studied in the Sydney Basin. Time was also be spent at The National Vegetable Industry Centre at Yanco, working with researchers on trial design, research planning and extension management and reporting. Processing tomato quality testing (soluble solids, acidity, colour etc) is conducted at Yanco in February/March each year, and exchange visits were timed for optimal training opportunities. The current method of farmer participation with researchers in scoring on-farm processing tomato cultivars in replicated plot and machine harvest row trials in the Riverina will be refined and assessed as a model for use in Cambodia. Novel methods of presentation of results used in the processing tomato industry were also tested.

The need for providing capacity building and training for postharvest research scientists was a critical priority for this project, as there was virtually no in-country expertise. In order to enhance the level of horticultural postharvest research beyond the life of this project, it was proposed that opportunities for scholarship (e.g. John Allwright fellowship) supported training be sought during the course of the project. A placement would be most effective towards the end of the project, with a focus on research issues most relevant to Cambodian needs (e.g. improvement of capabilities for extension of project outputs). Although one JAF candidate was nominated, it was not carried through due to English language difficulties. One of the CARDI scientists however did win an AusAID scholarship, and conducted his major project on tomatoes as part of the Australian component.

Development of a postharvest research facility at CARDI. The establishment of a postharvest research facility at CARDI required the provision of basic equipment to enable postharvest trials and assessments to be undertaken. A funded postharvest Technical Officer position was employed at Gosford Horticultural Institute to conduct work in the Sydney Basin, with technical assistance to develop new low cost postharvest systems and participate in project activities in Cambodia and Australia.

Training in supply chain management and marketing. Small group training on vegetable supply chains was carried out by Suzie Newman and Katinka Weinberger. Training resources on postharvest management of vegetable crops were developed as outputs of the project.

Cambodian technicians were able to benefit from the interaction with their regional counterparts at training activities. This collaborative training, which occurred in 2006 with GDA staff through the ADB/RETA project managed by Dr Weinberger helped to foster more sharing of technology from appropriate production systems on a regional basis. In addition, training synergies were optimised with the new ADB project (with Project team member Suzie Newman of NSWDPI participating in the ADB project start-up workshop in May 2005).

Measurement of economic benefits This component undertook capacity building in assessment of project costs and economic benefits, and document the economic dimensions of the Cambodian vegetable industry and project derived improvements to production, seed access and supply chain management. This component involved training through the ADB RETA project in Year 3 of the project, and AVRDC socio-economist, Dr Katinka Weinberger. It included socio-economic and postharvest assessments in Cambodia and in capacity building for assessment of economic benefits.

Several case studies were undertaken, along with economic cost/benefit analysis of the various project technologies investigated. These included drip irrigation, nitrogen fertiliser rates and black plastic mulches.

5.4 Objective 4 - To transfer plant pathology skills and technology from the Cambodian cereals program to the vegetable program

5.4.1 Sub-objective 4.1: Obtain preliminary data for the management of the bacterial disease in rice, including basic treatment and decision tools for advice on sowing retained seed

All experiments were conducted at CARDI under glass-house conditions by Mr Touch Ung and Mr Tek Samoeun under guidance of Dr Ben Stodart and Gavin Ash, from July to December 2008.

Three treatments reported to alleviate disease incidence were selected from a review of literature; hot water treatment, soaking in sodium hypochlorite and, separation of “healthy” seed by buoyancy. Hot water treatment had been shown to be effective at 52°C for 15min. without affecting germination and was verified on varieties commonly grown in Cambodia. Treatment with sodium hypochlorite (1% active ingredient) was performed as seed soak for 24 hours. Seed buoyancy was determined in 15% saline solution with removal of seed that floated (un-healthy seed) from the seed batch. Following treatments seed were sown in plastic pots utilising a randomised complete block design with unequal replication of treatments. Visually healthy, untreated seed were incorporated to provide baseline data for the treatments. Seed soaked in water were used as a control.

Retained seed from diseased crops was used to determine an acceptable level of disease before a new seed source is required for sowing. The determination of 10%, 20%, and 40% disease level in a seed set was assessed in terms of the effects on germination and yield.

5.4.2 Sub-objective 4.2: Provide direct training to new staff with in the Crop Protection Unit at CARDI in the processes of bacterial isolation and preliminary identification.

Liaison with Dr Preap Visarto determined the level of training and a schedule for the delivery of training. Ms Sim Puthea, Mr Touch Ung and Mr Tek Samoeun were provided direct hands-on training through field collections of diseased material and laboratory isolation of causal organisms. Filed visits to sites within Kandal, Kampong Cham and Svey Rieng were conducted, with laboratory based training occurring on site at the Plant Protection Unit, CARDI.

5.4.3 Sub-objective 4.3: Conduct initial disease surveys of vegetables in Kandal province to determine the occurrence of bacterial wilt.

During field visits, the identification of samples displaying typical symptoms of bacterial wilt was recorded. Collection of such materials was made to check field identifications.

5.4.4 Sub-objective 4.4: Provide a basic laboratory manual consisting of standard operating procedures and protocols to allow staff to confidently and correctly isolate bacteria and perform basic tests to progress towards identification to the genus level.

A survey of wet-chemistry protocols was conducted to determine inexpensive methods that provide clear information to direct staff to flow-on procedures. Following selection, hands-on training of Ms Sim Puthea, Mr Touch Ung and Mr Tek Samoeun was conducted in the Plant Protection laboratory at CARDI. Modification of some techniques provided the necessary information for the production of a laboratory manual covering all aspects of the implemented protocols.

For confirming identification and to allow further analysis of isolated organisms, Whatman FTA™ Cards were deployed for the collection and storage of genetic material. Short term culture storage was assessed to determine viability and application within the laboratory.

The viability and effectiveness of molecular technologies was determined upon a needs and knowledge analysis with Dr Preap Visarto, unit leader of Plant Protection.

5.4.5 Sub-objective 4.5. Initiate surveys of vegetable crops to determine the occurrence and severity of phytopathogenic viruses.

Identification of sites was performed by Plant Protection and Plant Breeding units at CARDI. The collection of plant material suspected of being infected by viruses by CARDI staff and Australian collaborators was conducted during visits April and June, 2009. Incidence was measured as the percentage of samples displaying field symptoms and harbouring the pathogen.

5.4.6 Sub-objective 4.6. Evaluate and modify detection techniques for phytopathogenic viruses to allow preliminary identification at CARDI.

Literature searches and information obtained from diagnostic laboratories was performed to guide the selection of suitable procedures. A nucleic acid hybridisation technology (Agdia Inc.) was implemented to confirm the presence of Begomovirus in tomato samples. Whatman FTA cards™ were evaluated to determine their suitability as an extraction medium for capture of DNA and RNA for PCR procedures.

Step by step training was provided to Mr Touch Ung and Tek Samoeun during visits to CARDI by Dr Stodart and Dr Ash.

5.4.7 Sub-objective 4.7. Generate data on the prevalence and severity of Sclerotium rolfsii in vegetable cropping systems in Cambodia.

Field surveys of sites within Kandal were conducted staff of the Plant Protection unit and Australian collaborators during May and June 2009. Information from farmers was collected where possible to obtain a field history for these sites. Prevalence of the pathogen was determined through identification of symptoms and the presence of confirmatory sclerotes. Severity was recorded as the percentage of crop affected.

An existing field trial at CARDI was used to monitor the occurrence of the pathogen throughout the growing season by staff of Plant Protection.

Glass-house experiments were designed to assess the affect of flooding on the survival of sclerotia, and the subsequent pathogenicity to susceptible crops. In a simple design, five nylon bags each containing ten sclerotes of S. rolfsii were buried to a depth of 2 cm in soil in plastic pots and subsequently submerged in water. At time periods of 0, 2, 4, 6 and 8 weeks, a bag was removed, sclerotes recovered and rinsed in water prior to being surface sterilised and plated on medium. Percentage germination was recorded after 5 days incubation. The experiment was conducted using four replicate pots. Utilising a complete randomised design, an additional set of pots were inoculated with 10 sclerotes were submerged in water. At time periods of 0, 4 and 8 weeks, water was withdrawn and soil allowed to dry for 7 days before seeds of mungbean were sown (3 seed/pot). Disease incidence and severity was recorded after 4 weeks in each of 4 replicate pots. Staff of the Plant Protection unit conducted all experiments with limited guidance by Australian collaborators.

5.4.8 Sub-objective 4.8. Provide laboratory protocols for the detection procedures for viruses.

As protocols were established, step by step procedures were documented and incorporated into the existing laboratory manual.

6 Achievements against activities and outputs/milestones (Table 3)

Objective 1: To map supply chain constraints, devise improvements and incentives for improving product marketability in the Cambodia vegetable industry

No.	activity	outputs/ milestones	completion date	comments
1.1	Map supply chain constraints, devise improvements and incentives for improving product marketability in the Cambodian vegetable industry (P)	1. Data and reports documenting supply chains (including the production sector -physical, social and economic components and potential supply chain champions) 2. Case study baseline data and report documenting and analysing economic incentives and strategies for using the economic data to foster adoption of supply chain improvements 3. Recommendations for modifying supply chains identified and consensus reached on priority areas. Those that have high impact at low cost will be addressed first	October 2007	Key produce quality problems for tomato and chilli identified and documented. Supply chains for chilli and tomato mapped. For tomatoes, a survey of 66 farmers in 3 districts (Saang, Kien Svay and Muk Kampoul) in Kandal province enabled baseline production and postharvest practices to be documented. This built on the earlier ADB survey that identified supply chain constraints. In addition, a further 42 farmers were surveyed using a revised version of the ADB questionnaire. This data was supplied to the ADB project. For chilli, a supply chain survey was undertaken of 32 farmers in Kampong Cham province, 66 farmers in Kampong Chhnang province, 40 retailers, 25 processors, 19 collectors and 20 wholesalers. This survey enabled supply chains to be documented and constraints identified. Impediments to variety uptake, production, & marketability identified.
1.2	Map supply chains and quantify losses	Supply chains mapped	1/3/08	Tomatoes and chilli supply chain studies complete (finalised in October 2008)
1.3	Identify supply chain innovations and supply chain champions	Innovations and potential champions identified	1/3/08	Innovations, and supply chain champions identified
1.4	Packaging materials - trials	Recommend improvements to industry	Ongoing	Work commenced in Year 3 of the project and prototype carry racks, bags and basket designs were evaluated by a small group of market wholesalers
1.5	Trials to measure and extend shelf life	Postharvest evaluations completed	1/4/08	Tomatoes, chillies and Chinese kale completed
1.6	Compare postharvest performance of new varieties	Market acceptance studies completed	1/5/08	Evaluations for tomato and chillies completed. Further consumer surveys required.

1.7	Develop cool chain quality indicators for the tomato supply chain (Australia)	Measure number of growers meeting standard	1/5/08	Work completed and report due September 2008

PC = Partner Country, A = Australia

Objective 2: To develop and demonstrate improved production and postharvest strategies that will underpin quality improvement and industry development

No.	activity	outputs/ milestones	completion date	comments
2.1	Conduct tomato screening trials	Complete field and market evaluations	1/4/08	Has been a core activity since commencement of project. Now taken to on farm trials
2.2	Conduct chilli and Brassica screening trials	Complete field and market evaluations	Ongoing	On farm trial stage for chillies, and 2 years of brassica evaluation at Dey Eth.
2.3	Demonstrate improved production management methods	Improved production methods (drip irrigation, mulching and fertiliser rate) demonstrated to farmers	1/4/08	3rd year of nitrogen rate trials at Dey Eth. IDE drip trials and mulching trials taken to or farm demonstrations
2.4	Conduct pest/disease audit on key vegetable types	Verify pest and disease list agrees with Cambodian lists	Ongoing	AYAD Adelle Dunn commenced work with GDA on a horticultural pests collection. Dr Sandra McDougall visited in February 2008 to commence identifications. Vegetable diseases likely to be addressed in follow-up ACIAR project.
2.5	Optimise postharvest handling and techniques. (P & A)	1. Performance data and recommendations on testing of prioritised technologies as assessed with cooperating farmers and wholesalers. 2. Performance data and recommendations for optimisation of cool chain handling for tomato and related vegetable crops in the Sydney Basin		Low-cost technologies developed and supply chain modifications developed and trialled including: - evaporative cooling systems - ice slurry pre-cooling -alternative packaging and transport options -on-farm harvesting and handling practices -effect of pre-harvest factors on postharvest quality. Higher yielding, indeterminate varieties with better postharvest characteristics (esp. firmness, shelf life and Brix) selected and made available to growers. Effects of breaks in the cool chain investigated. Postharvest workshops and farmer field school undertaken. Additional: Consumer & Cambodian grower surveys. Development of the IRREC deformation tester.
2.6	Engage private industry partners to evaluate new varieties	Local and overseas companies as collaborators	Ongoing	Apart from AQIP (rice seed company) there are no local seed companies dealing with vegetable seeds. Continuing discussions with AQIP.
2.7	Local company to package and	Commercial packaging of	1/6/07	Trial packaging by AQIP Seed company. CLN1462A package

	distribute AVRDC varieties	AVRDC lines		distributed to over 200 farmers.
2.8	Assist in evaluation of new AVRDC/commercial sector varieties	Variety evaluations completed	1/5/08	Initial screening trials of tomato and chillies continuing at CARDI. On farm evaluations commenced with select varieties.

PC = Partner Country, A = Australia

Objective 3: To improve R&D capacity in Cambodia in vegetable research, by ensuring maximum sharing of technology and know-how between Australian, AVRDC and Cambodian partners.

No.	activity	outputs/ milestones	completion date	comments
3.1	Post harvest training for Cambodian scientists	1. Trained personnel and training materials in survey methodology, post harvest research and field trial management. Well planned project activities. 2. Trained personnel and facilities for horticultural post harvest research capacity at CARDI improved.	Mid 2008	Research capabilities improved for both CARDI & GDA. Field researchers capable of initiating and maintaining institute and on-farm trials, evaluating and interpreting results. In-country (Cambodia) training on postharvest, survey methodology and several aspects of production. R&D staff study tours to Vietnam & Australia. Additional: Insect collection initiated by AYAD. Postharvest laboratory and coolroom established. Staff training has occurred.
3.2	Research trial management training for Cambodian scientists	Research management training completed and trials managed succesfully	1/4/07	Completed in 2007
3.3	Survey and evaluation method training for Cambodian scientists	Survey /evaluation method training completed	1/10/06	The socio-economics group at CARDI involved in production/supply chain surveys. Tomato and chilli surveys completed.
3.4	Set up demonstrations and conduct field days	Field days completed successfully	1/4/08	Six field days completed in 2007/08 on tomato /chilli varieties, IDE drip irrigation, mulching and nitrogen rate..
3.5	Develop extension materials	Extension materials distributed and evaluated for effectiveness	Ongoing	Brochures on tomato production and the tomato varieties Neang Pech and Neang Tamm produced. Also, guidelines on production of tomato seed has also been written by CARDI.
3.6	Measure economic and social impacts	Surveys complete	Ongoing	Five case studies completed on tomato farmers. Economic analysis of technologies including fertiliser and drip irrigation has been completed. Preliminary data available.

PC = Partner Country, A = Australia

Sub-objective 4.1. Obtain preliminary data for the management of the bacterial disease in rice, including basic treatment and decision tools for advice on sowing retained seed.

no.	activity	outputs/ milestones	completion date	comments
4.1.1	Design and conduct glass house experiments to determine the efficacy of simple seed treatment in alleviating bacterial disease of rice. (PC)	Analysis and recommendations on suitable seed treatments to reduce the effects of bacterial diseases of rice.	10/12/08	Final data set collected Several issues occurred – rats ate first seed lot. Watering was missed on several occasions
4.1.2	Design and conduct glass house experiments to determine the maximum recommended disease load for sowing retained seed. (PC)		Not completed	Not re-sown following rats destroying initial trial – lack of appropriate seed to repeat.
4.1.3	Evaluate results and determine basis for decision making tools. (PC/A)	Production of basic fact sheets to provide information on recognition of rice seed infected by bacteria, determination of disease load, treatment options and contacts for additional advice and assistance.	20/01/2009	Non-significant differences between treatments observed from experiments. Literature supports the use of the three treatments trialled.

Sub-objective 4.2. Provide direct training to new staff with in the Crop Protection Unit at CARDI in the processes of bacterial isolation and preliminary identification

no.	activity	outputs/ milestones	completion date	comments
4.2.1	Liaise with unit leader to develop an activity plan (PC)	Activity plan endorsed by participants	1/10/08	
4.2.2	Design training schedule and modules to appropriate level (A)	Training activities developed	1/10/08	BACT-ID system chosen and established at CARDI
4.2.3	Attend CARDI to deliver training (PC)	Staff competent in isolation and performing preliminary description activities for phytopathogenic bacteria	20/01/09	In three visits staff capable of independent isolation and preliminary identification using the BACT-ID system

Sub-objective 4.3. Conduct initial disease surveys of vegetables in Kandal province to determine the occurrence of bacterial wilt.

no.	activity	outputs/ milestones	completion date	comments
4.3.1	Cooperating farmers willing to participate in surveys (PC)	At least 3 sites selected	1/10/08	Three sites selected and visited on three occasions. Additional sites visited as situation permitted.

4.3.2	Design appropriate survey strategy (PC)	Implement strategy and staff trained to conduct future surveys	1/10/08	Given small size of plantings, whole field surveys implemented Plant breeding unit involved in surveys
4.3.3	Match farmer recognition with isolation of causal organism (PC)	Survey /evaluation method training completed		Symptoms of bacterial wilt not present at any site. In on-going surveys, symptoms reported to be bacterial wilt did not result in isolation
4.3.4	Train CARDI staff in isolation and identification of causal organism (PC)	CARDI staff confident in performing procedures	20/01/09	Bacterial wilt not isolated; other bacteria isolated from various crops used to provide training

Sub-objective 4.4. Provide a basic laboratory manual consisting of standard operating procedures and protocols to allow staff to confidently and correctly isolate bacteria and perform basic tests to progress with later additional training towards identification to the genus level

no.	activity	outputs/ milestones	completion date	comments
4.4.1	Determine appropriate protocols (A)	Protocols assessed and suitability determined	1/10/08	Assessment conducted in Australia and Cambodia
4.4.2	Deliver training in selected protocols (PC)	Staff competent in performing protocols	20/01/09	Hands on training provided during in-country visits
4.4.3	Evaluate and implement suitable storage system of identified samples for confirmation of identification (PC/A)	Cost analysis and viability of options determined	19/12/08	Considerations – power use, equipment cost, hands-on time
4.4.4	Produce a basic laboratory manual (A)	Manual completed and deployed to laboratory	28/02/09	Waiting on approval from PC and possible translation

Sub-objective 4.5. Initiate surveys of vegetable crops to determine the occurrence and severity of phytopathogenic viruses.

no.	activity	outputs/ milestones	completion date	comments
4.5.1	Liaise with the leader of the Plant Protection unit and staff within the Plant Breeding unit to identify regions of high production for survey activity. (PC)		March 2009	New unit leader appointed by CARDI, Dr Khay Sathya. A good working and personal relationship has been established.
4.5.2	Conduct field surveys in selected regions recording the occurrence of suspected viral disease. (PC)	Surveys completed and disease affected sites mapped and rated for severity	June 2009	

4.5.3	Match CARDI staff and farmers ability to recognise symptomatic plants with actual disease identification. (PC)	CARDI staff confident in identifying viral disease symptoms in the field	June 2009	Some difficulty with certainty of recognition due to ambiguus symptoms
4.5.4	Photograph and preserve diseased samples (PC)	Identified samples lodged in the CARDI disease herbarium	June 2009	Few positively identified samples lodged.

Sub-objective 4.6. Evaluate and modify detection techniques for phytopathogenic viruses to allow preliminary identification at CARDI, with detaled analysis conducted in Australia.

no.	activity	outputs/ milestones	completion date	comments
4.6.1	Research and select techniques based on ELISA and RT-PCR currently available for viruses in vegetable crops (A)	ELISA kits evaluated and RT-PCR protocols established in Australia.	May 2009	Elisa techniques considered unsuitable for CARDI and difficult to establish at CSU. PCR procedures preferred.
4.6.2	Modify techniques to make suitable for application in a basic plant pathology laboratory. (A)	ELISA protocols adjusted to suite deployment in Cambodia and preliminary protocols for RT-PCR established.	Not completed	Some difficulty in optimising the system. Recommend further investigation.
4.6.3	Train CARDI staff in the application of techniques. (PC)	CARDI staff confident in performing established techniques ELISA techniques used to identify phytopathogenic viruses in Cambodia. RT-PCR procedures established and conducted in Australia. Fact sheets produced for the common viral diseases in vegetables.	June 2009	CARDI staff confident in use of FTA cards for field collection and application in a laboratory setting ELISA techniques considered not suitable Some success in PCR procedures, but not all samples able to be amplified. Recommend further optimisation. Fact sheets in production

Sub-objective 4.7. Generate data on the prevalence and severity of Sclerotium rolfsii in vegetable cropping systems in Cambodia.

no.	activity	outputs/ milestones	completion date	comments
4.7.1	Survey district in which S. rolfsii had been identified during phase 1 of the variation. (PC)	Surveys conducted	June 2009	
4.7.2	Sample and map locations in which the disease occurs. (PC)	Data obtained on the prevalence and severity of S. rolfsii in cropping systems.	June 2009	
4.7.3	Obtain and record field history from farmers in affected areas. (PC)	Field history matched to disease data.	April 2009	Limited availability of farmers to obtain information. In some instances, farmers unwilling to provide information.
4.7.4	Monitor CARDI field trial currently infected with S. rolfsii. (PC)	Data generated on disease progress over a season for CARDI trial.	June 2009	
4.7.5	Establish glasshouse trials to determine management options for the disease. (PC)	Basic management options initiated under glasshouse conditions.	June 2009	

Sub-objective 4.8. Provide laboratory protocols for the detection procedures for viruses.

no.	activity	outputs/ milestones	completion date	comments
4.8.1	Evaluate and modify all protocols for use in the CARDI laboratory. (A)	Protocols modified for use and deployed in CARDI laboratory.	April 2009	
4.8.2	Step by step training of staff in all protocols. (PC)	Staff confident and competent in performing protocols.	June 2009	Staff confidently using FTA cards in the field and laboratory
4.8.3	Production of protocols for inclusion in the laboratory manual. (A)	Laboratory manual updated to include virus specific protocols.	June 2009	

PC = partner country, A = Australia

7 Key results and discussion

7.1 Objective 1 – To map supply chains and identify constraints to improvement of the Cambodian vegetable industry. (Cambodia)1

7.1.1 Tomato survey

This survey built on an earlier survey undertaken by the ADB RETA 6208 project looking at value chain analysis and identifying supply chain constraints. Farmers were asked about their production, postharvest and marketing practices. They were also asked about what they believed were the main causes of deterioration. A summary of the data obtained is attached in Appendix x as prepared by Ou Pich Ong. Most farmers were growing one crop per season with only 12% growing 2 or more crops. Fifty six percent of farmers rated colour stage as the most important thing that buyers looked at when they were buying tomatoes, whilst a further 21% rated freedom from blemishes as the most important quality trait. When asked how they decided when to harvest – farmers were relatively evenly split between demand by collector (44%) and when the fruit was at full red colour (39%). Most farmers were harvesting late morning or late afternoon, less than desirable times if the aim is to reduce field heat. The product was also spending a considerable amount of time on farm prior to being sent to market with 42% of tomatoes spending 2-6 hours on farm after harvest, whilst a further 21% remained on farm for 6-12hours. Seventy eight percent of farmers indicated that some of their fruit were unmarketable, with the main reasons given in Figure 5.

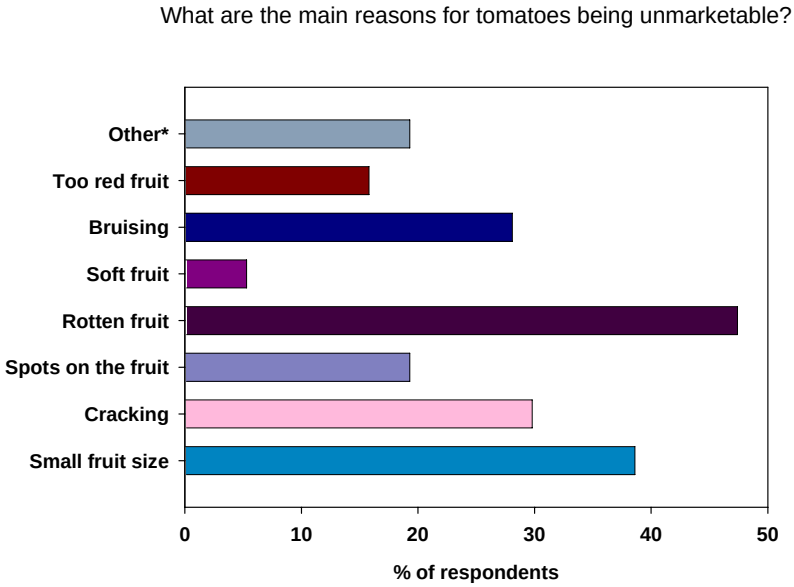


Figure 5: Main reasons for tomato fruit being unmarketable

[1] *Location of re-search/training.*

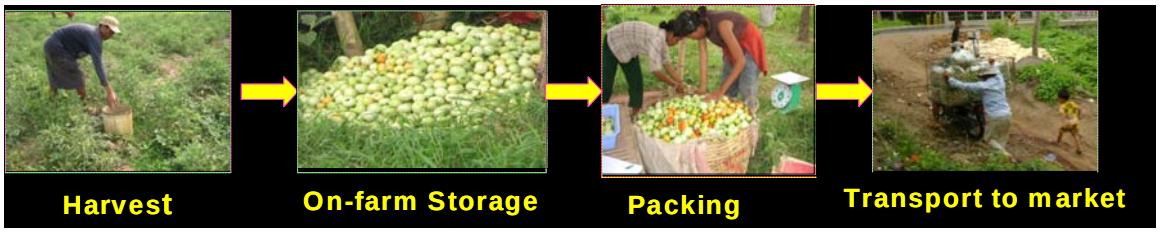
7.1.2 Tomato consignment trials

A series of consignment trials were undertaken from farm to market to gain a better understanding of tomato supply chains and to identify critical stages in the supply chain that lead to losses both quantity and quality.

Typically tomatoes were harvested throughout the morning with harvest often being completed around midday. Small plastic or metal buckets are often used to harvest tomatoes, with product then being stored on-farm either in full sun, in a shaded area or under the house. Product is then typically packed into 100kg baskets often mid-afternoon and then transported to the market in the evening. Temperature and impact loggers provided information on the environment surrounding the produce. Quality losses were assessed at transit points in the chain. Most physical damage resulted from bruising (Figure 6) with most of this bruising occurring on-farm during harvest and transport to the on-farm storage area. However the more severe bruising occurred during packing with the most damaged fruit coming from the bottom of the basket. Fruit largely retained their firmness along the chain, with only slight softening occurring.

Temperature management on-farm and packaging are two areas were intervention is warranted. Reducing the build up of field heat by completing harvesting earlier and storing in an appropriate area is likely to extend the shelf life of the product. Likewise designing more appropriate packaging is likely to reduce damage. For tomatoes these two areas became the areas of focus for a series of on-farm trials.

Fig 6 Damage occurring along the supply chain



Stages of Supply Chain	Control (8.30 am)	Harvest (9am)	Storage (9-10am)	Packing (2-3 pm)			Arrival at Market (6-7am)		
				Top	Mid	Bot	Top	Mid	Bot
Bruising Minor (%)	7.5	30	30	20	43	26	29	30	31
Bruising Moderate (%)		7	14		4	19	5		5
Bruising Major (%)						5		5	
Total Bruising (%)	7.5	37	44	20	47	50	34	35	36
Firmness (mm)	0.19	0.17	0.17	0.21	0.18	0.18	0.22	0.19	0.24

7.1.3 Chilli supply chain

Vegetable production is a major farming activity in Kampong Cham and Kampong Chhnang with 94% and 77% of the farms surveyed in these provinces producing vegetables (Table 4). Chilli is the major vegetable traded with cucumbers and gourds also being important (Table 5).

Table 4. Main farming activities in Kampong Cham and Kampong Chhnang

Main farming activity	Kampong Cham	Kampong Chhnang
Rice	50%	85%
Corn	66%	67%
Sweet potatoes/cassava	72%	6%
Vegetables	94%	77%
Fruits	16%	2%
Hogs	6%	26%
Poultry	16%	32%
Cattle	66%	35%
Sesame	9%	-
Mung bean	-	2%

Source: Surveys in collaboration between CARDI; I & I, NSW; AVRDC and GDA. N=32 in Kampong Cham and N=66 in Kampong Chhnang

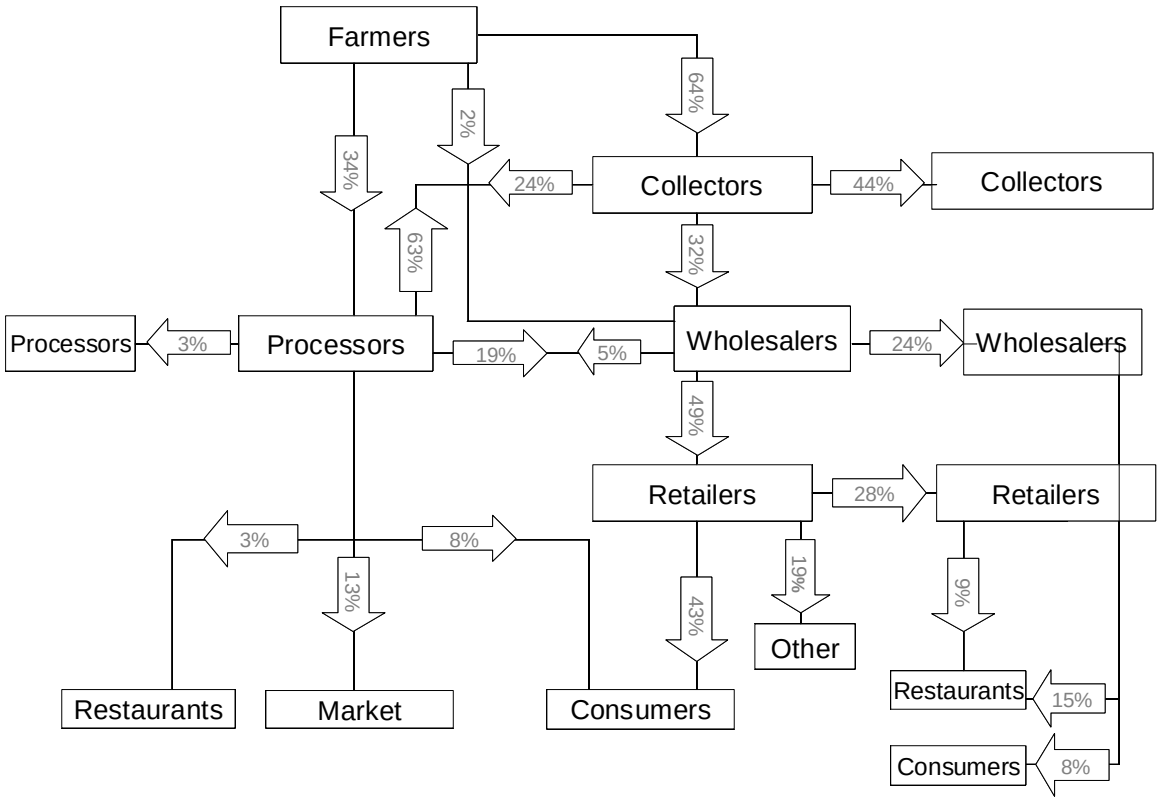
Table 5: Vegetable trading in Kampong Chhnang and Kampong Cham

Main vegetable trading	Farmer		Retailer		Processor		Collector	
	N	Percent	N	Percent	N	Percent	N	Percent
Alliums	0	0	31	12	0	0	0	0
Chilli	98	57	40	15	25	89	19	73
Chinese kale	0	0	21	8	1	4	0	0
Cucumber	34	20	27	10	0	0	4	15
Gourds	22	13	23	9	0	0	0	0
Kangkong	0	0	22	8	0	0	0	0
Other	4	2	25	10	1	4	3	12
other brassica species	0	0	21	8	0	0	0	0
Tomato	13	8	25	10	1	4	0	0
yard-long bean	2	1	24	9	0	0	0	0
Total	173	100	259	100	28	100	26	100

Source: Surveys in collaboration between CARDI, I & I, NSW; AVRDC and GDA, 2007

Marketing channels for chilli are shown in Figure 7. Nearly 2/3's of chilli is supplied to collectors, whilst the remaining 1/3 is directly processed. In some cases in Kampong Cham Thai based traders directly purchase chilli for direct export to Thailand. These traders also tend to provide seed and in some cases other inputs.

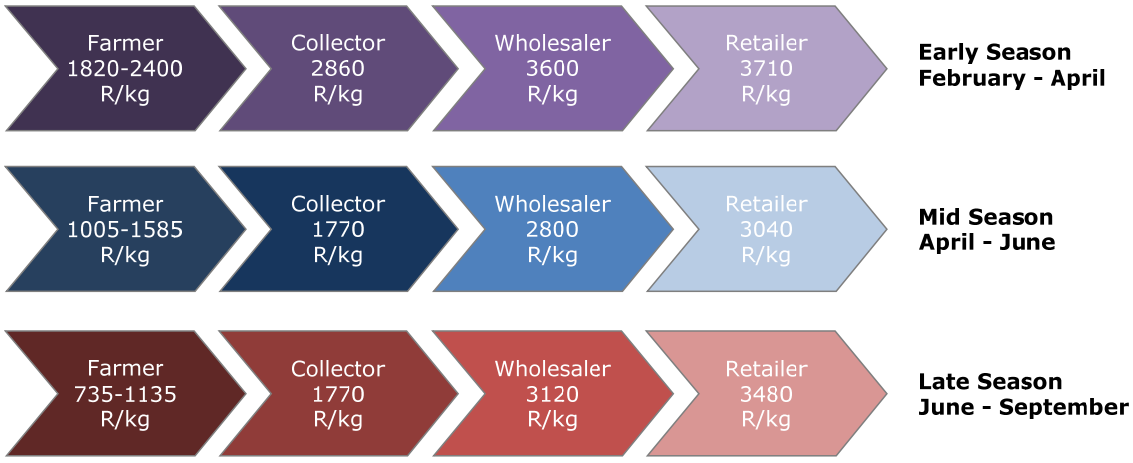
Figure 7: Overview of Chilli supply chains



Source: Surveys in collaboration between CARDI, I & I, NSW; AVRDC and GDA, 2007.

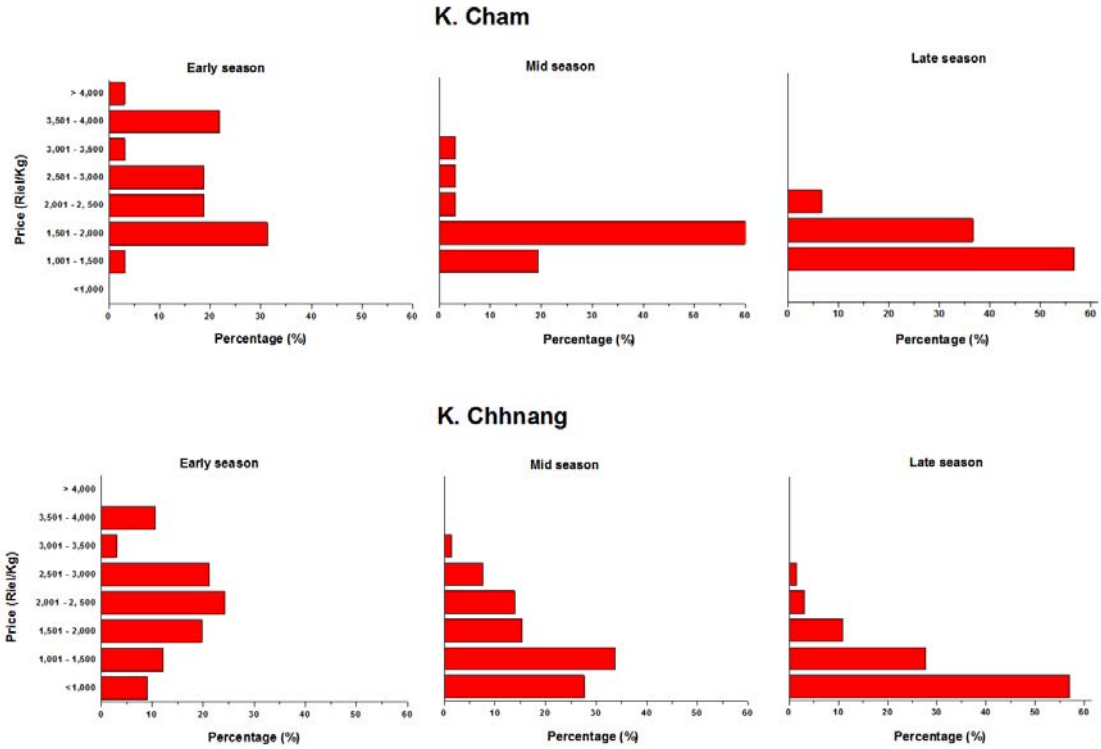
Fig 9 shows the prices received by actors in the value chain for fresh sweet chilli. Returns, particularly to farmers, tend to be higher but more variable earlier in the season.

Fig 8: Chilli value chain



Source: Surveys in collaboration between CARDI, I & I, NSW; AVRDC and GDA, 2007

Fig 9: Average price of fresh chilli in Kampong Cham and Kampong Chhnang



Source: Surveys in collaboration between CARDI, I & I, NSW; AVRDC and GDA, 2007.

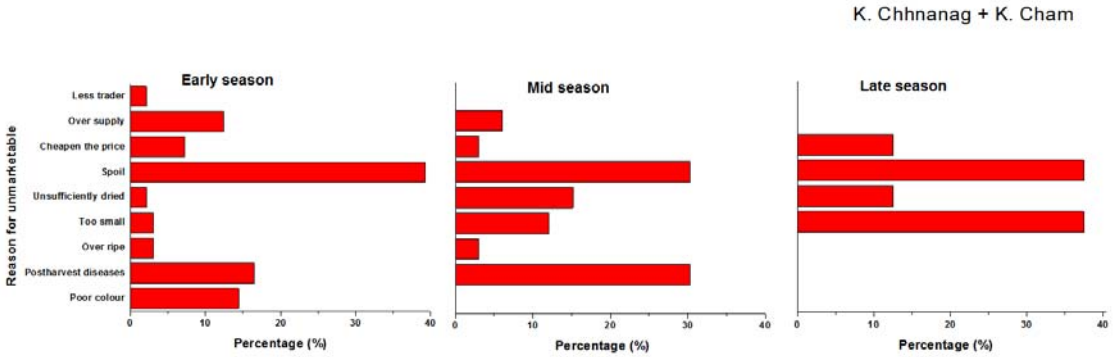
Extensive data was collected on chilli production and postharvest practices including seed source, preferred varieties, planting schedule, fertiliser use, irrigation type and frequency, production methods, harvesting practices, packaging methods and storage and transportation operations. A summary of these results is provided in Appendix 5, prepared by Srey Sinath.

Supply chain actors were asked to estimate product losses along the supply chain both in terms of an outright loss (ie unsaleable) and a quality loss (selling price needs to be discounted). In the case of chilli, product that is poor quality or no longer saleable as fresh chilli tends to be dried. Without a dried chilli market product losses would be considerably higher. Losses tend to be higher later in the season and also tend to be realised more at the farm and retail level. The main reasons for chilli being downgraded tend to be postharvest disease and other spoilage and also some sizing issues. In the case of dried chilli insufficient drying seems to be one of the major reasons given for chilli being discounted.

Table 6: Estimate of losses at various points along the chilli supply chain

Supply chain category	Harvesting Stage	Fresh chilli		Dried chilli	
		%Unsaleable (avg/100kg)	%Quality loss (avg/100kg)	%Unsaleable (avg/100kg)	%Quality loss (avg/100kg)
Farmer	Early season Mid season Late season	8.11 6.39 13.43	5.48 6.48 13.70		
Retailer	Early season Mid season Late season	1.94 1.86 2.52	1.15 2.05 2.98		10.67 6.92 7.17
Processor	Early season Mid season Late season	0.54 1.17 1.42	1.21 3.50 11.58	0.12 0.44 1.52	1.15 1.94 4.91
Collector	Early season Mid season Late season	0.38 1.35 1.36	0.21 1.26 3.64	0.00 0.00 1.17	0.17 0.08 4.33
Wholesaler	Early season Mid season Late season	6.26 3.45 11.50	16.43 1.63 35.00		

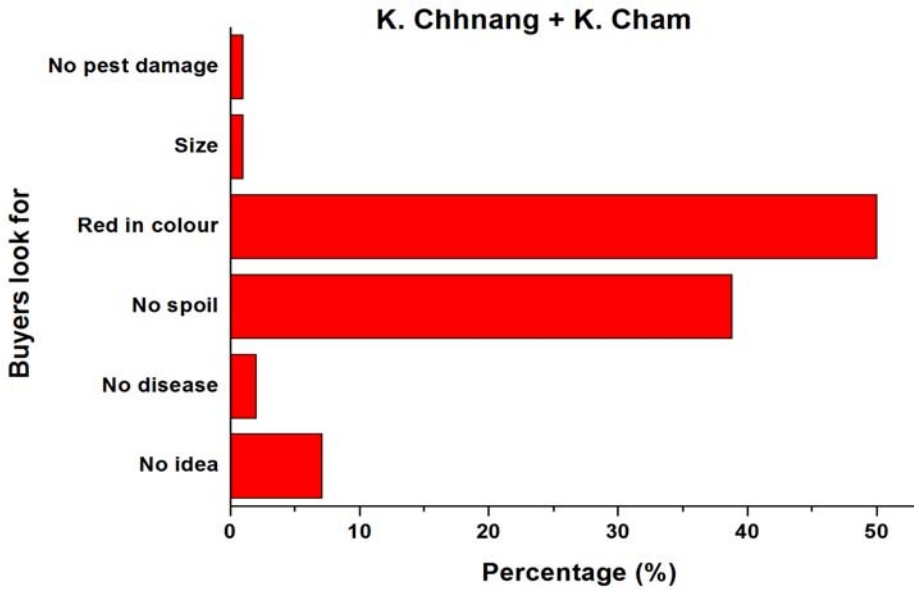
Fig 10: Main reasons for fresh chilli to be downgraded



Source: Surveys in collaboration between CARDI, I & I, NSW; AVRDC and GDA, 2007

Buyers were also asked what they look for when they buy fresh chilli. The main criteria seem to be red colour and no spoilage evident. The use of the term spoilage in this case also tends to relate to length of shelf life

Fix 11: What buyers look for in fresh chilli



Source: Surveys in collaboration with CARDI, I & I, NSW; AVRDC and GDA, 2007

7.2 Objective 2– To develop and demonstrate improved production and postharvest strategies that will underpin quality improvement and industry development. (Cambodia and Australia

- *To optimise vegetable production systems*
- *To optimise postharvest systems*
- *To improve access to reliable germplasm*

7.2.1 Variety evaluation

The extensive series of varietal trials carried out over the 4 dry seasons of the project included both research station and on-farm replicated trials and demonstrations. In addition the best tomato and chilli varieties were used in the nitrogen rate trials and drip irrigation/mulching demonstrations. A summary of the results from each season is included below.

Year 1 2005/06 **-** The tomato variety entries included AVRDC varieties compared to existing grower varieties and as yet untested hybrid varieties, which were donated to the project by commercial seed companies. The trial sites varied in soil type and management system, and therefore the results gave good indication of suitability of the entries Some of the traditional varieties although relatively high yielding have poor shelf life, and other undesirable traits such as a tendency to split and crack.

In terms of fruit yield, the best performing open pollinated lines include CLN 1462A and CLN2764 and the traditional line K1, and the best performing hybrids Dalila (East West Seeds), HET2 (AVRDC) and Jetayu (Marco Polo Seeds). Overall, the best performing line at Dey Eth was CLN1462A, with the fruit yield significantly higher than all other varieties (at the 5% level), although higher plant populations probably influenced yield. Some of the commercial hybrid

varieties, including Dalila and Jetayu performed consistently well at both sites. Further trials with these varieties would be required to determine if they perform consistently well enough to justify higher seed prices generally paid for hybrids. There was some variation between results at the CARDI and Dey Eth sites, the most notable being the poorer performance of CLN 1462A at CARDI.

Of the AVRDC lines, tomato breeder Dr. Peter Hanson suggested keeping CLN1462A and CLN2764 for next season's trials. He also noted that in Mali, researchers there had reported CLN2764 as Gemini virus resistant, which would important trait for Cambodia. Of the AVRDC hydrids, TLCV15 and HET2 could be dropped out as their performance was not exceptional when compared to some of the commercial hybrids such as Dalila.

Year 2 2006/07 **-** Tomato cultivar evaluations (Dey Eth Research Station and Rokor Koang and CARDI). Transplanting of the trials plants took place on 14th December at Dey Eth and 15th December 2006 at CARDI. Records of survival %, growth rates, days to maturity and yield from the five varieties in the trial were taken. There was little variation in days to maturity at both sites, with the earliest being TLCV15 at 81 days, and the latest being CLN1462A and CLN2498A (Neang Pech) at 85 days. There was some variation in yield between the two sites. At Dey Eth, the mean marketable yield (results not analysed yet) ranged from the highest, T56 at 47.24 tonnes/ha to CLN2418Aat 27.8 tonnes/ha. The control variety, CLN1462A ranked 2nd at 41.6 tonnes/ha. Non-marketable fruit was highest in TLCV15 and CLN2418A at around 5 tonnes/ha. The non replicated on farm demonstration at Rokor Koang was managed also by DAALI staff, and was transplanted on the 14th December 2006. TLCV15 and the local variety K1 produced the highest marketable yields at an impressive 54.9 and 52.4 tonnes/ha respectively.

At CARDI, Neang Pech (CLN2498A) was the stand out variety, with a significantly higher yield of 37.49 tonnes/ha, compared to all other varieties. Fruit weight was heaviest with this variety, and general plant vigour and health was excellent. Neang Tamm (CLN2418A) had a high percentage cracked fruit, which drastically reduced its marketable yield to the lowest of 17.11 tonnes/ha. CLN1462A performed below average at 19.31 tonnes/ha. There was no a significant difference between CLN1462A and TLCV15, but significant differences between T56 and Neang Tamm on marketable yield. TLCV15 was the earliest variety to flower, fruit set and mature at this site, with the first fruits ready for harvest at 81 days.

The varieties also showed varying degrees of disease susceptibility. T56 was devastated by Bacterial canker (*Corynebacterium michiganense pv. Michiganense),* with varying degrees of yellow leaf curl, bacterial wilt, canker and blossom end rot in the other varieties. It is interesting to note the bacterial canker can be seedborne, and this could explain its prevalence in T56. All 4 reps of TLCV15 suffered blossom end rot, and rep 1 was effected by waterlogging.

Chilli - Three chilli varieties, 9955-15, CCA 321 and local variety 3A(KK) were transplanted at Kbal Koh on 18th December. CCA 321 was a stand out performer in terms of mean marketable yield at 3.98 tonnes/ha, while 9955-15 and Local 3A yielded 1.83 and 2.78 tonnes/ha respectively. Of the non marketable fruit, fruit abnormalities accounted for the highest proportion of rejects, with up to 20% of 9955-15 fruit rejected at harvest. CCA 321 had the lowest proportion of non-marketable fruit, with approximately 21% of fruit rejected, while 9955-15 had up to 42% of fruit unmarketable. The on farm cultivar non-replicated demonstration at Rokor Koang was also sown on the same day, with CCA 321 again performing best at 11.57 tonnes/ha, while Local 3A also performed well at 11.3 tonnes per hectare. Unlike the research station trial, all varieties performed well at this site, with less than 1 tonne/ha separating yields. Due to plant losses early in the season, the CARDI trial was not harvested. However, seed was collected from most of the varieties to carry over for the 2007/08 season.

Year 3 2007/08 **-** Selections from the tomato and chilli trials were grown on eleven separate farms across three provinces, Kandal, Siem Reap and Kompong Cham. District and provincial staff assisted Cambodian Agricultural Research and Development Institute (CARDI) and Department of Agronomy and Agricultural Land Improvement (DAALI) team members in managing the sites, and conducting the field days, which were held in February 2008. AVRDC World Vegetable Centre plant breeders also attended the field days. Farmers participated in assessment of the varieties at the CARDI sites in Siem Reap, and this information fed into the evaluation process. Yield and marketability of each variety has been collected and will be reported at the project annual workshop in September 2008. Some of results are presented in this report.

The top three tomato varieties included in the on farm trials were Neang Pich, Neang Tamm and CLN1462A, with these compared with farmers standards at each site. The top yielding tomato variety was Neang Tamm, with marketable yield of 44.5 tonnes per hectare compared with the local variety at 23 tonnes per hectare. The chilli varieties were CCA 321, 9955-15 and PBC 142. These varieties also featured in the mulching and drip irrigation demonstrations.

Screening trials of 32 tomato lines and chilli lines were also conducted at CARDI. There were fourteen varieties of tomato including CLN2777E and CLN2777B showed some commercial potential, and will be advanced to the next stage of testing.

Figure 12: Neang Pech variety Harvested Fruits

Figure 13: Neang Tamm variety Experimental Field at CARDI

Year 4 2008/09 - Screening of multiple tomato and chilli lines at CARDI continued. One of the tomato lines, CLN2400B demonstrated comparable yield, shelf life and quality to Neang Pich,

but was less tolerant to disease and heat. Nematode resistance was also noted in CLN2679E, CLN2764A, CLN2714H and CLN2413D. In chilli, 5 lines were found to be comparable to the standard PP9955-15. PP9955-15 fruits are not well suited to the Cambodia market, as the fruit is large and yellow if picked early. There was also a reasonable level of anthracnose observed in most of the varieties.

Figure 14: Sample varieties out of the 2008/09 trials

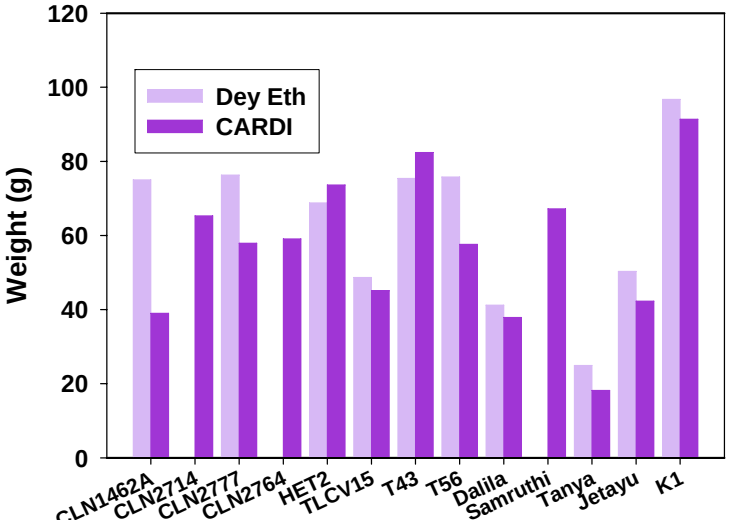
A full description of the CARDI variety trial program can be found in Appendix 1.

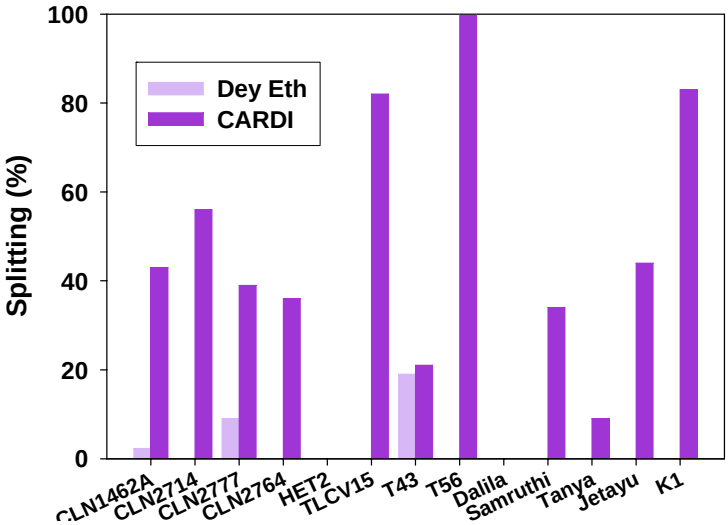
7.2.2 Evaluating the postharvest performance of tomato varieties

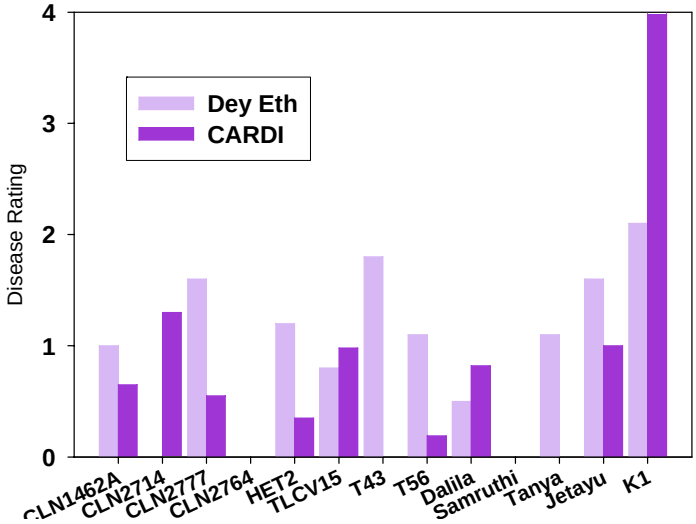
In 2006, the postharvest performances of 13 tomato varieties were evaluated at 2 sites. Figs 14 to 20, show the average weight, susceptibility to splitting, disease susceptibility, total soluble solids, weight loss and shelf life of the varieties tested. Varieties performed differently at the two sites. High levels of splitting in fruit grown at the CARDI site impacted shelf life (discussion will therefore be restricted to the Dey Eth site).

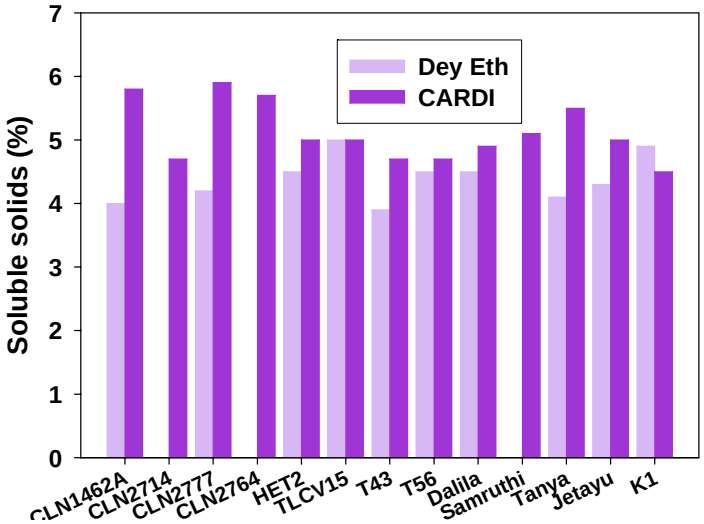
At the Dey Eth site, variety had a significant effect (5%) on fruit weight, weight loss, firmness, locule number, wall thickness and flavour. Several varieties had high rates of water loss and so retaining the calyx in these varieties will be important. TLCV15 and Dalila had the longest shelf life, with CLN1462A the only variety to have a shorter shelf life than the control TMK1 (Figure x). All varieties were firmer than the control TMKI. Varieties with the best flavour ratings (>7) were TLCV15, HET2, T43, T56 and Jetayu. In terms of total soluble solids levels, TLCV15, T56, Dalila, HET2 and TMK1 had the best levels (around 5%). Overall TLCV15 was clearly the best performing variety from a postharvest perspective.

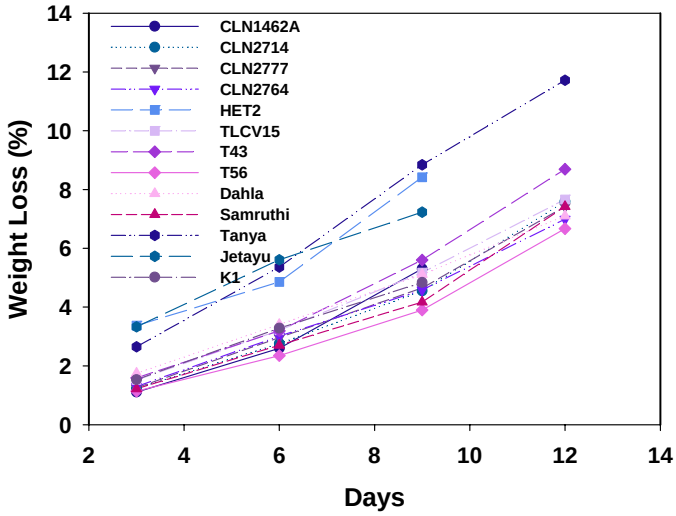
Figures 14-20 The average weight, susceptibility to splitting, disease susceptibility, total soluble solids, weight loss and shelf life of the tomato varieties tested at CARDI postharvest laboratory March 2006

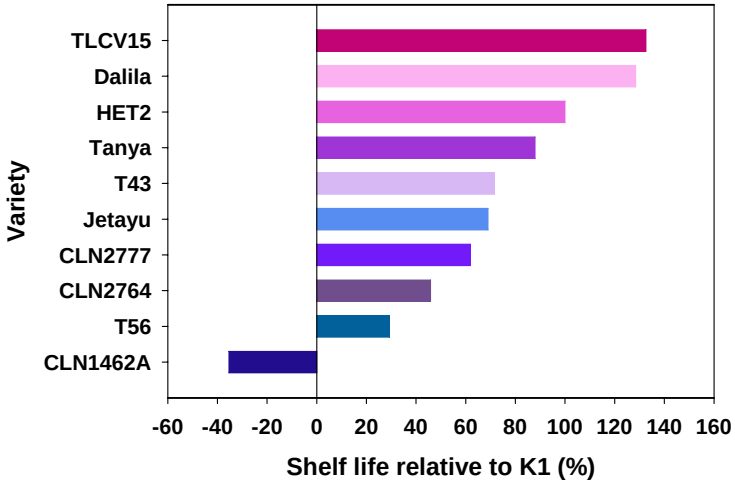












In 2007, 5 varieties KK2 (CLN1462A), TLCV15, T56, Neang Pich and Neang Tamm were evaluated further. Once again TLCV15 was the best performing variety with a shelf life of 11 days at 20ºC, but T56, Neang Pich and Neang Tamm also had good shelf life (7-8 days at 20ºC). KK2 (CLN1462A) had the shortest shelf life of 4.6 days. TLCV15, T56 and Neang Pich were sweet with total soluble solids of around 6%. Neang Tamm retained its firmness following storage. Each of the varieties tested in 2007 was considered to have market potential.

7.2.3 Production Technologies

IDE Drip Irrigation Evaluation

Most vegetable production regions located away from the Mekong floodplain experience water shortages between the months of December and May. This period is the main vegetable production season in southern Cambodia, so water is a major constraint to production. Most farmers in provinces such as Takeo, Svay Rieng and Prey Veng rely on small ponds for crop irrigation, and supplies are often depleted mid way through the dry season.

The International Development Enterprises (IDE) has introduced a low tech drip irrigation system. The system is well suited to vegetables and other cash crops such as sugar cane or sweet corn. Evaluations of the system commenced in Year 2 of the project, and are continuing into the new project. Adaption of the system to new provinces outside those that IDE is working in is being carried out by projects such as ours. Data from trials are fed back to IDE to assist to build a knowledge bank of drip in Cambodia under different environments, soil types and crops.

Outcomes from the drip irrigation trials are summarised below;

In the 2005/06 season, drip irrigation proved successful in fresh market tomatoes in trials at Kbal Koh. Total marketable fruit yield from the drip block was the equivalent of 12.62 tonnes/ha (63.1 kg/m2) was 26% higher than the hand watered block at 9.98 tonnes/ha (49.9 kg/m2). Average fruit weight from the 1st pick of the drip block was also higher on the drip block at 83.2gms compared to 71.0gms for the hand watered block. Total water used on the block was equivalent to 2.24 ML/ha for drip, and 3.13 ML/ha for the hand watered plot. Water use efficiency was 5.63 tonnes/ML on drip compared to 3.18tonnes/ML on hand watered plots.

A second trial was established in December 2006 to look at the benefits for chilli, with the treatments including IDE drip with black plastic, drip with rice straw mulch and drip with no mulch. These treatments were compared to hand watered plots under, plastic, rice straw mulch and no mulch. Transplanting of the crop took place on the 12th December 2006.

Data including labour, water use and marketable yields were collected. The results showed obvious advantages in using drip with about half the water volume required in the drip irrigation plots to produce equivalent fruit yields in to the hand watered chilli plots. The highest marketable fruit yield was in the drip irrigation and black plastic plot, with 10.51 tonnes/ha yield recorded, compared to 9.01 tonnes/ha for the hand watered plots.

Figure 21: Dr Paul Gniffke from AVRDC displays one of his chilli varieties in an IDE drip irrigation trial in Bati District Takeo in February 2008

The IDE drip irrigation demonstration was used to help train GDA and CARDI staff to calibrate

drip systems and measure water application rates as part of the Irrigation Management Course conducted in February 2007.

In 2007/08, the drip trials moved on farm to nearby Banteay Dek. The farmer was a highly regarded tomato grower, skilled with growing and water management, and consequently proved a great location for the farmer field day which was held in February 2008. He achieved 53.08 tonnes/ha equivalent on drip and black plastic compared to 51 tonnes/ha on handwatered black plastic combination. This yield was achieved with 30% of the water used in the hand water plot.

In 2008/09, GDA established two grower trials in Takeo, one on chilli and one on tomato. Water was drawn form a nearby ponds, typical of Takeo in the dry season. Similar results were found to the 2007/08 season trials. However there was a larger differential in the black plastic mulch vs unmulched plots. l

Most of the drip irrigation trials included comparisons between black plastic, rice straw mulch and unmulched treatments. In all trials over 3 years from 2005 to 2008, black plastic mulch treatments provided consistently higher yields than rice straw mulch and unmulched treatments. Pau Sinath from CARDI found that over 3 times the yield could be achieved using black plastic mulch compared with no mulched plots in a replicated trial at CARDI. Mong Vandy from GDA had great success with farmers adopting black plastic mulches for vegetables in several provinces, included the north western provinces of Banteay Meanchey and Battambang, some of which have very limited water resources. Most of these blocks were either hand-watered or flood irrigated. In some cases the straw mulch treatments were providing better benefit than the drip irrigation, and for a fraction of the price.

Nitrogen fertiliser recommendations for tomato and chilli

The objective of the nitrogen rate trials for tomato and chilli has been to develop more precise recommendations on fertiliser rates which provide optimum yield at the lowest rate, with reduced production costs and potential impact on the environment. While vegetables tend to require higher levels of fertiliser input than other field crops on a per hectare basis, the returns are also higher, so farmers can crop smaller parcels of land. This creates more opportunity for crop rotation which benefits the soil by minimising pest and disease build-up and allowing a resting phase between crops.

Fertiliser recommendations for vegetables have historically been based on general recommendations in AVRDC growing guides. Little or no testing of the appropriateness of those recommendations had been carried out.

Only one tomato trial was carried out in tomatoes in 2005/06. Rates of 0, 100,120,150 and 180kgs N/ha were used in this trial. Despite there being a classic linear response to N rates from 0 to 180kgs/ha, there was only a significant difference at the 5% level between the 0kgs/ha rate and all other rates. The 150kgsN/ha rate was judged to be the most appropriate rate from the trial results. Shelf life studies were carried out, but showed little difference between the treatments.

In chillies, two trials were carried out on Dey Eth Research Station in 2006/07 and 2007/08, and in the final year, a grower trial was carried out in Takeo in 2008/09. Nitrogen rates used in the chilli trials was 0, 100, 150 and 200kgs/ha. Rates of other nutrients remain constant. Urea was the nitrogen form used in all experiments.

In each chilli trial, there was a linear response to increasing nitrogen rates from 0 to 150kgs N/ha rates, with150kgs N/ha rate gave highest marketable fruit yields. Marketable fruit yields declined at the 200kgs N/ha rate.

Figure 22: Collaborator farmer alongside the chilli nitrogen trial at Takeo, February 2009

The 2008/09 chilli (*Variety 9955-15 shown at left*) trial in Takeo gave the best commercial results from the trials. Production costs data was collected, comparing the additional costs for fertilisers for higher rates with the potential added income through increased yields. Optimum yield was achieved at the 150kgs N/ha rate. The 150kgsN/ha rate produced an average of 24.19 t/ha valued at $14,5114 /ha gross income, with production costs of $2,406/ha. This compared to the more commercially used rate of 100kgsN/ha which yielded 18.9 t/ha valued at $11,358/ha with production costs at $2,316/ha. So for an additional investment of $90/ha, the grower would have received an extra $3,156 in income. The Cambodian researchers expressed this in terms of "economic efficiency" (EE) which is a simple division of gross income vs production costs. Using this method the EE was 6.03 for the 150kg N/ha compared to 4.90 for the 100kgN/ha rate. Use of this method to describe the economic benefits from a technology is crude, but in this case somewhat effective.

7.3 Objective 3– Improve R&D capacity in Cambodia in vegetable research, by ensuring maximum sharing of technology and know-how between Australian, AVRDC and Cambodian partners. (Cambodia, Australia and AVRDC)

- *To undertake training and capacity building*
- *To assess economic and social impacts*

Training Activities

2005/06 - In March and April 2006, four scientists (2 from CARDI and 2 from GDA) visited Yanco Agricultural Institute and Gosford Horticultural institute as part of a project study tour. The scientists received training in a range of field and postharvest trial management methods, data management and analysis, and crop agronomy/ breeding. A tour report was authored by the tour participants.

The following non-formal training was carried out during the projects 1st 12 months.

- Postharvest evaluation of tomatoes at CARDI
- Irrigation system management and sap nitrate analysis at GDA

- Survey design and process at CARDI
- Management of field experiments at Yanco
- Management of postharvest experiments at Gosford
- Operation of laboratory equipment including auto-titrator, colour meter, refractometer, firmometer, penetrometers etc.in Cambodia and Australia.

Two formal training courses were also arranged through the ADB RETA project;

- Cambodian staff (Mong Vandy and Sam An Dy, both of GDA) also participated in a post-harvest training workshop conducted in Vietnam (October 2005), organized by the ADB PH project.- Paul Gniffke
- ADB PH project conducted additional training in Experimental Design and statistical analysis in Phnom Penh (July 10-13, 2006), for 10 Cambodian researchers; a similar workshop was conducted in Lao PDR by Dr Paul Gniffke

2006/07 - **Vegetable Pest and Disease Identification Workshop – Kbal Koh Research Station, February 13th-15th 2007** - Dr Sandra McDougall, Research Entomologist and I&I NSW Industry Leader (Vegetables) and Gavin Ash, Associate Professor in Pathology at CSU completed a 3 day workshop on pest and disease identification, monitoring and preservation. Major outcomes from the workshop are summarised below.

The team held preliminary discussions about potential future work to improve pest and disease identification capability within GDA and how such work would complement other funded projects.

As a result of the workshop, GDA hosted an Australian Youth Ambassador for Development, Adelle Dunn, to work on establishing a reference collection of insect pest and beneficials found in vegetables. The project was linked closely to HORT/2003/045. Agreement was made that physical specimens of key pests be collected for the GDA collection and voucher specimens also be deposited in the existing CARDI collection. Photographic records of key pests, pest damage and beneficials were also collected, and leys developed for the major pests.

Recommendations following Pest and Disease Identification Workshop

- Progress discussion with ACIAR on possibility of a project on vegetable pest and disease identification, and methods of collection and storage of samples.
- Training is required on all aspects of pest and disease identification, collection and storage of specimens
- That resources be directed to training in pathology, entomology and weed science capability in GDA. It is recommended that training involve three masters scholarships for GDA staff to be awarded, one in each area. It is also noted that we have not been able to access entomological expertise at CARDI and if this is related to the lack of personnel with appropriate training then consideration be given for a PhD scholarship in Entomology for a CARDI staff member. All post graduate training should focus on developing field identification skills.

- CARDI and GDA are encouraged to co-operate through ACIAR projects to share knowledge and expertise. Dr Vuthy, a CARDI pathologist was trained as part of CIM/2003/030: Improving understanding and management of rice pathogens in Cambodia, be used to train GDA staff in basic plant pathology techniques. Have GDA use Dr Vuthy to assist in identifying or confirming identification of plant diseases. Note that no similar expertise in insect pest identification at CARDI has been available during either the September 2006 or February 2007 visits.
- That project staff on the various projects working in areas relating to improving pest and disease identification capability within Cambodia network to ensure complementary rather than competing or ineffective projects.
- When GDA finally move to new laboratory facilities that a pathologist work with GDA staff in organising the basic plant pathology equipment that is currently in storage. Training in use of the equipment should also be carried out and standard operating procedures be written in Khmer and English
- That any database used is readily accessible and preferably compatible with existing national database set up under an NZAid project that is currently not accessible due to software incompatibilities (as we understand).
- Improve interaction with the Agricultural universities and the ACIAR project teams.
- Encourage interaction between National IPM and plant protection group at DAALI, and the CARDI plant protection group and the ACIAR vegetable project team.
- To support the AYAD proposal for Adelle Dunn to work for 9 months with DAALI plant protection and IPM programs on collections of key insect pests and beneficials from the main vegetable crops. That she work with DAALI staff and Australian experts to put into place collection, photographing, identification and storage protocols for key pests and their beneficials on vegetable crops. That she starts the reference collection of specimens and photographs of key pests and beneficials on vegetable crops.
- Encourage Cambodian scientists to join PestNet as a means to assist with pest and disease identifications

Irrigation Management Training, Kbal Koh Research Station, February 2007. Twenty eight staff from Department of Agronomy research stations and thirty staff from the non government organisation CARE and International Development Enterprises (IDE) have been trained in management of drip, furrow and spray (watering can) irrigation. This is the first training course of its kind to be run in Cambodia. CARE is managing a large AusAID funded rural development program in Prey Veng, and one of the major strategies of program is provision of low tech drip irrigation systems to hundreds of poor families in Kampong Trabek District.

Training involved short lectures followed by practical demonstrations. Soil texturing, determination of soil water content, salinity testing, pH testing and dispersion/slaking tests were all performed by the participants. Short theory tests were also given during the day to consolidate the learning that was happening in practical sessions. Robert Hoogers conducted the training.

Field practicals were carried out by the group to measure the efficiency of drip, hand watering can and furrow irrigation (using a drag hose) in the Kbal Koh trials plots. Some interesting comparisons were noted during the practicals. For instance, it was recorded that irrigation time for a 10 meter bed using hand held spray cans (2) was 7 minutes, which includes filling from the

reservoir. Drip irrigation normally only takes 2 minutes which would include opening tap and checking the dripper outlets. Over an entire season this would translate to considerable savings in labour, which can be re-directed into other activities on the farm. Reduction in labour is a major component of drip compared to other forms of irrigation.

The idea of weather based scheduling was introduced as part of the training. This was a very new concept for participants. They were encouraged to consider which parts of the training they could deliver to farmers, and all completed an evaluation from on the course content and venue etc

Vietnam Study Tour 27th May – 5th June 2007. This study tour was undertaken as part of the ACIAR funded project "Improvement of vegetable production and post harvest system in Cambodia and Australia" (HORT 2003/045). Tour participants included 10 Cambodian vegetable researchers (five from CARDI and 5 from DAALI), one Cambodian collaborator farmer, Dr Paul Gniffke (chilli breeder from AVRDC) and Mark Hickey (I&I NSW and Project Leader). Scientists from The Institute of Agricultural Science for Southern Vietnam (IAS), and Can Tho University in the Mekong Delta coordinated the tour visits and accompanied the party. The tour commenced on Sunday 27th May and concluded on Tuesday 4th June, 2007.

The purpose of the visit was threefold;

- To inspect vegetable production systems, postharvest technologies and marketing channels in southern Vietnam
- To expose Cambodian project research team members to new production and marketing methods and encourage them to think about how some of the more appropriate systems might be applied to the Cambodian vegetable industry.
- Establish new contacts with Vietnamese colleagues.

The study tour included visits to grower fields, net house and greenhouse production units. One large and one small tomato grafting nursery businesses were also visited in and around Dalat. Several markets were visited including the wholesale The Duc market north of HCM, and the retail markets in Dalat and Can Tho. The tour was hosted to a large processing factory in Ang Guang province (baby corn, mushroom, pineapple, and okra), which was followed by inspections of supplier grower fields nearby.

Discussions were held with several grower cooperatives around Ho Chi Minh and Mekong Delta, and an organic vegetable export business (Organik) in Dalat. Research trials conducted under IAS and Can Tho University managed projects were also inspected. Discussions were also held with teams of researchers from IAS in Ho Chi Minh, the Potato Vegetable and Flower Research Centre in Dalat, and the Can Tho University team.

A survey of study tour participants was completed at the conclusion of the tour. Some of the key learnings, as nominated by the participants at the conclusion of the tour, were as follows;

- Methods using grafting tomatoes for improved resistance to waterlogged soils during the wet season, and bacterial wilt. Over the last five years, 90% of the tomato industry in Dalat has switched over to using grafted tomatoes.
- Use of raised, plastic mulched beds in the Mekong Delta region for production on cucurbits during the wet season.
- Use of net houses to reduce impact from heavy rainfall during the wet season.
- Use of integrated pest management (IPM) and minimal pesticide methods to avoid pesticide residue issues in vegetable products.

- Innovative packaging, cooling and transportation (including refrigerated containers) methods.
- Establishment and management of grower marketing cooperatives to supply fresh and processing vegetable markets.
- Provision of high quality germplasm of improved vegetable varieties using tissue culture and high quality disease free seeds from commercial sources.
- Application of quality assurance and Good Agricultural practice systems (GAP) to meet the requirements of supply to processing export and domestic vegetable markets.
- Supply and quality management requirements of major wholesale markets (such as Metro) and supermarket outlets.
- Establishment of contacts with fellow researchers, seed company representatives and material/input suppliers in Vietnam

The farmer participant on the tour, Mr Pho Pich followed through on several of the technologies seen in Vietnam. In the two subsequent years of the project following the project, Mr Pich tested new trellising systems, drip irrigation, plastic mulch and high yielding tomato varieties. He hosted a project field day, and numerous farmers in his village have since started growing tomatoes under guidance from Mr Pich.

2007/08 - Postharvest training and development of experimental protocols with the postharvest team at CARDI continued in 2007/08. New guidelines for Chinese kale were developed to compliment the protocols written earlier for tomato and chillies.

As part of preparation for the field days in February, the project team worked together to design posters. This informal training activity resulted in an effective collection of posters which will remain useful resources for the team.

The arrival of Adelle Dunn as an Australian Youth Ambassador (AYAD) in the Plant Protection Team at DAALI to work on building horticultural pests collection in September 2007 opened up several opportunities for training. Dr Sandra McDougall from NSW DPI at Yanco is supervising Adelle's project, and spent time with the team during February 2008. Sandra and Adelle conducted field training on collection techniques in the field, as well as training in preservation, storage and mounting of specimens.

7.4 Objective 4: To transfer plant pathology skills and technology from the Cambodian cereals program to the vegetable program

Following the completion of ACIAR project CIM/2003/030 in June 2008 the Plant Protection Division (PPD) at CARDI had the capacity to isolate and identify major pathogens of rice. Due to the departure of key staff within the division at the same time as the project completed, this capacity was undermined.

A plant protection component was added to HORT/2003/045 in order to re-establish the fundamentals of plant pathology at CARDI and provide new staff members within PPD the necessary training required. The results and discussion presented below represent the achievements made in the period of July 2008 to June 2009. It must also be emphasised that these achievements occurred working with PPD staff having little or no prior experience in the discipline of plant pathology.

At this point in time, PPD consists of several key staff members, Mrs Soeur Somany, Mr Touch Ung and Mr Tek Samoeun. The current division leader, Dr Khay Sathya, was appointed to

CARDI in January 2009 and has provided excellent leadership and collaboration for the project. The staff members have all received some level of training in plant pathology procedures, with Touch Ung and Tek Samoeun taking on the major responsibilities. The transfer of skills from cereals based program to the vegetable program has been smooth and successful, with PPD staff now confident in the sampling, isolation and identification of a broad range of pathogens from a wide variety of crops.

Sub-objective 4.1. Obtain preliminary data for the management of the bacterial disease in rice, including basic treatment and decision tools for advice on sowing retained seed.

The basic experimental set-up utilised in these experiments provided a model for training staff within the Plant Protection Division in experimental design, data collection and analysis specifically for plant pathology research. In previous independent experiments, the division had set-up field trials to examine broad scope questions such as “what diseases affect this crop?” While surveys of this nature can be useful, without appropriate monitoring, sample collection and identifications the results may be misleading.

In a previous project (CIM/2003/030) results indicated that bacterial disease on rice was having a major effect on yield and quality (Final report). However the project was unable to examine methods to control such disease. The three simple methods chosen (hot water treatment, buoyancy in saline and surface sterilisation with bleach would all be able to be conducted by farmers at a suitable scale. While the generated data did not show any significant differences in the treatment affects on disease, several reports in literature have indicated that the treatments suggested provide good management options for the disease issue (Chun et al., 1997; Miché and Balandreau, 2001). Further work in this area would be beneficial to CARDI and rice production in Cambodia.

Performing these experiments provided a sound training basis for the staff within Plant Protection, offering a specific question to address. From this work, Mr Touch Ung and Mr Tek Samoeun have grown in confidence to identify questions of importance and begun to set-up and run experiments independently at CARDI.

Sub-objective 4.2. Provide direct training to new staff with in the Crop Protection

Unit at CARDI in the processes of bacterial isolation and preliminary identification

In consideration of the training provided under previous ACIAR projects and the changes in staff at within Plant Protection, a deficiency in the skills required for bacteriology was identified. Given the importance of several vegetable diseases associated with bacteria, specific training in the discipline was provided.

Field surveys were conducted to provide hands-on training in the identification of symptoms associated with bacterial infection, covering a variety of horticultural crops. While vegetables were the focus, crops as diverse as mungbean, Papaya, mango and coffee were examined at various times during the survey work, providing the PPD staff with broad exposure to different cropping systems and disease symptomology. Collections of diseased materials were made during the surveys and subsequent laboratory analysis ensued.

Laboratory isolations were conducted mainly by PPD staff with assistance and guidance by Gavin Ash and Ben Stodart. A survey of literature resulted in the selection of the BACT-ID system (Black et al., 1993; Black and Sweetmore, 1994) as a suitable method for laboratory identification to the genus level of plant pathogenic bacteria. The simple biochemical tests can be performed in small volumes, using re-useable plastic vessels, thus providing a cost effective system for the laboratory. Each of the seven tests can be conducted at the one time, with

results generally available within 48 hours. All tests provide un-ambiguous results and interpretation can be completed using the supplied software.

As a result of the training and introduction of the BACT-ID system, the PPD staff have successfully identified phytopathogenic bacteria from cabbage (Xanthomonas campestris pv campestris), kale *(Xanthomonas campestris pv campestris*), and rice (*Pseudomonas sp.).*

One important success was the identification and subsequent management of leaf rot in Phalaenopsis orchid at CARDI. By applying sound pathology procedures, the team was able to isolate the causal organism, identify to genus level (Erwinia) using BACT-ID and apply Koch's postulates to prove pathogenicity. This resulted in advice being given to the nurserymen on the management and subsequent control of the disease within the shade-house. Subsequent DNA analysis was performed by applying pure culture to FTA cards, followed by the amplification and subsequent sequencing of the 16s rDNA gene. This resulted in the identification of *Erwinia chrysanthemi.*

Sub-objective 4.3. Conduct initial disease surveys of vegetables in Kandal province to determine the occurrence of bacterial wilt.

During the course of pathology projects and in discussion with NGOs involved in production issues, reports of bacterial wilt had been received. Anecdotal evidence existed that the disease was widespread and severe, with several reputable identifications of the causal organism, *Ralstonia solanacearum*. In order to provide training in the identification of the disease symptoms and its cause, surveys were conducted around Kandal province to determine its presence. Across all survey periods (July 2008 to June 2009) the disease was not identified. On several occasions farmers believed that the bacteria was present, however subsequent examination revealed that water logging, fungal disease and other abiotic issues were the likely cause.

While this in no way suggests that the disease is not present, in the production areas examined it is unlikely to be as serious threat in the districts surveyed. This may well be due to the adoption of improved production practices introduced in the past few years and the presence of tolerant varieties gaining acceptance with growers and consumers. Continued monitoring within the province is suggested along with the widening of surveys to other production areas.

Sub-objective 4.4. Provide a basic laboratory manual consisting of standard operating procedures and protocols to allow staff to confidently and correctly isolate bacteria and perform basic tests to progress with later additional training towards identification to the genus level

The laboratory manual was provided over several drafts, with the final document available from February 2009. Translation of this document needs to be addressed, however with the technical information included within the document, this may prove difficult.

In addition to the provision and implementation of the BACT-ID system, several further protocols were introduced to improve the capacity and capability of the PPD, and Cambodian plant pathology in general:

Whatman FTA cards have been implemented to provide additional information and identification procedures. The capture and storage of genetic material to these cards using bacterial culture has proven successful during the progress of this project, with several identifications made to

the species level *(Xanthomonas campestris pv campestris, Erwinia chrysanthemi, Pseudomoans fuscovaginae).*

Provision of a digital camera and microscope adapter for the imaging of disease symptoms, identifying structures for remote assistance in identification and documentation of disease causing organisms.

Provision of GPS enabled field camera for the capture of field images with associated geo-tagging to provide enhanced mapping capabilities.

Sub-objective 4.5. Initiate surveys of vegetable crops to determine the occurrence and severity of phytopathogenic viruses.

Capacity within CARDI for the identification of phytopathogenic viruses was identified as a requirement to complement existing skills in fungal and bacterial identifications. To improve this, surveys directed towards the field identification of viral infection were established within Kandal province at sites selected by CARDI collaborators. Again, while vegetable crops were the focus other horticulture crops were also examined. Field sites were visited in two occasions between April and June 2009, with several other sites examined as reports of disease occurrence were received.

At each site, farmers were asked their opinion of disease symptoms, when problems were first noticed and what they thought the underlying issue was. PPD staff also provided their own evaluation of the disease symptoms and a decision was made wether to collect samples or not. The symptoms recorded for tomato included stunting of plants or new growth, yellowing of leaves, chlorotic leaves, both upward and downward curling of leaves (particularly young leaves) and in a few cases leaf mosaics. Unfortunately at each survey time no fruit was present displaying disease symptoms. Suspected samples were photographed and documented and collections made for laboratory analysis.

The symptoms associated with virus infection of tomato by farmers and PPD staff were recorded at each of the sites examined, indicating that viruses are wide spread. In addition, the identification of insect vectors was also noted at each location. Severity ranged from minor infection (less than 5% of the crop) to moderate infection (10-20% of crop) and was consistent within the areas surveyed. Some correlation was observable between farmer knowledge of virus spread and the severity of infection. In cases where farmers had received some training in the control of viruses, rouging and insect control had resulted in decreased severity compare to neighbouring fields were limited controls had been practised. It is also noteworthy that these farmers were using less chemical pesticide due to the practise of rouging and destroying disease plants.

The diagnostic service provided by Agdia Inc., for *Begomovirus* identification was utilised to provide a preliminary analysis of samples. Results indicated positive identification of *Begomovirus i*nfection in samples when a combination of symptoms (leaf curl, stunting of new growth and yellowing of new leaves) was recorded. In addition, samples displaying leaf curl and “shoe string” appearance of new growth also resulted in a positive diagnosis. However, when only one symptom was noted, such as leaf curl or leaf yellowing, no diagnosis was made. It is likely that such symptoms are associated with other factors such as heat stress, nutrient deficiency and in some instances insect damage. These results indicate that farmers and collaborators probably over estimate the occurrence of viral infection in tomato crops, attributing symptoms caused by abiotic factors to viral infection.

PPD staff are now confident in the decision making processes required for the sampling of suspected viral infection of tomato. In addition, several other viral infections were observed in

Papaya (ringspot virus) and eggplant (unknown virus) which provided useful training models for staff.

Figure 23: Typical leaf symptoms associated with Begomovirus infection of tomato

Sub-objective 4.6. Evaluate and modify detection techniques for phytopathogenic viruses to allow preliminary identification at CARDI, with detailed analysis conducted in Australia.

An evaluation of ELISA and PCR based techniques resulted in the selection of PCR and nucleic acid hybridisation techniques as most efficient and suitable to the conditions at CARDI. While ELISA equipment is available at several institutions (both the Royal University of Agriculture and the General Directorate of Agriculture) the available expertise to operate these systems is not present. In addition, the cost and storage of reagents and consumables was considered to be too high to be sustainable under the current financial situation.

CARDI currently houses equipment required for genetic analysis, with thermal cyclers, electrophoresis apparatus and imaging equipment available within the Plant Breeding Division. Thus the adoption of PCR techniques is feasible in the immediate future and the cost associated with operation is viable. The limiting factor again is personnel to operate and perform procedures. One of the major issues with viral detection is the collection and storage of samples, and the subsequent isolation of genetic materials. While many procedures are available in the literature, most required the use refrigerated transport of samples, specialised preparation of samples and/or the use of hazardous chemicals for extraction. Several papers on the use of Whatman FTA cards for the collection of field samples were available *(Ndunguru, 2005; Roy and Nassuth, 2005; Rodoni, 2009)* reporting the suitability of this system for viral detection. These cards require no prior sample preparation, can be used in the field or laboratory and provide material for direct use in PCR procedures without the use of hazardous

chemicals. In addition, the cards are able to be imported into Australia with minimal quarantine restrictions. Therefore, their use was implemented at PPD.

While the collection procedures used have been based on literature reports the successful identification of plant pathogenic viruses from Cambodian samples has yet to be achieved. It is hope that further optimisation and experimentation will result in a more positive outcome. The main benefit of this system is cost reduction in terms of consumables and in terms of required training in procedures. Furthermore, preliminary evidence from experiments conducted by the plant pathology team suggests that the cards are also suited to the identification of fungi and bacteria directly from infected plant materials.

Figure 24: Application of disease plant material to Whatman FTA cards in the field

Sub-objective 4.7. Generate data on the prevalence and severity of Sclerotium rolfsii in vegetable cropping systems in Cambodia.

Along with the survey of viruses, the presence of the soil-borne fungal pathogen, *Sclerotium rolfsii*, was determined. The pathogen was found in low levels at several of the sites examined within Kandal province, with infection of long bean, tomato, peanut and mungbean crops observed. Given the wide host range of the pathogen and that most of these crops are grown by farmers in Kandal, it is probably no surprise that the disease is widespread in the province. Severity appears to be low with approximately 2-5% of crops being affected.

As part of a field trial conducted at CARDI, PPD staff identified *S. rolfsii* on both mungbean and peanut. Again, the level of infection was low at less than 2% of the crop. It was decided that the trial should be monitored for infection as part of a long term analysis of the pathogen. Over the course of six months the severity did not increase with very few plants becoming disease following planting. In addition, the spread of the pathogen did not increase in the trial, however this may be related to the limited soil disruption used between plantings.

While severity was low, the high prevalence of the pathogen and the ease of infection made this a useful model for designing and conducting management experiments. Several reports in the literature indicated that the pathogen could be managed using submergence in water to deplete the survival structures (sclerotes). Therefore, a pot trial was established to examine the length of submergence time required to achieve control. PPD staff were guided through the design process and this resulted in a randomise design being established. Results indicated that sclerote germination could be reduced by approximately 70% after 4 weeks of submergence and that the severity of infection was reduced by half at this time. Increasing the length of submergence time only reduced sclerote germination by a further 5%, but virtually eliminated the infection severity.

As a result of the use of *S. rolfsii* as a training model for experimental design, PPD staff have increased their confidence and competency in planning and conducting research experiments and trials for the management of plant diseases. This will provides CARDI with the ability to provide management options backed up by sound scientific study to the farming community.

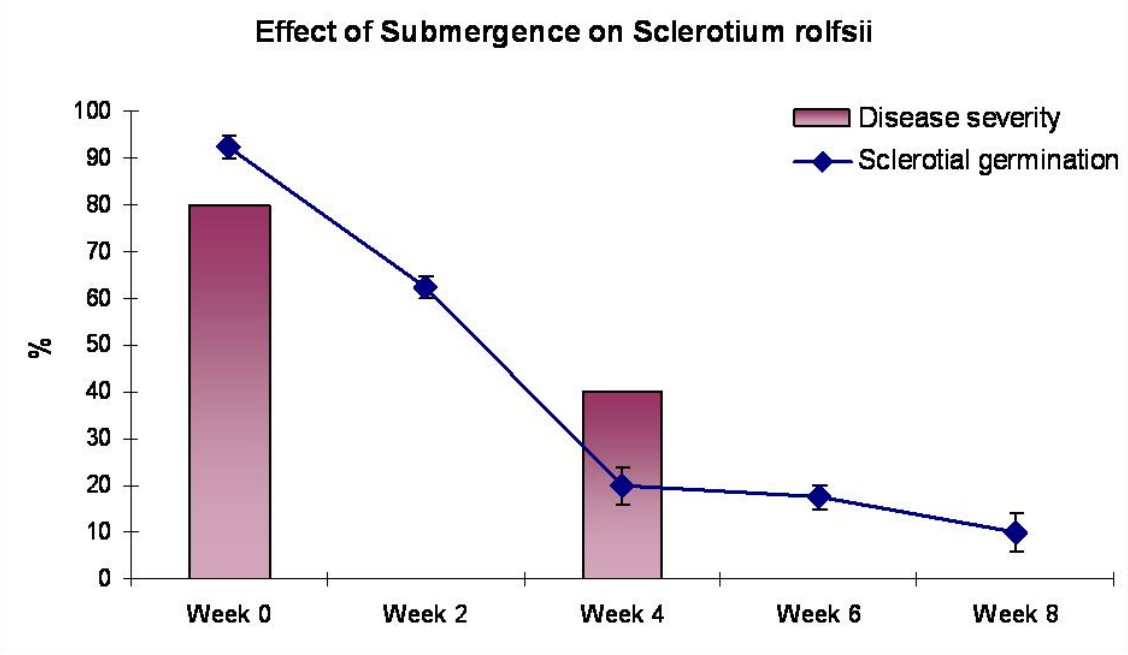


Figure 25: Effect of submergence time on sclerotial germination and infectivity of Sclerotium rolfsii

Sub-objective 4.8. Provide laboratory protocols for the detection procedures for viruses.

The final detection procedures are yet to be optimised and implemented. Collection protocols for FTA cards have been developed and are in use by PPD staff. It is envisaged that suitable protocols will be available within two months and a phased introduction of the protocols will occur at CARDI following appropriate training and with permission access to the required equipment.

Miscellaneous results

As a result of conducting the field surveys for bacterial disease, viruses and S. rolfsii, it was noted that the patterns of distribution for several symptoms indicated that the diseases were being brought into the fields rather than already being present. Discussion with farmers revealed that for crops such as tomato, long bean and mungbean, seedlings were grown at nursery sites

away from the main field and then transplanted. Thus it was likely that infection was occurring at the nursery level due to poor sanitation practices. In order to assist in improving nursery production, soil sanitation methods could be adopted to reduce pathogen inoculum levels. The plant protection team has initiated an experiment to examine the effect of soil solarization on inoculum density and infectivity at CARDI. This initial trial is expected to be completed by December 2009.

Due to the increased awareness of CARDIs capabilities in plant protection activities, the team was asked to provide advice and comment on viral infection in rice. Over the past four years, Cambodia and Vietnam has experienced large outbreaks of brown plant hopper (BPH), resulting in severe yield loss. These yield losses are not only due to the direct damage caused by the insect but also due to the subsequent infection by viruses that the insect transmit. The AQIP seed company had supplied CARDI rice seed to many farmers who experienced yield loss after reporting BPH infestation and subsequent stunting, grassy appearance and low seed set. These symptoms are commonly associated with rice grassy stunt which had been identified in the region by IRRI scientists in 2007 as part of CIM/2003/030. Framers and NGOs were suggesting that CARDI and AQIP had supplied infected seed resulting in the losses experienced. The pathology team contacted Dr Il-Ryong Choi, Plant Virologist, IRRI for expert comment. According to Dr Choi the most likely cause is either rice grassy stunt or rice ragged stunt. He has indicated that the viruses are widely spread throughout the Mekong delta, with southern Vietnam experiencing damage from the viruses this season. Dr Choi also indicated that a latent infection can occur in which infected plants do not display symptoms. Thus, a source of inoculum maybe present but not visually detectable. Dr Choi was also certain that no transmission via seed is possible. A report was prepared by the pathology team for CARDI and AQIP stating these results.

During the course of the pathology component of this project, the PPD have established good working collaboration with members of the Plant Breeding Division at CARDI. As a result, the staff of PPD have been asked on several occasions to provide assistance and recommendations for disease management. On one particular occasion during a visit by Drs Ben Stodart and Gavin Ash the team was approached by Mr Nin Charya to examine a sesame trial at CARDI. Initial examination suggested infection by a fungal pathogen believed to be causing stem necrosis, stem distortion and stunting. The symptoms were similar to those described for Charcoal rot. Subsequent laboratory isolation identified *Macrophomina phaseolina* from all disease samples. The team decided to use the trial as a model for the development of a disease rating scale to provide consistent quantitative analysis of disease issues. Following development the staff of PPD performed an independent assessment of the variety trial, and identified several varieties showing tolerance to the disease. These results provide valuable information to the breeding program and have given PPD staff experience in the development and application of disease rating for breeding purposes.

7.5 Australian Component

A survey of a 13 growers was conducted at the end of the varietal testing program to assess the level of uptake of the new varieties. The survey found that during the three years of the project, 7 growers had changed the variety mix, and were now growing at least one of the new types. Felicity was the most popular variety grown, followed by Messina and Sarina, aswell as a grape variety, TTC8925. Reasons given for changing varieties included higher yields, longer shelf life, better sweetness, heat resistance and more uniform marketable size. Nine growers in total intended to grow the new varieties in the future and most had moved away from T30 and T38 completely. All of those growers, bar one, stated that were now growing the new varieties as a result of the ACIAR project district trials.

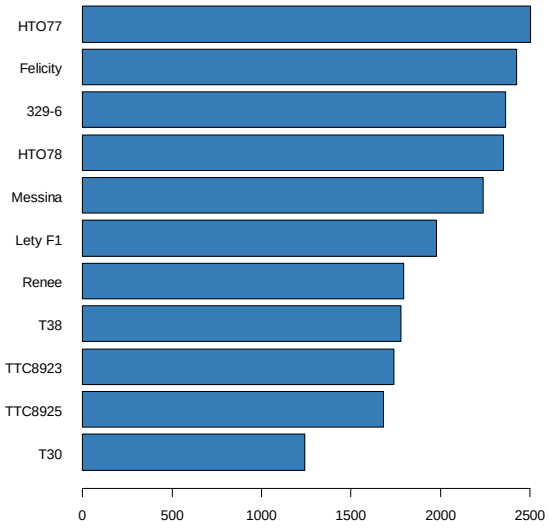
Figure 26: At the Gosford greenhouse tomato field day, ACIAR Project Officer Sorathy Michell and Dr Sophie Parks explains the greenhouse tomato nutrient trial.

Summary of cherry tomato variety trials - Autumn 2007 Yield

In the field, the average yield ranged from 1241g/plant for T30 to 2504 g/plant for HTO77 (Table 27). However, the effect of variety on yield (g/plant) was not significant (P=0.05). This was because there was a large amount of variability between the blocks (P=0.07).

Table 7: Average cherry tomato yields Autumn 2007

Variety	Average yield (se)	
HTO77	2504.5	(270.4)
Felicity	2426.6	(263.9)
329-6	2362.4	(270.4)
HTO78	2351.4	(264.0)
Messina	2238.4	(270.0)
Lety	1978.2	(270.2)
Renee	1794.2	(270.2)
T38	1777.7	(263.9)
TTC8923	1741.8	(270.2)
TTC8925	1683.5	(270.2)
T30	1240.8	(270.2)



7.5.1 Fruit Quality

Fruit were harvested at ¾ red, held in a 20ºC space until fully ripened and then assessed for size, weight, shape, colour, firmness, total soluble solids (Brix) and titratable acidity. Each sample comprised 20 fruit, per replicate.

7.5.2 Fruit characteristics

Table 8. Fruit size, diameter and firmness at harvest

Variety Number	Variety name	Fruit size (g)	Fruit diameter (mm)	Firmness at harvest*
V1	T30 (Elite)	10.4	29 x 29	0.654
V2	T38	8.3	27 x 28	0.695
V3	Messina	14.1	26 x 28	0.446

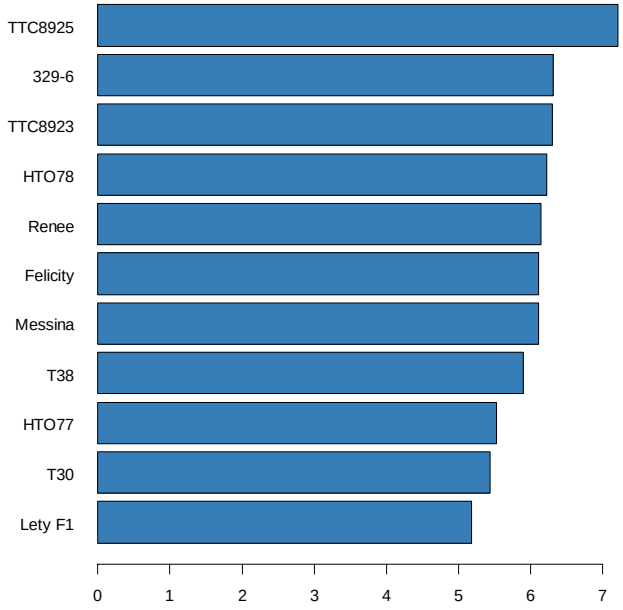
V4	Lety F1	9.8	24 x 26	0.489
V5	HTO77	11.3	29 x 26	0.624
V6	HTO78	9.7	28 x 24	0.615
V7	TTC 8925	5.1	24 x 19	0.707
V8	TTC 8923	7.3	27 x 20	0.576
V9	Felicity	11.8	27 x 27	0.569
V10	Renee	8.7	24 x 25	0.579
V11	329-6	8.0	23 x 24	0.601

*The larger the number the softer the tomato

7.5.3 Total soluble solids (TSS or Brix)

TSS was higher in field grown tomatoes with TTC8925 being the sweetest at 7.2. In the field trial, most varieties had a similar TSS (around 6) with a few varieties HTO77, T30 and Lety F1 having lower TSS (<5.5).

Figure 27. Total Soluble Solids



LSD=0.60

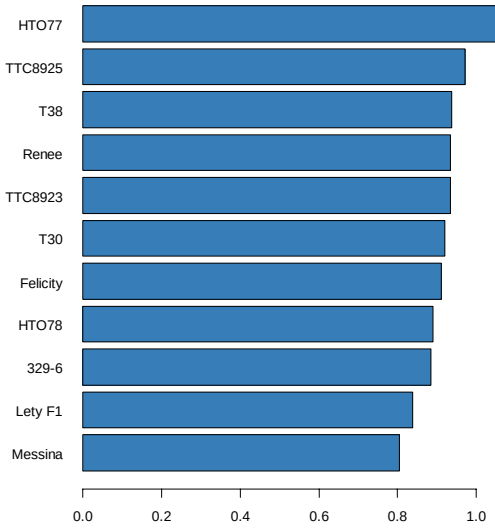
7.5.4 Shelf Life

A second sample of 20 fruit /rep at ¾ red was harvested and allowed to ripen at 20ºC. Once the fruit reached full red, 10 fruit were stored at 10ºC while the remaining 10 were stored at 20ºC. Tomatoes were assessed for firmness, shelf life and weight loss.

Firmness following storage

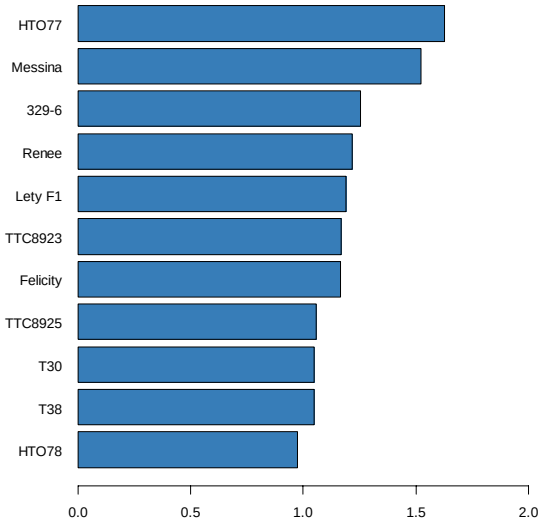
Firmness was measured using a compression test two times a week. The graphs below show firmness at 17 days following storage at either 10ºC or 20ºC. Note the softer varieties are at the top of the graph and the firmer varieties at the bottom of the graph. At both temperatures, HTO77 was the softest variety and also had a short storage life.

Fig 28. Firmness at 10ºC



LSD=0.059

Fig 29. Firmness at 20ºC

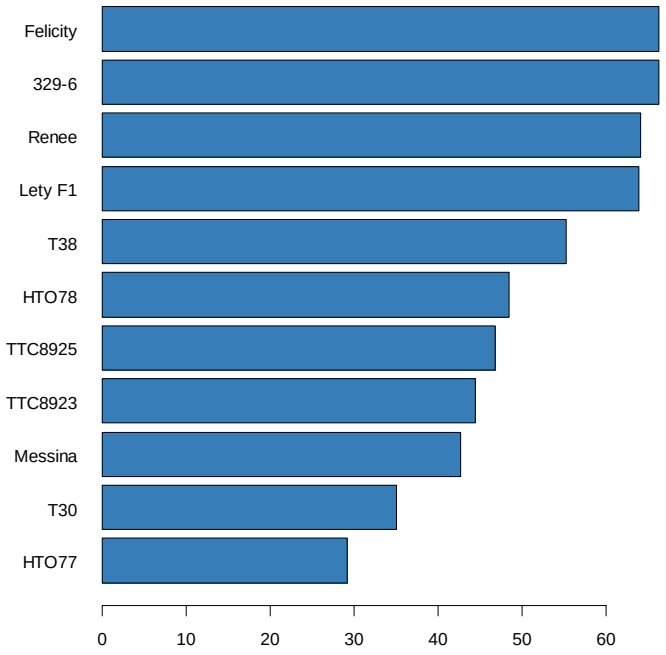


LSD=0.081

Shelf Life

Shelf life was evaluated at both 10ºC and 20ºC. Figure 5 shows variety shelf life following storage at 10ºC. In this case shelf life was calculated as the average of 10 fruit and this can tend to overestimate shelf life when looking at a punnet of tomatoes. A second way of evaluating shelf life would be to say that shelf life ends when 1 tomato in a punnet is beyond its use by date and these results are provided in Table 4.

Figure 30. Shelf life at 10ºC



LSD=10.95

Table 8. Shelf life at 10ºC (shelf life deemed to terminate when one tomato was discarded).

Variety No.	Variety	Shelf life (days)	Standard error
V1	T30 (Elite)	18.3	4.3
V2	T38	20	2.4
V3	Messina	22.5	1.5
V4	Lety F1	36.0	12.0
V5	HTO77	24	0
V6	HTO78	20	2.4
V7	TTC 8925	31	0
V8	TTC 8923	26	6.2
V9	Felicity	38.3	6.4

V10	Renee	36.5	7.2
V11	329-6	58.5	3.3

7.5.5 How do the varieties compare?

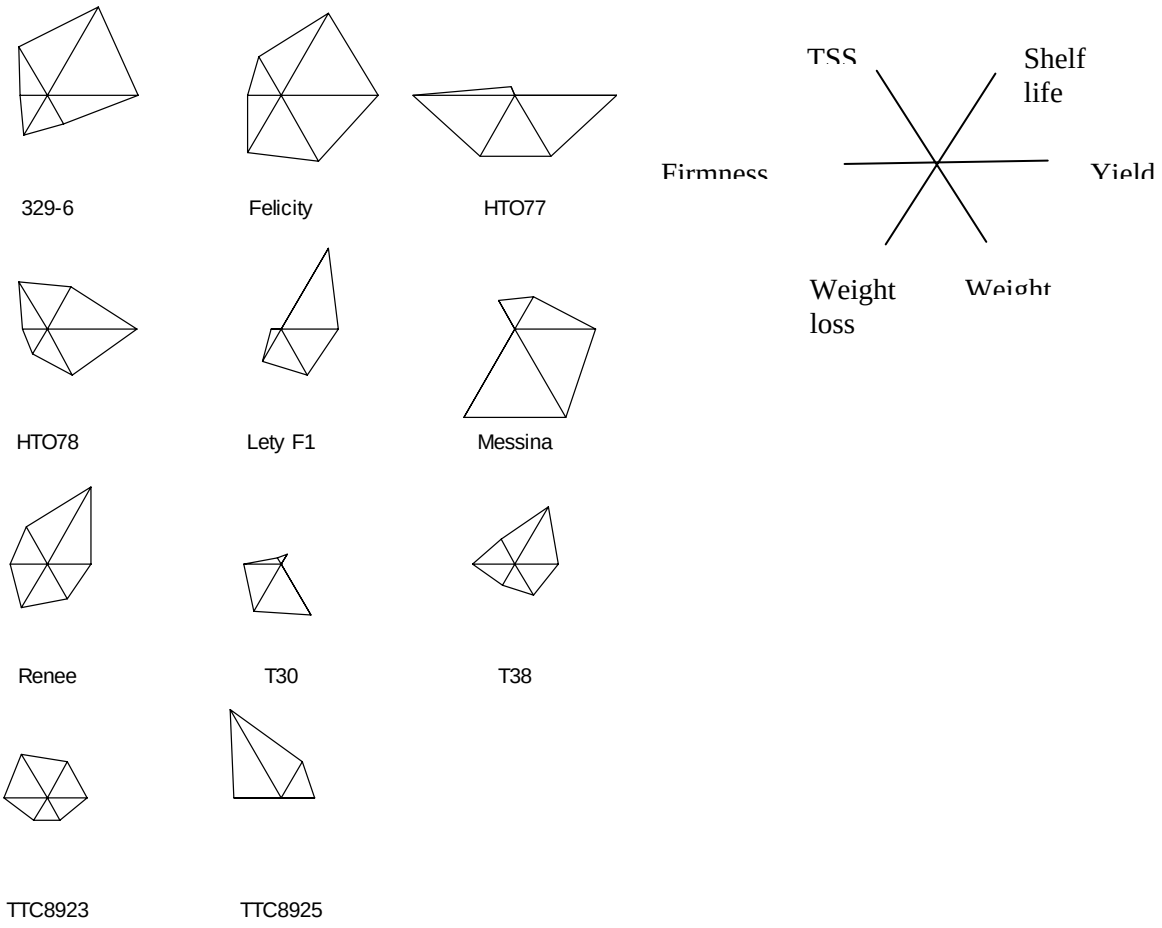
Table 5 gives the rankings from highest to lowest for each variety for six characteristics – yield, average fruit weight, shelf life, TSS, firmness and weight loss. This provides a quick and easy way to compare how the varieties performed. For example, Felicity had a high yield, good fruit size and shelf life but had a higher rate of water loss than some of the other varieties. In contrast, T30 yielded poorly, had a poor shelf life and low TSS.

Table 9: Rating of cherry tomato varieties for six postharvest characters

Yield	Weight	Shelf Life	TSS	Firmness	Wtloss
HTO77	Messina	329-6	TTC8925	Messina	TTC8925
Felicity	Felicity	Felicity	329-6	Lety F1	TTC8923
329-6	HTO77	Lety F1	HTO78	HTO78	T38
HTO78	T30	Renee	TTC8923	329-6	HTO78
Messina	Lety F1	T38	Felicity	Felicity	Lety F1
Lety F1	HTO78	HTO78	Renee	Renee	329-6
Renee	Renee	TTC8925	Messina	T30	Renee
T38	T38	TTC8923	T38	T38	T30
TTC8923	329-6	Messina	HTO77	TTC8923	Felicity
TTC8925	TTC8923	T30	T30	TTC8925	HTO77
T30	TTC8925	HTO77	Lety F1	HTO77	Messina

A star diagram also gives us another way of depicting this data. A variety that performed well across all categories would be pictured as a well balanced hexagon. The length of line relates to how well the variety performed for that given characteristic, so a bigger hexagon is better than a smaller hexagon.

Figure 31: Star diagram of varietal characters

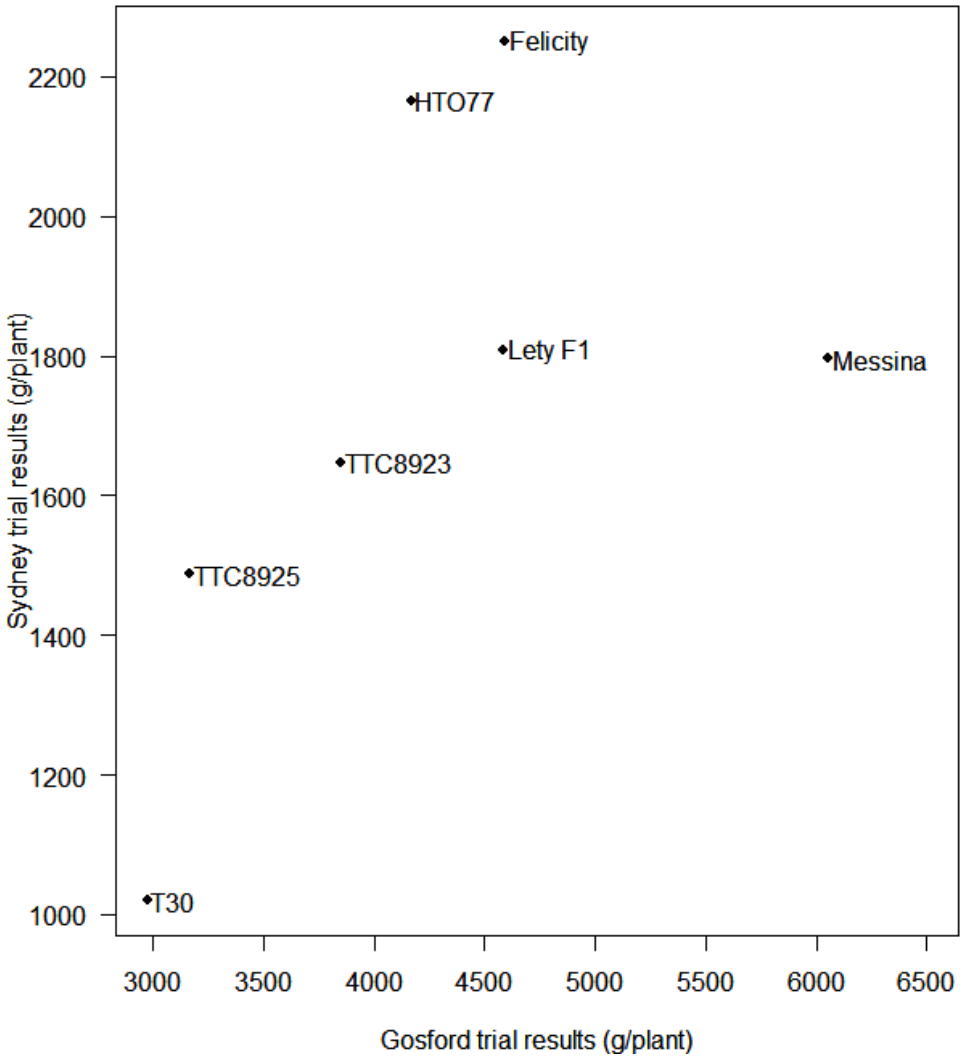


In this report, we have only provided a snapshot of the main results. As part of this trial we also collected data on ethylene production, colour, firmness throughout storage life and titratable acidity.

7.5.6 Comparing Sydney "field grown" yields to "greenhouse" Gosford, Spring 2007

The diagram below shows how the performance of the cherry tomato varieties compared between the greenhouse at Gosford to the field at Sun Ly's. The closer the variety to the top right hand corner, the better the variety performed at both sites. Please note that TTC8923 and TTC8925 are grape tomatoes.

Figure 32: Comparison of yields in glasshouse (horizontal axis) to field grown (vertical axis) cherry tomatoes

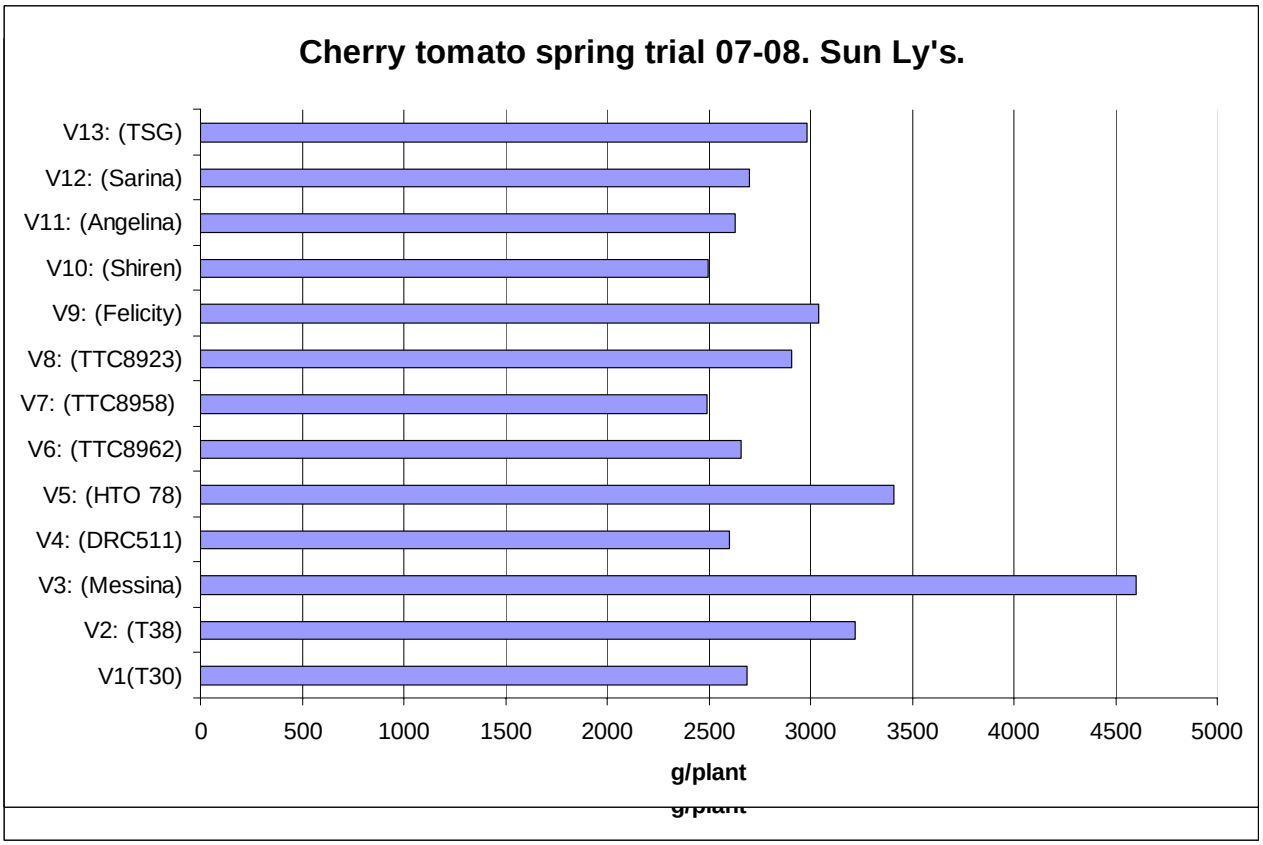


Cherry Tomato trials - Spring 2007

Location – Cecil Park, Sydney

Planting Date – 28th September 2007

Figure 33: Spring 2007 cherry tomato yields



Conclusions

- Over the autumn 2007 and spring 2007 trials, Messina and Felicity were the two most consistent performers in terms of fruit yield.
- The standard types T30 and T38 performed better in the spring planting than the autumn planting.
- Fruit shape for varieties HTO77 and HTO78 were not acceptable for the cherry tomato market.
- Of the grape tomatoes, TTC8923 and TTC8925 were consistent performers, with Sarina also performing well in the spring planting.
- The 2006 spring trial at Horsley Park was not harvested due to spotted wilt infection, and the 2008 autumn crop at Cecil Park was not harvested due to weather damage.

- A survey conducted in June 2008 of 13 growers asking them about the varieties grown in 2008 compared to 2006 showed there had been a shift towards the new cherry tomato varieties. Felicity was the most popular cherry tomato, followed by Messina. Of the grape tomatoes, TTC8925 and Sarina were also popular. However the older varieties T30 and T38 remain the standard type.

7.6 Evaluation of HORT/2003/045

At the inception workshop for the new vegetable project HORT/2006/107 in October 2009, the project team was asked to nominate the strengths and weaknesses of the previous project HORT/2003/045 with a view to identify areas for improvement, an ongoing work to be addressed in future. The findings were as listed overpage;

HORT/2003/045 Strengths	HORT/2003/045 Weaknesses
• Identified commercial heat tolerant/disease resistant tomato lines (Nov-Feb) Neang Pich and Neang Tamm • Identified three commercial chilli lines, 9955-15, PBC142, CCA (average)- year round production • Research facilities upgraded at GDA and CARDI • Greatly improve exchange of information and skills between MAFF/ AVRDC/ DPI/ RUA /CARDI/GDA • Pilot IDE drip irrigation created a lot of interest • IDE are a project partner- can share expertise/budget • Postharvest- low cost-technologies/locally tests (best harvest time, evaporation cooler packaging) • Identified postharvest losses/weaknesses. • Good success of on farm trials • Chea Thai best Chinese kale variety • Tomato grafting successful • Plastic mulching provides high benefit to trial management and to farmers • Plant pathology team is now involved in project • Great team + collaboration – horticulture is seen as a positive model for other (GDA+ CARDI + RUA + CAVAC + CSU + I&I NSW) • Capacity of team greatly improved	• Need to look at production system to produce in hot season tomatoes (take advantage of) • Chili testing at CARDI required more test • Need better extension to the farmers • Need many farmers exposed to drip trials in dry provinces i.e Takeo • Postharvest-more farmers need to be introduced and supply chain partners testing. • Limited farmer involvement in selecting varieties- more involvement needed “participatory farmer selection” from planning stage • Large number of combined technologies and on-farm trials • Postharvest training needs to be at village level. • Tomato grafting and Chinese kale needs to be extended to famers field • Shortage of tomato seed, i.e. Neang Pich. – will be a problem if demand created • Variety names (KK3 + Neang Pich) need to be harmonised – MAFF Seed committee to discuss • Plastic mulch + other input supplies needed to be discussed with input supplies • Disease management needs improvement in research trials/famers • Inter-init + inter-institution communication needs improvement • Farmer capacity in mulching, irrigation management, drip etc, needs improving

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project has made advances in several areas

- Apart from yield assessments for the new varieties, important information on disease tolerance has also been gathered in the trials. For instance, in one of the Siem Reap trials, the CARDI varieties Neang Pich and Neang Tamm had only 7% of plants infected with tomato yellow leaf curl virus (TYLCV) compared to 26% of plants in the local variety. This accounts for the yield differences, with the new varieties yielding almost double that of the local varieties.
- Screening trials of 32 tomato lines and chilli lines were also conducted at CARDI. The tomatoes were screened for disease (including tomato yellow leaf curl virus and bacterial wilt) heat tolerance. There were fourteen varieties of tomato including CLN2777E and CLN2777B showed some commercial potential, and will be advanced to the next stage of testing.
- The chilli production and marketing surveys concluded that the most common losses farmers reported of their crop was from spoilage and postharvest disease rots, for the processor it was losses from insufficiently dried product leading to spoilage, and for the collector, it was poor product colour. The survey also found that 42% of the chilli seed was produced by farmers themselves, with only 17% purchased in the market, and10% of the seed provided by the trader/processor.
- Successful adaptation of the “firmometer” to measure fruit firmness in Cambodian tomato varieties by the CARDI postharvest team.
- The Plant Protection Department staff now have a basic theoretical knowledge of viral diseases, modes of transmission and management practices to compliment their knowledge of bacterial and fungal pathogens.
- A horticultural pests collection has commenced at DAALI with the assistance of an Australia Youth Ambassador (AYAD). The project is commencing work on vegetable pests, and will expand into fruit crops.
- The training of PPD staff at CARDI in bacterial isolation and identification, and preliminary identification of viruses has provided competent personnel to conduct aspects of these specialisations in plant pathology. Along with the implementation of experiments designed to examine management strategies this provides CARDI with the capacity to develop and implement sound research activities suitable for publication in scientific journals.
- An increased awareness of CARDIs capacity in plant pathology and disease management has resulted in several instances where staff have been asked to provide expert opinion in disease matters. Given appropriate funding and maintenance of current staff, this would be expected to increase in the future.

- A range of methods for measuring characteristics of cherry and grape tomatoes has been developed as part of the Australian component of the project. A methodology for measuring fruit firmness (using the firmometer), shelf life, brix and titratable acidity have been combined to evaluate a range of fruit characteristics. Consumer taste testing provided additional information in the assessment process. This information was presented back to seed companies and industry.

Longer term scientific impacts will flow, as there has been significant improvement in skill levels in areas such as postharvest and vegetable pathology research. These disciplines in particular were coming off a very low base, as they were few skills existing in Cambodia prior to the project. The CARDI postharvest and pathology groups are now recognised as national technical specialists, and will in future be able to provide services to a wide range of clients.

The improved collaboration between CARDI and GDA in itself will result in an improved impact from research at a farmer level over time. CARDI's research expertise is complimented by GDA's extensive networks of extension officers, who have day to day contact with farmers. Providing those staff are trained and familiar with the latest vegetable research developments, and have access to the technical people involved with that research, the farming community will continue to benefit from project related research well into the future.

8.2 Capacity impacts – now and in 5 years

- Following project training conducted in Cambodia and Australia, the Cambodian researchers at both CARDI and DAALI are competently planning, establishing and recording results from experiments in the field and laboratory. There is also an improvement in their ability to design experiments and analyse the results themselves, although this is an area where further training required. The AVRDC researchers commented that the 2007/08 trials were of better quality than previous years. Substantial progress was evident in the postharvest team, where the research planning and implementation was handled with minimal intervention from Australian counterparts.
- The project had a greater emphasis on extension in the final 18 months of the project, and although there were contrasting approaches taken to farmer field days by the GDA and CARDI teams, both were effective. The CARDI team involved the farmers in assessing the tomato varieties in the field, creating a lot of interaction between the researchers and the farmers. Rankings were given to the varieties, and the farmers were better informed on how to judge a variety, looking attributes such as plant shape, fruitfulness and disease resistance. The GDA team used collaborator farmers to speak about the management practices employed in the variety and drip irrigation demonstrations, and the subsequent questions and discussions among the farmers was lively.
- The establishment of the postharvest laboratory at CARDI was also completed in mid 2008, with the installation of a dedicated coolroom for horticultural produce.
- The Plant Protection Department (PPD) at CARDI now has an operating pathology laboratory capable of carrying out a range of tests and disease diagnostic work.

- At the start of this component of the project in July 2008, CARDI were without personnel with the expertise and confidence to conduct research, development or extension activities in plant pathology. Following a relatively intensive 12 months in which field surveys, laboratory training and research experiments have been conducted, CARDI now have several staff members with the capability of performing RD&E activities. Once again, with appropriate support these staff members can be expected to grow in experience and competence to become the specialist pathologists required in Cambodia.
- With networks established at the Royal University of Agriculture it is hoped that future impacts can be delivered by providing assistance in the education of future generations of agricultural scientists.
- The GDA Plant Protection team also benefited from the placement of the AYAD Adelle Dunn to work on a horticultural pests collection. This project ran in parallel with a rice pests collection sponsored by NZAid, so the timing for such a project was ideal. A very strong foundation for an excellent horticultural pests collection based at GDA has been created, which hopefully will continue to build with the skills imparted by Adelle during her 12 month project. The collection is held in metal specimen cabinets at the Plant Protection Office, and computer based keys along with mounting and preparation materials have been provided for the work to continue.

Figure 22: Part of the GDA Horticultural Insect Pest Collection created as part of the AYAD program in 2007/08.

8.3 Community impacts – now and in 5 years

- As the focus in the first 18months of the project was on skill building and research, the farming community was only properly engaged in the final 18 months of the project. Interest levels in some of the technology and information delivered by the team were very high, and uptake of varieties and some production technologies such as black plastic mulch has been rapid. The follow on project will build on this momentum, and greatly improved farmer uptake is expected.
- The improved varieties and production technologies introduced to communities during the project will have significant impact on livelihoods generally through improved yields, increased incomes, greater diversification and increased capacity to invest in equipment and infrastructure on-farm. The follow-up ACIAR project will study the flow on impacts of these improvements both on-form and throughout the community.
- The case studies carried out in Banteay Dek District Kandal suggest that with the rapid expansion in tomato production occurring in one village, several associated businesses were also benefiting. These include collectors, input sellers and casual workers finding employment.
- Given the short duration of the plant pathology component and the nature of the activities, it is difficult to assess community impacts. During field surveys, an emphasis was placed on discussion with farmers and their importance in solving crop production problems. Given the current capability of the PPD at CARDI, it would be expected that flow on impacts at the community level would develop in the next five years.

8.3.1 Economic impacts

- The economic impact of the project is best demonstrated in the following case study of Kandal farmer Mr Pho Pich. Mr Pich is a project collaborator, and travelled to Vietnam in June 2007 with the project team to look at vegetable production methods in Dalat and the Mekong Delta. In 2007/08 dry season, he collaborated with a drip irrigation experiment and a grafted tomato trial. He has also grown CLN1462A for several years, and is a long term co-operator with Kbal Koh Vegetable Research Station. Mr Pich established an on-farm demonstration of CLN1462A on the IDE drip irrigation, combining new trellising techniques he learnt about on the Vietnam study tour. In February 2008, he hosted a field day on site, and spoke about the innovative methods he is using to other farmers. In April it was reported that Mr Pich had harvested in excess of 500 kilograms of marketable fruit from the trial area of 5m x 10m, or the equivalent of 100 tonnes per hectare. This has resulted in an income of approximately $100 US from the trial area. Over the last 2 years, Mr Pich's net earnings have increased from 3 to 4 million riel in 2006 to 6 to 7 million riel in 2008, largely due to use of improved tomato varieties such CLN 1462A. He is also receiving a premium price for his tomatoes, as they are highly acceptable to the consumer. More detail on case studie can be found in Section 11.2
- Ms Srey Sinath from the Socio-economic team at CARDI has produced economic analyses of several technologies being tested in the project. Sinath spoke with farmers who hosted the GDA trials in Takeo Province during the 2008/09 season. Yields, market prices/kg, production costs and income were recorded, and the economic efficiency calculated. The tables can be found in Appendix 3. Economic efficiency is defined as the gross income divided by the total production costs. The technologies analysed were;

- Chilli varieties (9955-15, CCA-321 and Dai Neang (local). 9955-15 was the best gross margin by far, with equivalent US$7,400/ha income compared to US$1380 for CCA-321 and US$2,500/ha for the local variety Dan Neang.
- Nitrogen use in chilli at rates 0, 100, 150 and 200kgs/ha
- Drip vs handwater irrigation and mulches on chilli
- Black plastic mulch and drip irrigation on tomato

Rate of fertliser used	0/80/100	100/80/100	150/80/100	200/80/100
Yield in kgs fruit /100m^2	230	250	260	265
Price US $/kg	0.6	0.6	0.6	0.6
Costs/100 m^2	49.58	53.19	54.49	55.80
Gross income US $/100 m^2	138	150	156	159
Net income	88.42	96.81	101.51	103.20
Economic efficiency	2.78	2.82	2.86	2.85

Table 10: Results of analysis from nitrogen use in chilli production. Only a marginal advantage was gained from use of higher rates of fertiliser.

- The analysis of fertiliser use suggests that while there was an advantage in using nitrogen fertiliser in combination with P&K fertilser, no significant economic advantage was gained by using rates above 100kgs of N/ha.
- Comparison of drip versus hand irrigation for chillies on plastic, rice straw and no mulch treatments showed that there was greater advantage in using rice straw mulch than the irrigation treatments or the plastic mulch. Plastic is relatively expensive in Cambodia, increasing costs per hectare by up to $400. Marketable fruit yields were highest for plastic mulch, but the costs outweighed the benefit. Although no cost was attached to the rice straw, future studies should include a cost to the farmer, as rice straw has alternative uses and therefore has a value.
- In tomatoes, drip and hand irrigation were similar economic efficiency, but plastic mulch tended to give the better economic returns. It should be noted that the capital cost of the drip irrigation system was not factored into the equation. The analysis was based on the crop gross margin only.

- The accurate identification of disease causing organisms is essential for developing and implementing management strategies. A reduction in direct yield loss and a reduction in operational costs associated with chemical application can be achieved with accurate disease identification and sound management advice. Associated with this is as increase in the quality of the commodity.

8.3.2 Social impacts

- The most apparent social impact from the project to date is the crop diversification occurring among the target farmers, particularly in Kandal Province. Kbal Koh Vegetable Centre staff, led by Mong Vandy, has been able to increase their level of involvement with the local farmer community though this project, and evidence of their impact on farmer practice and improved livelihoods is clear. The case study outlined under the Economics impacts section outlines how this has been achieved. The project through its involvement with growers, collectors, transporters and market agents is also encouraging more discussion between the supply chain players. The project team has observed a better level of communication starting to occur along the supply chain.
- Improvement in disease recognition and diagnosis in the coming five years will see an impact on the sustainability of farm enterprises. With growing farmer confidence comes increased rural investment and an improvement in educational opportunities for rural children.

8.3.3 Environmental impacts

- The production research component of the project has included investigations into effectiveness of low-tech drip irrigation on tomatoes and chillies, and development of recommendations on nitrogen fertiliser use for both crops. Although still being evaluated by farmers, the IDE low tech drip irrigation system is ideal for vegetable production in low water supply situations, such as mid to late dry season when water supplies are generally low. Research at Kbal Koh in 2006 demonstrated that a 25% increase in tomato yields can be achieved using 30% less water than hand watered plots, or 5.63 tonnes/ML compared to 3.18 tonnes/ML. Similar water savings were achieved in Year 2 with chillies.
- The objective of the nitrogen rate trials for chilli and tomatoes has been to develop more precise recommendations on fertiliser rates which provide optimum yield at the lowest rate, with reduced production costs and potential impact on the environment. While vegetables tend to require higher levels of fertiliser input than other field crops on a per hectare basis, the returns are also higher, so farmers can crop smaller parcels of land. This creates more opportunity for crop rotation which benefits the soil by minimising pest and disease build-up and allowing a resting phase between crops.
- Accurate disease identification along with sound management advice will reduce the reliance on pesticide and fungicide applications. This therefore reduces the risk of environmental contamination by chemicals.

8.4 Communication and dissemination activities

Project communication occurred at various levels. Within the project, annual reporting and planning workshops provided a coherent basis for joint planning between the various groups and organisations. Department and institute directors were consulted on a regular basis, attended the planning workshops wherever possible and even participated in field days and farmer workshops. In February 2009, the ACIAR Project Review Team praised the strength of the linkages that had been formed between farmers and CARDI/GDA researchers. This strong and visible partnership is considered essential to addressing the major challenges with vegetable production in Cambodia.

The project also maintained sharing of information and resources with several NGO programs, most notably International Development Enterprises (IDE) and the Cambodian Agricultural Market Information Project (CAMIP). Collaborative training in pest and disease identification and irrigation was carried out with IDE. The agro-industry group at the Royal University of Agriculture (RUA) also participated in training workshops. Several of the project team members from GDA worked on the ADB RETA project, enabling an efficient use of resource people and equipment.

The foundation of building partnerships with farmers was through the network of collaborator farmers and both district and provincial level departments of agriculture or PDAFF. The PDAFF staff provided local support for liaison with farmers and trial maintenance, and although not official project members, were an integral part of the team. On farm demonstrations wherever possible, were used as field day locations. The full list of project extension activities are presented here.

Table 11: Field days and workshops conducted during HORT/203/045

Activity	Date	Location	Description
Tomato harvest and storage best practice	March 2007	Saang District Kandal	*The post harvest team from CARDI and GDA gave presentations of harvest handling and storage*
Tomato/chilli field day	*March 2007*	*Mok Ampil District, Kandal*	*GDA hosted farmers at trial site to inspect varieties grown under best practice management.*
Irrigation training workshops	*March 2007*	*Prey Veng*	*In collaboration with IDE conducted farmer and technician training in the field at prey Veng. 15 farmers and 10 technicians attending.*
Tomato field day	*February 2008*	*Siem Reap*	*The CARDI team presented two field days with 30 farmers attending each. Farmer varietal evaluations and talks on postharvest. Innovative methods used to assess farmer evaluation results*
Tomato and chilli field day	*February 2008*	*Kompong Cham*	*The GDA team presented at trial sites looking at tomato and chilli varieties. A small farmwalk at another site in the afternoon to look at drip irrigation in chilli trial.*
Tomato drip irrigation field day	*February 2008*	*Banteay Dek, Kandal*	*Featured the IDE drip system on tomatoes. Crop management, irrigation scheduling and system set up and maintenance. 30 commercial growers attended*
Chilli field day	*March 2009*	*Bati District, Takeo*	*40 farmers attended during the project review field visit. Included varieties, drip irrigation and fertiliser experiment*
Tomato drip irrigation field day	*March 2009*	*Tram Kok District , Takeo*	*Inspection of drip irrigation trial with small group of farmers and PDAFF staff*
Farmer exchange visit	*February 2009*	*Tram Kok District Takeo*	*20 farmers from Kompong Som visited the Takeo site to learn about tomato production under black plastic mulch and drip irrigation. Hosted by GDA staff*
Cherry tomato variety field days	*April 2007 to May 2008*	*Cecil Park, Sydney and Gosford*	*Three field days on tomato varieties. Grower evaluations and postharvest presentations. Included field trip to inspect greenhouse production at Gosford.*

Tomato postharvest workshop	*August 2007*	*Horsley Park, Sydney*	*Storage, postharvest performance of test varieties, handling, packaging*
Management of tomato spotted wilt virus	*December 2006*	*Horsley Park*	*Workshop following severe outbreak in Spring 2006 crop*
Field schools	*February to May 2008*	*Cecil Park*	*Series of three workshops - Topics included irrigation scheduling, pest and disease management and nutrition*

- Publications in the form of posters and factsheets were produced by the team. Titles so far produced include;
  - *"Neang Pich" and "Neang Tamm" - New tomato varieties* - CARDI Plant Breeding Group, 2007.
  - *"Commercial tomato seed production*" Nin Charya, Plant Breeding Group, CARDI, 2008
  - "*Postharvest management in commercial tomato production in Cambodia*" Ly Sereivuth, Kong Sam Ouen and Mong Vandy GDA 2007
  - "*Nitrogen fertiliser use in chilli production*" Kong Sam Ouen, GDA 2009
  - *"Chinese kale production in Cambodia"* Ngi Samnang, GDA, 2009
  - "*Harvesting packaging and transport best practice for tomatoes*" Som Bunna, Sambath Sonnthida, Pann Visal and Huon Sereyvuth CARDI February 2009
  - "Extending storage life of Chinese kale" Poster Sambath Sonnthida, Som Bunna, February 2009.
  - *"Cherry tomatoes consumer preference - Which cherry tomato do you prefer?*" Poster Suzie Newman and Wei Liang, I&I NSW, May 2007
  - “Greenhouse cherry tomato trials Autumn 2007” Newman S Hickey M, Liang W, Malcolm P, Michell S Workshop publication December 2007
  - “Field cherry tomato trials Autumn 2007” Newman S Hickey M, Liang W, Malcolm P, Michell S Workshop publication December 2007

  Laboratory manuals also include
  - “SC1 Mapping tomato supply chains” Newman S, Experimental protocol, July 2007
  - “ CPH2 Improving postharvest management of tomatoes” Newman S, Experimental protocol, February 2007
  - “CPH1 Postharvest handling of Chinese kale” Newman S, Experimental protocol February 2007
  - “CPH3 Improving the postharvest handling of Chinese kale” Newman S Experimental protocol September 2007

- The majority of communication and dissemination activities for the plant pathology component has occurred at the laboratory level. During field surveys, face to face communication with farmers and district agronomists was emphasised and conducted whenever possible.
- Laboratory manuals, collection protocols and survey sheets were written for the PPD at CARDI and disease fact sheets are currently being drafted.

9 Conclusions and recommendations

9.1 Conclusions

- The significant improvement in new areas of research for the Cambodian research organisations has been perhaps the highlight of the project. Both the postharvest and pathology laboratories were built up from scratch, and the country now has a competent team addressing issues that impact on vegetable productivity and quality. Retention of trained and competent staff and reasonable operating budgets for both laboratories will be required to ensure ongoing success.
- Under this project, CARDI and GDA have developed a truly collaborative approach to vegetable research and extension. The strengths of the two organisations, namely CARDI in research and higher level analysis and diagnostics, and GDAs extensive networks of competent field technicians and training/education expertise are complimentary. CARDI and GDA researchers worked side by side in all aspects of the project, including field days, workshops and research planning. MAFF has been so impressed with the results that this model is now being applied across other crop and discipline areas, resulting in a stronger agricultural R&D capacity in Cambodia.
- At least three tomato varieties, two chilli varieties and one Chinese cabbage variety have been identified as having commercial suitability. Several of these varieties are now under commercial production, and an increasing number of growers across a number of production regions are expected to be growing these varieties in the future. Shelf life tests at CARDI highlighted some of the weaknesses of current varieties (ie the relatively short shelf life of 4.6 days for CLN1462A), emphasising the need to continually screen new varieties based on both production *and* postharvest traits.
- As open pollinated types, growers have the flexibility to retain a percentage of their tomato and chilli crop for seed production, minimising production costs. However, ongoing purity and quality of farmer produced seed will require attention if alternative seed production mechanisms such as commercial scale production by specialist companies are not found.
- The key production technologies investigated by the project including IDE drip irrigation, plastic mulches and improved nitrogen fertiliser recommendations are showing promise of enhancing productive capacity of farmers, addressing some of the key constraints to the vegetable industry. These constraints include chronic water shortages in the dry season, weed management and labour availability and efficient use of costly inputs such as fertiliser.
- The provision of training and capacity building activities in the discipline of plant pathology has re-established the capability at CARDI following the departure of key staff. The staff of the PPD are confident and competent in performing basic research activities, undertaking field surveys and performing laboratory procedures associated with the isolation and identification of phytopathogens from a broad range of crops.
- The establishment of the horticultural pests collection at GDA has provided a basic tool to industry which will prove its worth in years to come. The collection has significance in several areas, including phytosanitary requirements for market access, identifying key pests from major districts, and training field staff in correct identification of vegetable pests.

- There's been several spin-off benefits from the work with Cambodian vegetable growers in the Sydney Basin. A much broader base of cherry tomato varieties is now available to growers, with several of the new varieties having superior market and grower appeal. Better yields, more uniform fruit shape, extended shelf life, improved disease tolerance and diversity through access to both cherry and grape types are just some of the benefits. Growers also now have a better understanding of postharvest "best practice", tomato spotted wilt virus management, irrigation management and pest identification as a result of project efforts.

9.2 Recommendations

The March 2009 project review recommended a continuation of the work commenced in HORT/2003/045 with a few variations. Among those recommendations was the addition of the Royal University of Agriculture to the project team, integrating planning and project activities with CAVAC wherever appropriate, and a greater emphasis on extension. As the review stated, the project has built up good momentum, with a solid team of enthusiastic young researchers. The new project *HORT/2006/107 Strengthening the vegetable industries in Cambodia and Australia through adoption of improved production and postharvest practices* has been approved, providing continuity for ongoing research activity.

As the work progresses it will be important to learn from HORT/2003/045, and build on the results achieved over the last 4 years. The most important lessons have helped shape the recommendations are listed below;

- More emphasis on farm demonstrations and trials for production issues such as irrigation, varieties and fertiliser is sensible approach to take for the next project. Some improvement in trial management, both in on farm and research trials is required to ensure that management practices are not a constraint to the performance of the trial crop. Selecting highly skilled growers as co-operators is important for the on farm activities. Ensuring that good basic agronomy is employed on research trials is also critical to achieving reliable crop data. More attention to areas such as healthy seedling production, efficient irrigation and drainage and fertliser management for research trials will be required. A best practice approach should be taken in regards research trials management.
- Further work with the IDE "low-tech" drip irrigation system is required. The project team believes that better measurement of water applied and timing of irrigations can be improved, and may require more training of farmer co-operators to achieve this. It may be appropriate to test the IDE drip system along side a well managed furrow system, for example, if looking to maximise cost effectiveness and crop yields.
- The survey work conducted during the plant pathology component of this project has highlighted the fact that disease issues have an important impact in yield and quality aspects of not only vegetable production, but horticulture in general. While an increase in capacity has been demonstrated there remains the requirement for further training through research to achieve the level of expertise required for sustainable crop production.
- Further work is required to establish appropriate capacity in the detection of plant viruses in Cambodia. In addition, the establishment of research and training activities within the key institutes of GDA and RUA is required. This is particularly important for RUA which provides the majority of education in agricultural sciences.

- Some effort was made early in the current project to set up some small scale activities in vegetable seed production. Seed production is a routine part of activity for both CARDI and GDA vegetable teams, but distribution, packaging and promotion of the seed was not well developed. At CARDI, the bulk of the seed produced was used for research purposes only. In the first year of the project, AQIP seed company produced a trial pack of CLN1462A and labelled it in Khmer, even giving it a new name of “Princess Tomato”. The seed was distributed to farmers through the project team and some NGOs working in various provinces. Clearly, the business side of the vegetable seed equation needs major input. Embedding a separate vegetable seed component within CAVAC is a good idea, and will certainly provide the commercial imperative lacking in the past.
- Linkages with NGOs IDE, CAMIP and others, and the AQIP Seed Company will require nururing in the new project. To ensure this does happen, establishment of formal linkages with those projects is necessary, and it is important these linkages are addressed in the new project proposal.
- Development of skills in economic analysis of new technologies to help determine its appropriateness for Cambodian farmers is another area that needs attention in the new project. Srey Sinath form the CARDI Socio-economics group has been accepted to study an economics Masters with Dr Bob Farquarson under a John Allwright Fellowship at the University of Melbourne commencing in 2010. Some preliminary studies were carried out by Sinath and her team, aswell as the GDA team, and further development in this area is required as new technologies come onto the scene.
- One area that needs strengthening in the project team is production of educational material for farmers. There are some recent examples of good publications for farmers and technical / extension workers (see attachments), but there is room for improvement. While the results of the research have been encouraging, the outcomes have not always been captured in form of a publication, whether it be a conference paper, scientific journal article or famer factsheet. Researchers need time allocated to write these publications, and guidance/training in producing appropriate forms for the target audience. More use could also be made of video or still pictures for use in grower meetings or groups, and some of these areas should be explored in the new project. A Youth Ambassador (AYAD) position specialising in desktop publishing and media has been proposed, with the position based at CARDI.

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11 Appendixes

11.1 Report on Variety Trials Conducted by CARDI Plant Breeding Division from 2005-2009

ACIAR Project PHT/2003/045 (ACIAR-06)

Compiled by Mr Nin Charya

Introduction

"Improvement of production and post harvest management systems in Cambodia and Australia Project" is a collaborative project between Australia and Cambodia. In Cambodia, two institutions, the Cambodian Agricultural Research and Development Institute (CARDI) and former Department of Agronomy and Agricultural Land Improvement (DAALI) (now is known as General Directorate of Agriculture or GDA), implement the project based on their own expertise. It started in October 2005 and will be completed in April 2009.

Project objectives are to

(1) map supply chain constraints, devise improvements and incentives for improving product marketability in the Cambodian vegetable industry (Cambodia);

(2) develop and demonstrate improved production and post harvest strategies that will underpin quality improvement and industry development (Cambodian and Australia);

(3) improve R&D capacity in Cambodia in vegetable research, by ensuring maximum sharing of technology and know-how between Australian, AVRDC and Cambodian partners (Cambodian, Australia and AVRDC) .

According to objective 2, CARDI's Plant Breeding Division has a goal to source the appropriate germplasm for agronomy and postharvest research. While the improved tomato and chilli varieties adaptable to Cambodian warm climate and agroecosystem are not very accessible to growers, it is even very important for Plant Breeding (PB) to carry out the variety evaluation trials in order to identify new crop varieties with high yield potential, disease resistance, heat tolerance and good fruit quality.

To achieve the goal, PB has conducted several experiments for tomato and chili variety identification during the last four years.

II. Tomato Variety Trial

Experiment 1: Yield comparison of 13 tomato varieties

Persons in charge: Sakhan Sophany and Nin Charya

Location: CARDI

Duration: October 2005-April 2006

Objective: to compare differences in yield potential of hybrids and OPVs.

Introduction

As in current practice, most tomato growers use local varieties which are OPVs and have little knowledge in hybrids, the project aim to introduce the hybrid tomato to the growers by comparing the yield and shelf life of hybrids against OPV. PB was responsible for field trial to compare the yield and Agricultural Engineering team was responsible for postharvest experiment to compare shelf life and quality.

Narrative summary

Twelve varieties (8 hybrids and 4 OPVs) were tested against KK1, the local OPV, in Cambodian Agricultural Research and Development Institute's experimental field (Table 1). The crops were sown on November 11, 2005, transplanted on December 16, 2005 and harvested in February 2006. The trial was originally laid out in 4-replicated RCBD. However, according to seedlings damage by disease (damping off) before trasnplanting, the number of reps was reduced to 3. The main data collected were days to flowering (DTFL), days to fruit setting (DTFR), days to maturity (DTM), number of flowers and fruits per cluster (in order to calculate fruit set percentage), fruit yield per plot and 20 fruit weight were collected. In addition, the number of plants at harvest, diseases and insects occurrence was also recorded.

There was no significant difference among varieties for DTFL, DTFR and Fruit Weight (g) but there was significant difference at $P<0.01$ in DTM and Fruit Setting percentage and $P<0.05$ in Marketable Yield among varieties (table 2). Variety 1, 7 and 8 started maturing at 67 to 70 days after sowing while the rest started maturing from 96 dyas (table 2). For fruit set, most varieties had higher fruit set rate than local check except V1 that was lower and V7 and V8 that were not significantly different from local check.

Referring to yield, no varieties yielded significantly higher than local check. On the other hand, the hybrids yielded higher than OPVs (except local check). The variety with highest yield is V9 (hybrid Dalila) provided 13.10 t/ha. The come-after are TMK1 (12.84 t/ha, inbred local line), Jetayu (8.52 t/ha), Samruthi and HET2 (8.47 t/ha) and Tanya (8.16 t/ha). For the OPV, the maximum yield was 5.64 t/ha obtained from CLN2714-17-23-29-6-12.19.

Variety 4 (CLN2764-99-13-18-10) was removed from the analysis as the data was available in rep 1 but the other two reps were not available as the transplants died.

Table 1: List of varieties included in variety trial

No.	Genotypes	Source	Type
1	CLN1462A	AVRDC	Inbred line
2	CLN2714-17-23-29-6-12.19	AVRDC	Inbred line
3	CLN2777-168-27-1-7	AVRDC	Line
4	CLN2764-99-13-18-10	AVRDC	Line
5	HET2	AVRDC	Hybrid
6	TLCV15	AVRDC	Hybrid
7	T43	Southern Seed	Hybrid
8	T56	Southern Seed	Hybrid
9	Dalila	East-West	Hybrid
10	Samruthi	East-West	Hybrid
11	Tanya	East-West	Hybrid
12	Jetayu	Marco-Polo	Hybrid
13	TMK1	Local	Inbred local line

Table 2: Days to flowering (DTFL), Days to fruit set (DTFR), Days to mature (DTM), Fruit Set (%), Marketable yield (MYLD) (t/ha) and Fruit Weight (g).

Entry	DTFL	DTFR	DTM	FRUIT SET (%)	MYLD (T/ha)	FR. WEIG (g)
1	50.67	60.67	69.67	16.32	1.92	30.00
2	73.33	81.67	109.00	49.82	5.64	74.17
3	68.33	78.33	108.33	39.73	4.46	58.33
4	-	-	-	-	-	-
5	63.33	69.67	100.33	33.52	8.47	63.83
6	68.00	74.67	99.33	45.20	5.51	163.33
7	44.67	48.67	66.33	27.80	7.40	50.83
8	45.67	49.67	67.67	26.73	5.46	37.50
9	62.00	68.67	96.33	57.91	13.10	39.75
10	71.67	79.00	102.33	48.21	8.47	68.33
11	69.67	78.67	101.67	56.83	8.16	15.00
12	67.00	73.67	102.00	50.49	8.52	45.83
13	65.33	73.67	99.00	23.77	12.84	90.17
Mean	62.47	69.75	93.50	39.69	7.50	61.42
SE	11.17	12.46	15.66	6.41	2.06	36.89
LSD 5%	ns	ns	ns	18.80**	6.05*	ns

Experiment 2: Yield and Fruit Quality Potential Assessment on tomato

Persons in charge: Sakhan Sophany, Nin Charya and Kong Kynet

Location: CARDI

Duration: Nov 2006-March 2007

Objective: to compare differences in yield potential of hybrids and newly released varieties of CARDI.

Introduction

To confirm the result of previous trial that aim to compare the yield potential of hybrids and OPV, this trial was conducted to compare the hybrids with OPV. However, only two hybrids (T56 and TLCV15) that performed well were selected to compare with the newly released OPV (Neang Pich and Neang Tamm and CLN 1462A or TMK2). Neang Pich and Neang Tamm were released by CARDI as high yield, heat tolerant and TLCV resistant cultivars. TMK2 or CLN1462A was released to the farmer by Kbal Koh research station for its high yield potential.

Narrative summary

The five varieties were sown on 22 November 2006, transplanted on 7 December 2006 and harvested in March 2007. The trial was laid out in RCB design with four replications in Cambodian Agricultural Research and Development Institute (CARDI) to assess the yield and other characteristic. The data collected were days to flowering (DTFL), days to fruit setting (DTFR), days to maturity (DTM), number of flowers and fruits per cluster (in order to calculate fruit set percentage), fruit yield per plot and 20 fruit weight were collected. In addition, the number of plants at harvest, diseases and insects occurrence was also recorded. Like the

previous trial, the fruits were picked and put in Post harvest trial of agricultural engineering team to test the fruit quality and shelf life of the 5 varieties.

In term of DTF, DTFR, DTM, and YIELD, the difference among varieties was very significant (P<0.01). 'T56' started flowering and setting fruit later than the other varieties but started maturing the earliest after TLCV 15 (Table 3). In contrast, 'Neang Pich' and 'CLN1462A' started maturing the latest (85 days after sowing). Among the 5 varieties, 'Neang Pich' yielded the highest (37.49 t/ha) while 'Neang Tamm' yielded the lowest (17.11 t/ha) (P<0.01). However, the lowest yield of 'Neang Tamm' resulted from fruit cracking. The 3 introduced varieties ('CLN1462A', 'TLCV15' and 'T56') were not significant different from each other but significantly lower that 'Neang Pich' and only 'T56'that yielded significantly higher than 'Neang Tamm'.

Table 3: Days to flowering (DTF), days to fruit set (DTFR), days to mature (DTM) and marketable yield (YIELD) of the 5 tomato varieties tested in DS 2007 (Nov 2006-March 2007).

Genotypes	DTF	DTFR	DTM	YIELD
CLN1462A	37	47	85	19.31
TLCV 15	34	43	81	19.10
T56	39	49	82	21.04
Neang Pich	35	45	85	37.49
Neang Tamm	33	42	83	17.11
Mean	36	46	83	22.81
5% LSD	2.81**	2.40**	1.38**	2.24**

Experiment 3: Tomato screening for high yield potential and heat tolerance

Persons in charge: Sakhan Sophany, Kong Kynet and Roeun Siranet

Location: CARDI

Duration: Nov 2007-March 2008

Objective: 1. To identify lines producing high yield under high temperature condition (heat tolerance)

2. To select lines that is resistant to multi-diseases and well adapted to the environment.

Introduction

High temperature is the big challenge for tomato growers. While the other production technologies cannot cope with this problem, the heat tolerance cultivar is only panacea. In addition, the tolerance varieties also need to be high yielding and tolerant to various diseases

mainly viral diseases. CARDI had released two varieties that were tolerance to heat and resistance to tomato leaf curl virus (TLCV) but a higher yielding potential cultivar with the same adaptability is required.

Narrative summary

Thirty one inbred lines from AVRDC were tested against 'Neang Pich'in a non-replicated observational yield trial in CARDI during dry season from November 2007 to February 2008. the data on days to flowering (DTF), days to fruit set (DTFR), days to mature (DTM), marketable yield (MYLD), fruit set percentage (FRS), and other disease occurrence were recorded.

In average, the crop started flowering at 95 days, the fruit set was 44% and the marketable yield was 37 t/ha. 'Neang Pich' was among the varieties that mature after 95 days, the fruit set was greater than 44% (47.06%) and yielded higher than 37 t/ha (52.25 t/ha). No lines yielded higher than 'Neang Pich' but 9 lines that yielded very close to 'Neang Pich' were selected for further testing (table 4).

Table 4: DTM, %FRS, Marketable Yield and disease incidence of the 9 lines selected from screening in DS 2008 for further testing against 'Neang Pich'

No	Line Code	DTM	% FRS	MYLD	Disease Incidence	
					TYLCV %	BER %
1	CLN2777E	98	40.00	47.25	6.06	-
2	CLN2777B	98	40.74	47.23	-	-
3	CLN2585C	94	40.00	46.35	9.09	-
4	CLN2777A	94	39.29	41.62	-	-
5	CLN2679E	93	75.00	40.70	-	-
6	CLN2764A	99	45.00	40.38	-	-
7	CLN2714H	95	52.17	38.08	-	-
8	CLN2413D	98	38.89	37.87	4.76	-
9	CLN2400B	92	55.00	36.62	-	-
10	Neang Pich (check)	96	47.06	52.25	-	-

Experiment 4: On-Farm Adaptive Trial on Tomato (OFAT-Tomato)

Author: Sakhan Sophany, Kong Kynet and Roeun Siranet

Location: Siem Reap Province

Duration: Oct 2007-April 2008

Objective:

to disseminate the two new varieties released by CARDI to the farmers

to evaluate farmers' reaction to the new varieties

Introduction

While the growers have limited access to improved cultivars, it is important for the project to disseminate the new varieties to them. 'Neang Pich' and 'Neang Tamm' were included in 10 on-farm adaptive trials (OFAT) in Siem Reap district, Siem Reap province in collaboration with the provincial department of agriculture of Siem Reap.

Narrative summary

'Neang Pich' and 'Neang Tamm' were tested against the 'KK2' and other farmers' popular varieties which were normally bought from the market (hybrids or no background information). Farmers' reaction on the varieties and yield were recorded. Two field days were organized to get the farmers involved in the evaluation of the new varieties. The evaluation was based on plant vigour, growth duration, fruit shape, and satisfactory.

Based on yield, 'Neang Pich' and 'Neang Tamm' provided high marketable yield, 43.30 t/ha and 44.49 t/ha, respectively but had lower non-marketable yield, 5.81 t/ha and 7.25 t/ha, respectively. 'KK2' and farmers' varieties (check) provided lower yield but higher fruit damage comparing to the first two varieties. In addition, the occurrence of TLCV was also lower in 'Neang Pich' and 'Neang Tamm' (table 5). Hence, most farmers prefer 'Neang Pich' and then 'Neang Tamm'.

During the field days farmers were asked how did they like the varieties. The majority of the farmers preferred 'Neang Pich' to the other varieties (Table 5). Based on the result from the evaluation sheet, most farmers preferred 'Neang Pich' because of its strong plant vigour, medium growth duration and good fruit shape (Table 6).

Table 5: The fruit weight (FW), Farmers' preference (FP), Yield, and TLCV occurrence. The average of 10 OFATs in Siem Reap in DS 2008.

Nº	Genotype	FW (g)	FP (%)	Yield (t/ha)		TLCV (%)
				Mar-Y	Non-Y	
1	Neang Pich	84.34	62.50	43.30	5.81	7
2	Neang Tamm	75.27	37.50	44.49	7.25	7
3	KK2	71.43	12.50	34.57	8.44	15
4	Check	51.47	0	23.06	9.59	26

Table 6: Percentage of total farmers evaluating the 3 traits (plant vigor, growth duration and fruit shape) of the four varieties of the 10 OFAT in Siem Reap in DS 2008.

Varieties	Plant Vigor			Growth Duration			Fruit Shape		
	Strong	Medium	Poor	Late	Medium	Early	Good	Fair	Bad
Neang Pich	75.50	24.50	0.00	18.00	82.00	0.00	90.00	10.00	0.00
Neang Tamm	27.00	68.00	5.00	7.00	91.00	2.00	40.00	57.00	3.00
KK2	38.00	62.00	0.00	19.00	81.00	0.00	30.00	63.00	7.00
Check	8.50	24.00	67.50	16.00	57.50	24.50	24.00	64.00	12.00

Experiment 5: Advance Yield Trial of Tomato (AYT-tomato)

Author: Sakhan Sophany, Nin Charya, Roeun Siranet and Im Ladoeun

Location: CARDI, Prek Leap and Kandal Stung

Duration: Nov 2008-March 2009

Objective: To identify tomato cultivars which are adaptable to different environments

Introduction

Nine lines selected from screening in 2008 were included in AYT in 3 different location in DS 2009 in order to further confirm statistically the best performance varieties. Three experimental sites namely CARDI (well-managed environment), Kandal Stung district (medium-managed environment) and PLNSA (disease stress environment) were selected to test the nine lines.

Narrative summary

The crops were sown in November and transplanted in December 2008. Among the three trials, only the one in CARDI that went smooth and obtained very high yield. One trial in Kandal Stung failed to produce yield because of heavy rain (prior to flowering) that led to water lodging.

In CARDI, the crop only suffered minor infestation of southern blight during a few weeks after transplanting and fusarium wilt from flowering to fruit development. However, this did not affect yield very much. The average yield was 27.59 t/ha. 'Neang Pich' appeared to be the best in term of yield and resistance to TLCV and some other diseases.

The one in Prek Leap National School of Agriculture (PLNSA) was infected by nematodes and fungal disease and only 4 lines survived. The trial was sown again on 11 February 2009 and transplanted on 3 March 2009. Similarly, the trial still suffered high and complex stresses from heavy rain (led to water lodging), viral disease (Spotted Wilt Virus, TLCV), fungal diseases (leaf blight), blossom end rot (BER) especially on CLN 2400B. As a result, the average was only 2.07 t/ha while the maximum was 4.38 t/ha. However, from this trial we leant that four lines were resistant to nematode root knot (CLN 2679E, CLN 2764A, CLN2714 H and CLN 2413D).

Among the 9 varieties, no new lines provided significantly higher yield than 'Neang Pich' in both location even though in PLNSA (with heavy stress) CLN 2585C provided higher yield. More or less from the two trials we found that 4 lines yielded significantly lower than 'Neang Pich' in both locations (CLN2777E, CLN2777B, CLN2777A and CLN2764A). 'CLN2777A' in CARDI died of diseased infection at seedling stage and in PLNSA yield only 1.13 t/ha (Figure 1 and Table 7).

For the fruit set, in CARDI it was over 50% in general while in PLNSA it was below 50%. This should be resulted from high temperature and other stresses (heavy rain and diseases) during plant growth.

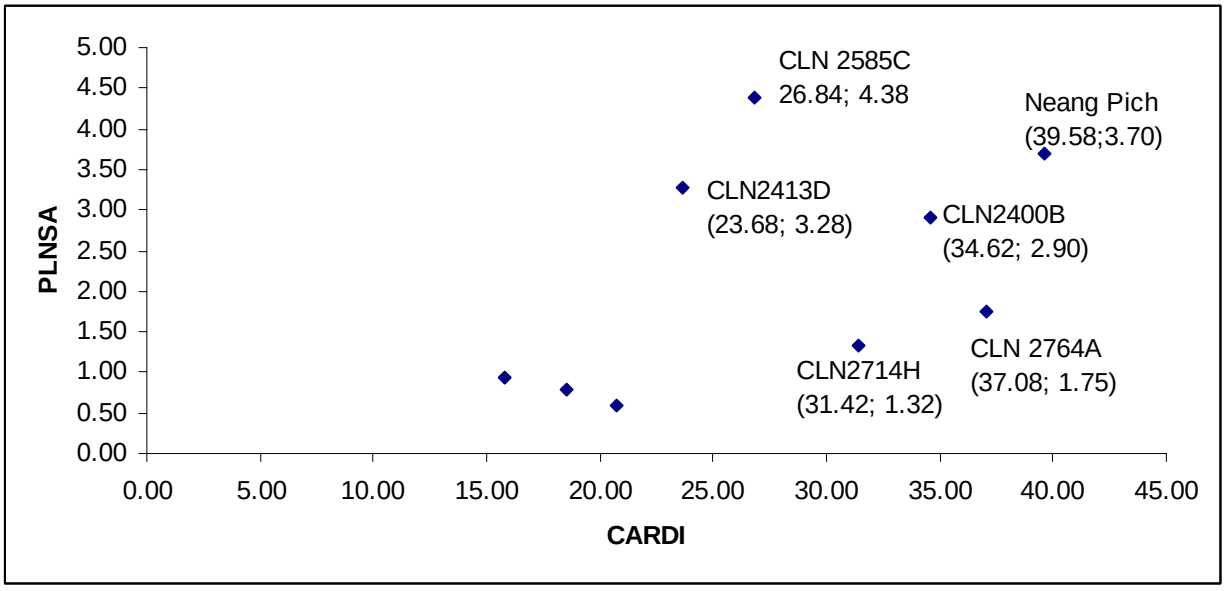


Figure 1: The yield performance of the nine lines in CARDI and Prek Leap National School of Agriculture (PLNSA) in DS 2009.

Table 7: Days to flowering (DTF), Days to fruit set (DTFR), Days to mature (DTM), Fruit set (FS) and Marketable yield (MKYLD) of the ten tomato lines tested in CARDI and (PLNSA) in DS 2009.

Lines	DTF (days)		DTFR (days)		DTM (days)		FS (%)		MKYLD (t/ha)	
	CARDI	PLNSA	CARDI	PLNSA	CARDI	PLNSA	CARDI	PLNSA	CARDI	PLNSA
CLN2777E	49.67	53.67	57.00	60.67	91.00	95.67	57.52	16.32	15.83	0.94
CLN2777B	48.67	52.33	56.00	59.33	87.67	94.33	59.66	31.12	18.54	0.78
CLN2585C	49.00	50.67	58.33	57.67	88.33	92.67	65.40	47.66	26.84	4.38
CLN2777A	-	52.67	-	59.67	-	94.67	-	19.35	-	1.13
CLN2679E	48.33	52.67	56.00	59.67	89.67	94.67	67.45	27.35	37.08	1.75
CLN2764A	50.33	53.00	59.00	60.00	91.67	95.00	66.76	18.05	20.73	0.59
CLN2714H	49.00	52.33	58.33	59.33	89.33	94.33	51.13	34.03	31.42	1.32
CLN2413D	50.33	52.67	58.00	59.67	92.00	94.67	50.08	28.56	23.68	3.28
CLN2400B	49.33	49.00	56.00	56.00	87.67	91.00	57.37	35.64	34.62	2.90
Neang Pich	51.00	52.67	58.67	59.67	91.33	94.67	59.58	29.32	39.58	3.70
Mean	49.52	52.17	57.48	59	89.85	94	59.44	29.74	27.59	2.07
LSD 5%	ns	1.93**	ns	1.93**	ns	1.93**	ns	17.20*	13.93*	1.82**

Experiment 6: On-Farm Demonstration of Neang Pich and Neang Tamm.

Author: Sakhan Sophany, Nin Charya, Roeun Siranet and Im Ladoeun

Location: CARDI

Duration: Nov 2008-March 2009

Objective:

to disseminate the two new varieties released by CARDI to the farmers

to evaluate farmers' reaction to the new varieties

Narrative summary

In 2008, the OFAT-Tomato in Siem Reap was very successful and the farmers there were very fond of 'Neang Pich' and 'Neang Tamm' varieties. The project aimed to extend the two new varieties to the farmers in other provinces where tomato is a potential crop. Eight field demonstrations were conducted in Sa Ang (6 demo) and Kien Svay (2 demo) districts. The production technique was a combination of researcher's and farmers' practices. The seeds were sown to the cell packs with fungicide spray and urea dressing. In the main field, the farmers preferred to use their own practice i.e. planting on flat beds, hand watering, etc. In Sa Ang district, four farmers sowed on 18 November 2008 and transplanted on 13 December 2008, other two farmers sowed on 23 November 2008 and transplanted on 20 December 2008. In Kien Svay, sowing was delayed until 28 December 2008 but according to insect and damping-off damage, they were resown on 12 February 2009 and transplanted on 8 March 2009.

Unfortunately, all demonstration fields were damaged due to water lodging after heavy rain, virus-transmitted insects (aphids, jassids etc), nematodes, and other diseases for the field demonstration in Sa Ang while the field demonstration in Kien Svay were damaged by repeated heavy rain during hot climate. All the crops reached flowering but failed to produce fruits. Only few plants produce fruits.

Implication of the result

From the first year trial, hybrids were normally better than introduced OPV but according to its reliance on import and the quality control is beyond the ability of local authority (provincial department of agriculture, CARDI etc) while some OPV i.e 'Neang Pich' and 'Neang Tamm' were comparable in term of yield, the hybrids should be set aside for a while at the moment and these two OPVs should be disseminate extensively to the farmers and to the place that are suitable for them. Meanwhile, the resource persons in hybrid seed technology in the country should be focused. This should start first with the government agency i.e CARDI and/or Department of Horticulture and Secondary Crops of GDA then be transferred to private agency rather than start with private agency at once.

"Neang Pich" and "Neang Tamm" provided higher yield than the other lines including some hybrids. They were resistant to TLCV and other diseases and tolerant to heat and have good fruit quality. "Neang Pich" and "Neang Tamm" were not very tolerant to heavy rain (mainly water lodging) and nematode root knot. Thus planting time should avoid heavy rain period especially from transplanting to fruiting and the field should be free of nematode root knot. Even though these two varieties are resistant to TLCV, bacterial wilt and a few other diseases but there are many strains of virus. The gemini virus vectors i.e. white fly and thrips (for tomato spotted wilt virus) should be well-managed and preventive or control spray should be applied when the population of these insects reaches threshold level.

The lines that were observed resistant to nematode (CLN 2679E, CLN 2764A, CLN2714 H and CLN 2413D) should be considered for further testing as they also have comparable yield potential to 'Neang Pich'.

"CLN2400B" was comparable to Neang Pich and Neang Tamm in yield, shelf life and quality but not in tolerance to heat and diseases.

As farmers' practice in tomato production was very poor, the next On-Farm trial or field demonstration of the new varieties should go together with other technologies such as sowing seeds in the cell packs, transplanting on raised beds with plastic mulching etc because this will provide two fold benefits. First the farmers will learn the new technologies that save their time and labour. Second, the crops have more chances to reach their potential and farmers can choose the best variety and have more confident to the researchers.

III/ Chili Variety Selection for Anthracnose resistance

Experiment 7: Chilli Variety Selection for Anthracnose resistance

Author: Sakhan Sophany, Nin Charya, Kong Kynet, Roeun Siranet and Im Ladoeun

Location: CARDI

Duration: June 2007-March 2009

Objective: To identify new chilli varieties with anthracnose resistance

Introduction

Forty five lines of chilli were requested from AVRDC to be tested in series of trials in CARDI in 2008 for their tolerance to anthracnose. Each line was planted to 5 m2 plot with 50 cm x 40 cm plant spacing. The screening had no replication. The selected lines were put in the preliminary yield trial (PYT). The same plot size and spacing were used but the number of replication was increased to two. From the PYT, 10 lines were selected and planted in 3 replication advance yield trial (AYT) using the same plot size and spacing.

Chilli for screening was sown on 13 August 2007 and transplanted on 10 September 2007. The harvest started on 4 December and ended on 22 December 2007. For the PYT, sowing started on 18 January 2008 and transplanting started on xx, February 2008. Harvest started and finished on . For AYT, sowing started on 11 December 2008 , transplanting started on 12 January 2009, harvesting started and finished .

Narrative summary

Among the three years of experiment only PYT in 2008 that the crop grew well and provided average yield of 8.40 t/ha. In the screening in 2007 and AYT in 2009, the crop did not grow very well according to water stress (lodging) and insect damage (fruit fly) that led to average yield lower just around 4.39 t/ha. During the experiment, the occurrence of anthracnose was very mild so that we could not identify the anthracnose resistant lines. In contrast, due to high temperature during crop growth only heat tolerant lines that perform very well and of those were selected for further testing (Table 8). For AYT in dry season 2009, chemical spray (imidacloprid and chlorpyrifos) was applied to save fruits from fruit fly damage.

Table 8: Lines selected from the screening in wet season 2007 and tested in PYT in dry season 2008 and AYT in dry season 2009.

No.	Lines	PYT	AYT	Heat tolerance*	Disease Resistance*
1	PP0007-2231	✓	-	-	-
2	PP0007-2244	✓	-	-	-
3	PP0007-2247	✓	-	-	-
4	PP0037-7544	✓	-	-	-
5	PP0037-7558	✓	-	-	-
6	PP0037-7569	✓	✓	Excellent	-
7	PP0042-24	✓	✓	-	-
8	PP0042-31	✓	✓	Fair	CMV, CVMV, PVY, BW
9	PP0107-7006	✓	✓	Excellent	-
10	PP0107-7047	✓	✓	Excellent	-
11	PP97-7127	✓	-	-	-
12	PP97-7644	✓	✓	good	CVMV, PVY, BW
13	PP9852-019	✓	-	-	CVMV, PVY, Anthracnose
14	PP9852-090	✓	-	-	-
15	PP9852-091	✓	-	-	-
16	PP9852-100	✓	-	-	CVMV, BW, Phytophthora
17	PP9852-149	✓	✓	-	BW
18	PP9852-170	✓	-	-	-
19	PP9852-173	✓	-	-	-
20	PP0107-7058	✓	✓	Excellent	-
21	PP0107-7062	✓	✓	Excellent	-
22	PP9955-15 (check)	✓	✓	Excellent	CMV, PVY, BW

* The information was obtained from the pepper database of Dr. Paul Gniffke.

Among the nine lines tested in AYT, there were 5 lines that provided high yield and were comparable to the check (PP9955-15) in the three season of testing. In screening in 2007, lines 'PP97-7644' provided the highest yield (8 t/ha) while 'PP0107-7006', 'PP9955-15' (check), and 'PP0042-31' came second, third and fourth with 5t/ha; 4.92 t/ha and 4.43t/ha of fruit yield, respectively. In PYT in dry season 2008 and AYT in dry season 2009, the lines 'PP97-7644' 'PP0042-24', PP0042-31, yielded similar to each other. In addition, other two lines 'PP0107-7058' and 'PP0107-7062' which did not yield as high as the earlier mentioned lines in the screening in 2007 appeared to perform very well in PYT dry season 2008 (14.15 t/ha and 17.38 t/ha, respectively) and in AYT dry season 2009 (3.78 t/ha and 3.22 t/ha, respectively) (Table 9).

From this result, 'PP0042-31', 'PP0042-24', 'PP0107-7062' and 'PP97-7644' should be considered for on-farm adaptive trials.

Table 9: The yield comparison of well performed lines during the 3 seasons testing

No	Genotypes	Screening WS 2007		PYT DS 2008		AYT DS 2009	
		MKY(t/ha)	Rank	MKY(t/ha)	Rank	MKY(t/ha)	Rank
1	PP0037-7569	2.22	8	9.55	8	6.71	2
2	PP0042-24	3.49	5	12.95	4	4.68	5
3	PP0042-31	4.43	4	12.55	5	6.15	3
4	PP0107-7006	5.00	2	9.40	9	1.80	9
5	PP0107-7047	3.17	6	11.26	7	1.30	10
6	PP97-7644	8.00	1	12.38	6	3.83	6
7	PP9852-149	3.10	7	9.20	10	3.78	7
8	PP0107-7058	0.12	9	14.15	2	3.22	8
9	PP0107-7062	N/A	N/A	17.38	1	5.42	4
10	PP9955-15 (Check)	4.92	3	13.94	3	6.95	1
	Mean	3.83		8.40		4.39	
	LSD (5%)			3.17 **		3.07**	

Implication of the result

‘PP0042-31’, ‘PP0042-24’, ‘PP0107-7062’ and ‘PP97-7644’ should be increased seeds and further tested in AYT in CARDI with good management and go to on-farm trials in the field where is similar to CARDI and no history of anthracnose damage.

The failure to get anthracnose resistance line was resulted from no severe disease infestation in the field. The next screening should involve the inoculation of anthracnose spore with the plants in order to identify the resistant lines.

Heat tolerance should be the major traits to be considered for new varieties of any crops from temperate zone because of the warm climate in Cambodia.

Fruit fly appeared to be the remarkable issue as it will cause severe damage if no appropriate and effective measure is taken. Fruit fly management practice should be considered and if possible the PB team should try to identify the lines that tolerate to fruit fly.

11.2 Impact Documentation of RETA 6208-Cambodia and HORT/2003/045 in Banteay Dek District, Kandal Province

Farmer case study 1 (Adapted from the ADB RETA Project Team Case Study)

Mr. Popich is a vegetable farmer from the vegetable-growing village of Bantheydek, Banteay Dek Commune, Kiensvay District, Kandal Province, Cambodia. He is married and his wife and 2 daughters help him in farm operations until the harvested produce is loaded to the transport vehicle of collectors. He has a 1.2 ha vegetable farm with tomato as the major crop at the back part of his house which is about 60 m away from the Mekong river. Other vegetables grown and observed during the visit were yardlong bean and bitter gourd. Standing crop of tomato observed included 3 varieties; two AVRDC varieties-CLN1462A and CLV1461i cherry tomato, both at fruiting stage, and 'Mongal' variety from Vietnam at flowering and early fruiting stage. There were two sections of the farm planted to CLN1462A, one on a 13x60 m area for production purposes and the other on a 5x10 m experimental area of the IDE-AVRDC project on drip irrigation (compared to hand irrigation) and mulching (plastic mulch, rice straw and no mulch). During the visit, the CLN1462A production area was at its 5th harvest (planted in Jan 2008) and has been producing about 600 kg fruits per harvest (two harvests per week). The experimental area was planted to CLN1462A in Nov 2007 and has so far produced more than 500 kg fruits. The farm also showcased AVRDC interventions in the entire production chain, from choice of variety (CLV Net and RETA 6208 projects), cultural management techniques (ICM project, in addition to that developed by Kbal Koh Agricultural Research Center or KKARC), to harvesting and postharvest handling operations (RETA 6208). The farmer started growing CLV1462A after attending the training on postharvest technology of tomato and chili held in KKARC in early 2007 and abandoned the use of the local tomato variety.

The interview and pictorial documentation of the farmer's resources and his operations from harvesting to loading of fruits to the transport vehicle of two collectors (pls see attached) were conducted while the farmer and his family members were doing harvesting, hauling, sorting and packing of tomato. Harvesting started at 7 am and was on-going when the visiting team (RETA 6208-Cambodia National Coordinator, Local Postharvest Expert and Regional Project Coordinator) arrived. The results of the interview are as follows:

1. Why have you decided to change your practices in harvesting and postharvest handling of tomato?

Losses were high and income was low. The local tomato variety had also low market demand while CLN1462A, cherry tomato and Mongal variety have many buyers who collect them in the farm. The buyers/collectors informed that these varieties have high consumer demand in different provinces of the country. This was confirmed by Collector 1 who relayed that the tomatoes she will get from the farmer has already wholesaler-buyer in Phnom Penh (about 35 km away) who will bring the fruits to Sihanoukville and Siem Reap provinces. This collector also shared that wholesaler-price of tomato is 200 reil/kg higher than that she paid to the farmer. She further revealed that she did not incur losses as the packed fruits (using high-density polyethylene bag at 22 kg fruits/bag) are bought by the wholesaler without examining the fruits as they know already about the quality and resistance to handling damage of CLN1462A.

2. What are the changes in your harvesting/postharvest handling procedure that you get from KKARC (formerly Kbal Koh Vegetable Research Station) or RETA 6208? Compare these with your previous practices.

All aspects in tomato production (including variety) and postharvest handling were obtained from the trainings conducted by KKARC. For CLN1462A tomato which was grown staring early 2007, specific harvesting/ postharvest handling methods are as follows:

- Harvesting at mature green to breaker stage. Few fruits at more red-than-green stage are also harvested since this cannot be avoided.
- Harvesting during the cooler part of the day and placing the harvested fruits under a shaded area near the farm and road where sorting and packing are done.
- Using harvesting and hauling containers with smooth surfaces, such as plastic pails and basin made of tin or metal, and careful handling during harvesting and hauling.
- Sorting fruits by separating the mature green and breaker fruits from those at more advanced stage of ripening while fruits with damage (insect pests, disease and blossom end rot, wind scars) and off-shaped are discarded.
- Packing using plastic bags at 20-22 kg capacity depending on the requirement of the collector.
- Careful loading of the packed fruits into the transport vehicle of the collector.
- For cherry tomato, the fruits are harvested at red-ripe stage and more careful harvesting and hauling are observed. The fruits are sorted, discarding those with damage (similar to that of CLN1462A, including growth cracks) and packing in carton box at about 10 kg/box.
- Previous practices: In 2006 and earlier, the local variety (no name) is used and proper harvesting and handling were not known yet. The fruits are not sorted and of mixed quality and maturities in a pack using bamboo baskets at about 200 kg fruits per basket.

3. How did you overcome the added costs and efforts expended for the changes in your harvesting/postharvest handling practices?

The changes were simple and added costs were not that big except labor. However, family members (wife and 2 daughters) help in the different harvesting and handling operations.

4. What benefits did you get when you change your harvesting and postharvest handling practices?

- Losses avoided – With the new procedures, loss is not incurred. Previously, about 10 kg fruits per 200 kg basket is lost due mainly to physical damage.
- High price of fruits – CLN1462A during this period is priced at 700 reil/kg. In 2006, the local variety is priced at only 300 reil/kg. Cherry tomato is priced at 1000 reil/kg.
- Income increased – Net earnings increased from about 3-4 million reil in 2006 to 6-7 million in 2007. (1 USD=4000 reil)

5. Can you see changes in your life because of the improvements in harvesting and postharvest handling practices? What changes?

Life is now easier than before because there is enough food and money for everything, including the purchase of a new motorcycle and improvement of residential land near the national road. Contribution to social and civic activities (e.g. improvement of farm roads, construction of new pagoda) is also much higher now than before,

Additional Notes (February 2009)

Pich is growing two varieties of tomato this year; Mongal and CLN1462A. Price for CLN1462A was higher during November to January. At that time it was 2000 R/kg compared to 300 R/kg in February. Mongal is returning better price now. Mongal produces higher yields (400kgs higher for 1900 plants). Supply of Mongal during Nov-Jan from Vietnam was high therefore price was low. Next year he will grow 1462A early and Mongal late.

Over the last 2 years more farmers have moved to growing tomatoes. There are 140 families in the village, 70 grow vegetables and now 30 families grow tomatoes. 5 years ago only 5 families grew tomatoes.

Pich decided not to continue with drip irrigation. He feels the big advantage would e if he was farming in a district well away from the river. He can irrigate easily from the river with a hand hose and pump.

Mr Pich attended the study tour to Vietnam, and brought may ideas back with him

In terms of new research, he would like to see more research into bacterial wilt resistant and tomato yellow leaf curl virus resistant varieties.

Mr Pou Pich, 2nd from left inspecting raised bed and trellising set-up in Vietnam. Mr Pich subsequently adapted these trellis and bed systems for his farm.

The flow chart below describes the growing, harvesting, packaging and transport system used on Mr Pich's farm.

The visiting team with the farmer and his wife

The farmer's 1.2 ha vegetable farm

CLN1462A tomato at 5th harvest (planted Jan 08)

CLN1461i cherry tomato

CLN1462A in drip irrigation-mulching expt producing so far >500 kg fruit on 5x10 m area (planted Nov 07)

The farmer's house

The farmer's family (wife, 2 daughters and grand daughter) and products (CLN1462A and cherry tomatoes)

Harvesting CLN 1462A tomatoes usually starting 7 am; note the use of protective clothing and plastic pail as container

Hauling using containers with smooth surface (plastic pail, basin) to a shaded place near the farm and road for sorting

Sorting by separating green/breaker fruits from more red ones and discarding damaged ones due to insect, disease, wind scar and blossom end rot

Arrival of Collector 1 who helped in sorting and packing in high-density white-colored polyethylene bag at 22 kg fruits/bag, with last bag mixed with more ripe fruits placed at the top portion of the bag

Loading bags of fruits to transport truck of collector 1; note 2 big bamboo baskets of tomato from other farmers

Departure of Collector 1 and arrival of Collector 2 with fruits in blue-colored bags at 20 kg/bag, followed by loading to the vehicle (trailer attached to a motorcycle)

Red-ripe cherry tomatoes being the last to be sorted and packed; sorting by separating fruits with growth cracks, blossom end rot and other damage; filling of used carton box as packaging container at more or less 10 kg per box

Securing the box by tightly binding with plastic twine; recording weight of each box as boxes are not of the same size unlike the plastic bags; loading to the vehicle of Collector 2

Postharvest operations finished before lunch time

Giving of token of appreciation to the farmer

Grower 2 Em Houy, Banteay Dek Commune, Kandal

Em Houy, his wife and daughter grow Mongal and CLN1462A. This is the first year he has grown 1462A. He is testing CLN1462A after seeing Pou Pich's crop, and was impressed by the high yield. They started growing tomatoes 3 years ago. Before that they only grew cucumbers. Tomatoes are better profit, and pest and disease control is easier. They intend to increase area in future. The family has learnt a lot from Pou Pich about growing tomatoes, particularly pest management. The CLN1462A crop has not been harvested yet.

Mrs Em Houy and her daughter in their tomato field.

Grower 3 Mom Sroy, Banteay Dek Commune, Kandal

Mom Sroy and his wife have grown tomatoes for 3 years. Before that they grew snakebean and radish. The shifted to tomatoes because of the better returns, need for less labour and easier to control pests. Last year they grew CLN1462A and Mongal, but this year they only grow Mongal. However CLN1462A tastes better. Sroy attended Pou Pich's project field day. Following the field day, he changed several aspects of his tomato farming. He now uses small plastic bags for transporting the fruit rather than large baskets which damaged the fruit. He also learnt about the importance of harvesting in the early morning cool. As a result they got better prices for their fruit this year, and managed to sell everything they sent to the market, which is unusual. Their market agent is very happy with the improvement in their fruit quality. Sroy also attended training at Kbal Koh last year, and learnt a lot about irrigating his crop. He changed the growing practice by putting tomatoes up a bed, with a shallow furrow in which the water runs between them. Now he keeps the foliage dry and gets healthier plants and better yields. He would like more information on fruit borer and leaf miner.

Mrs Mom Sroy sorts tomatoes into 20 kilogram plastic bags for transport. She learnt about using bags for packaging at Pou Pich's field day.

11.3 11.3 Economic Analysis of Project Technologies

Ms Srey Sinath, Socio-economist, CARDI

Fertiliser economics

The data reveals that the total cost of nitrogen trial is a little bit higher than (hand and drip) irrigation 49.58 to $ 55.80 compared to $34.60 up to $54.60 respectively. The cost around $40/100m2 [$4000/ha; this cost is very high for a small land] is higher than the cost of $2700/ha.

In the fertiliser treatments, nitrogen can generate money, however, the relative returns are lower than hand and drip irrigation; EE of nitrogen range from 2.78 to 2.86 compare to EE of hand and drip irrigation that range from 2.6 to 4.7.

Table 1: Economics of nitrogen fertiliser use in chilli

	Fertilizer/100m2			
		9955-15		
	0-80-100	100-80-100	150-80-100	200-80-100
Yield/100m2	230.00	250.00	260.00	265.00
Price $	0.60	0.60	0.60	0.60
Total Costs	49.58	53.19	54.49	55.80
Income	138.00	150.00	156.00	159.00
Gross margin	88.42	96.81	101.51	103.20
EE	2.78	2.82	2.86	2.85

** Economic efficiency is defined as the gross income divided by the total costs*

In the comparison of drip versus hand irrigation for chillies on plastic (Table 2), rice straw and no mulch treatments showed that there was greater advantage in using rice straw mulch than the irrigation treatments or the plastic mulch. Plastic is relatively expensive in Cambodia, increasing costs per hectare by up to $400. Marketable fruit yields were highest for plastic mulch, but the costs outweighed the benefit.

Although no cost was attached to the rice straw, future studies should include a cost to the farmer, as rice straw has alternative uses and therefore has a value. In tomatoes, drip and hand irrigation were similar economic efficiency, but plastic mulch tended to give the better economic returns. It should be noted that the capital cost of the drip irrigation system was not factored into the equation. The analysis was based on the crop gross margin only. The cost of applying fertilizer per 100m2 range from $6.60 to $11.82 excludes the cost of spraying, harvesting, and labour. The cost of fertilizer is very expensive that farmers cannot afford to apply rates higher than about 100kgs/ha.

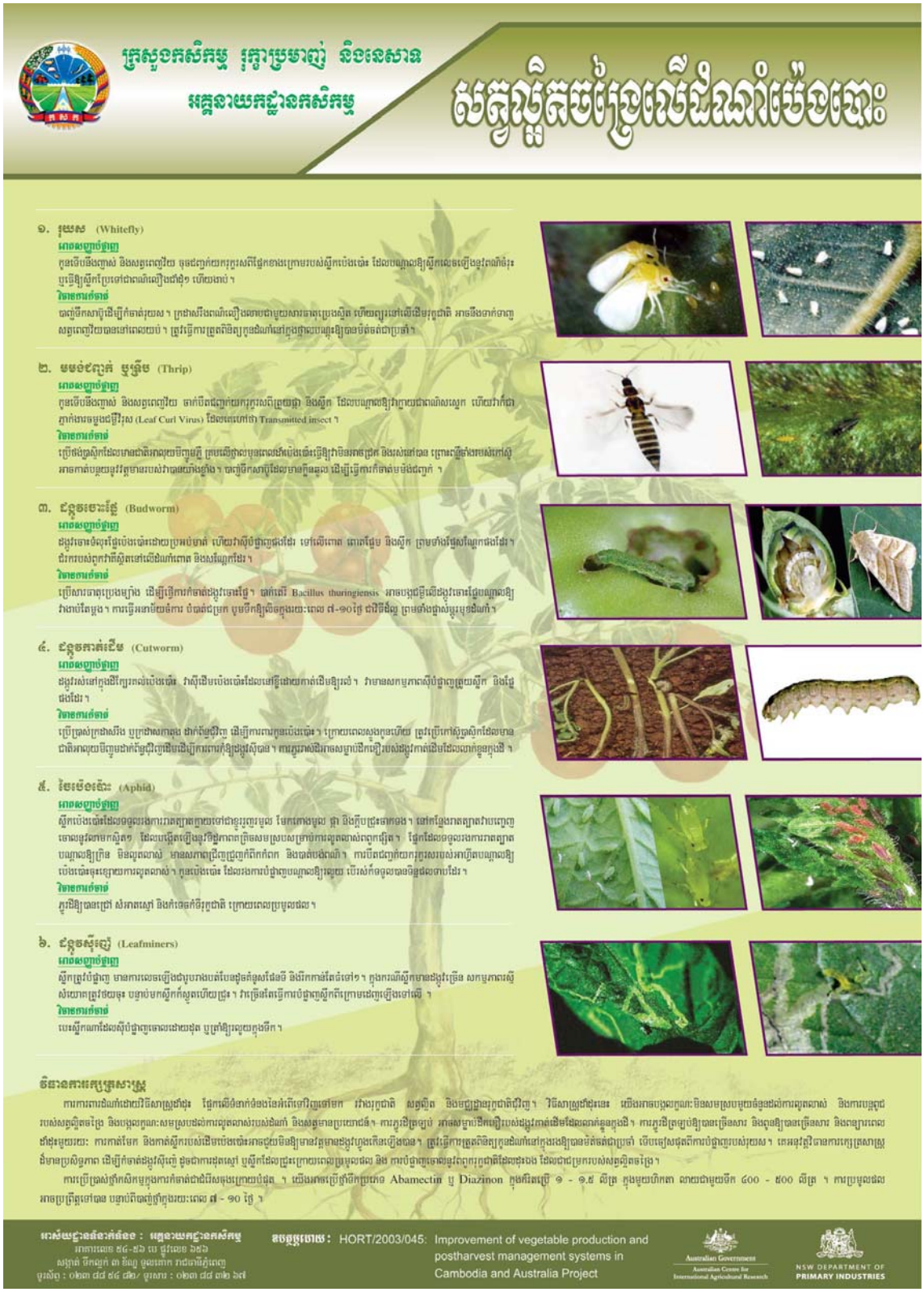
Table 2: Economic analysis of drip vs hand irrigation under mulched and non-mulched growing systems.

Economic Analysis on Chilli (drip and hand)/100m2									
	Variety			Yield kg/ 100m2	Price $	Total Costs $	Income $	Gross margin $	EE
Drip irrigation	9955-15	Rice straw	Cost ($)	301.3	0.5	34.6	150.7	116.0	4.3
		Non rice straw	Cost ($)	286.6	0.5	34.6	143.3	108.7	4.1
		plastic	Cost ($)	340.8	0.5	54.6	170.4	115.8	3.1
	CCA-321	Rice straw	Cost ($)	310.4	0.5	34.6	155.2	120.6	4.5
		Non rice straw	Cost ($)	288.8	0.5	34.6	144.4	109.8	4.2
		plastic	Cost ($)	337.9	0.5	38.1	169.0	130.8	4.4
Hand irrigation	9955-15	Rice straw	Cost ($)	326.7	0.5	34.6	163.4	128.7	4.7
		Non rice straw	Cost ($)	192.1	0.5	34.6	96.1	61.4	2.8
		plastic	Cost ($)	287.9	0.5	54.6	144.0	89.3	2.6
	CCA-321	Rice straw	Cost ($)	317.5	0.5	34.6	158.8	124.1	4.6
		Non rice straw	Cost ($)	208.3	0.5	34.6	104.2	69.5	3.0
		plastic	Cost ($)	319.6	0.5	38.1	159.8	121.7	4.2

11.4 Appendix 4 Sample project factsheets produced by GDA

11.5


ក្រសួងកសិកម្ម រុក្ខាប្រមាញ់ និងនេសាទ
អគ្គនាយកដ្ឋានកសិកម្ម
សត្វល្អិតចង្រៃលើដំណាំម្ទេស
១. ដង្កូវកាត់ដើម (Cutworm)
អាចសម្គាល់ឃើញ
នៅពេលថ្ងៃ Caterpillars នៅក្នុងដី ហើយវាស៊ីប្រូសដំណាំម្ទេស ចន្លោះយប់វាអាចស៊ីកូនដើមដំណាំថ្មី១ ហើយកាត់ដើមម្ទេសឱ្យដួលរលំ ។ លើសពីនេះ
ទៅទៀតវាស៊ូរន្ធកាត់ផ្លែម្ទេស និងដាក់ពងកើតមានមេម៉ាស៊ីមក្នុងរយៈពេលខ្លីៗ ។
វិធានការបង្ការ និងព្យាបាល
ក្នុងការកំចាត់ដង្កូវកាត់ស្លឹកដោយប្រើប្រាស់គីមី Caterpillars នៅពេលដែលវានៅក្មេងពិបាកប្រយុទ្ធ ដោយសារតែវាស៊ីស្លឹក ។ នៅពេលដែលវា សំណាងនៅក្នុងដី
នោះហើយមានការលំបាកក្នុងការកំចាត់វា ។
- ក្នុងរយៈពេលមួយខែមុនពេលវា ប្តូរសាច់ក្នុង ត្រូវប្រើថ្នាំដែលមាន Caterpillars ឬមីក្រូប៊ីដែលដោយ ដើម្បីលើកដៃគ្រវែកូន ដោយលិចទឹកមានអាយុ
និងសត្វចាស់ស៊ីបំផ្លាញ
- ប្រើផេរ៉ូម៉ូនសម្រាប់ប្រមូលផ្តុំ ឬស្រាយផេរ៉ូម៉ូន ដែលកំពុងស្រាយ
- ត្រូវប្រើប្រាស់សារធាតុ ប្តូរស្លឹក ឬ បន្ទះស្អាត: ដាក់ជិតដីឱ្យដើមម្ទេស ដោយដាក់បន្ទះស្អាតៈចៅក្នុងដី ជម្រៅ ២.៥ ស.ម ដើម្បីសំលាប់នេះ
អាចបណ្តាលឱ្យប្រូស Caterpillars ស្លៀកវាងចិចដាច់ដាច្រើនជាង។
២. សត្វទន្សាំកូរុះ (Flea beetle)
អាចសម្គាល់ឃើញ
សត្វពេញវ័យស៊ីស្លឹកកូមីតេចង្កុត និងស្លឹកខ្ចី។ ហើយវាកំស៊ីស្លឹកតាមរន្ធតូចៗជាច្រើន ។ ហើយគេអាចសំគាល់ស្នាមស្លាមនៃការបំផ្លាញដោយធ្វើឱ្យមានរន្ធតូច។ នៅពេលដើ
ស្លឹក។ ក្នុងករណីមានការរីករាលដាលខ្លាំងធ្វើឱ្យក្តូបម្ទេសក្មុងផ្នែកបណ្តុះត្រូវមានការបំផ្លិចបំផ្លាញទាំងស្រុង។
វិធានការបង្ការ និងព្យាបាល
- ជ្រោយដីនៅជំណាក់កាលក្រាំរបស់ដីកប្បី និងសំអាតស្មៅជុំវិញចំការដើម្បីបំផ្លាញជំរកបស់វា
- ដាក់ជីបំប៉នបន្ថែមដើម្បីបង្កើនល្បឿនដែលការលូតលាស់របស់ដំណាំ
- មេធ្យោបាយដែលធ្វើប្រសិទ្ធភាពការប្រើប្រាស់ថ្នាំគីមីកម្ទេសៈ គឺជាការធ្វើដំណាំឆ្លាស់ជាមួយនឹងដំណាំ ដែលស៊ីមេធ្លីដូច អំបុះ Solanaceae
ឬធ្វើដើមកំណាក្បាស់ដែលដើម្បីការពារស្លឹកក្នុងតំបន់អាចធ្វើដើមកបាន ។
៣. ដង្កូវស៊ីផ្លែម្ទេស (Fruitworms)
អាចសម្គាល់ឃើញ
ដង្កូវស៊ីស្លឹក ឬពោតផ្លែម្ទេស តែជាទូទៅការខូតខាតមិនសូវជាច្រើនប្រភេទប្រាកដជាដង្កូវស៊ីដំណាំ យើងតែងតែឃើញវាស្ថាស់នៅពេលវាបំផ្លាញច្រើនទេ និង
ផ្លាស់ប្តូរទីកន្លែង ។
វិធានការបង្ការ និងព្យាបាល
- សំអាតស្មៅ និងក្តៅជុំវិញចំការ ដែលមានជីរកសត្វចង្រៃ
- ក្រោយពីប្រមូលផលម្ទេស ត្រូវយកការសំណល់ចុត ឬកប់ដោយ
- ប្រើថ្នាំ Bacillus thuringiensis (Bt) ពេលដែល Caterpillars នៅក្មេង ។
៤. ខែម្ទេស (Aphid)
អាចសម្គាល់ឃើញ
ខែម្ទេសស៊ីជញ្ជក់ត្រួយ ឬស្លឹកខ្ចី ដែលកំពុងលូតលាស់នៅផ្នែកខាងក្រោមនៃស្លឹក ជាកន្លែងសំរាប់ការពារខ្លួនវាពីកំដៅថ្ងៃធ្វើឱ្យក្រួចជាតិក្រិច រុលលាតទៅរាប់
ក្នុងករណីបំផ្លាញធ្ងន់ធ្ងរ ។
វិធានការបង្ការ និងព្យាបាល
គេអាចទៀសវាងពីការបំផ្លាញដែលក្នុងកំឡុងពេលជាន ដោយប្រើមីក្រាំដាក់ ១ទីឡូក្រាមលាយជាមួយមីកសាប៊ូ ២០លីត្រ ដើម្បីបាញ់កំចាត់ ។ ហើយអាច
ប្រើថ្នាំកសិកម្មបាញ់ទៅលើដំណាំ ក្នុងករណីមានការបំផ្លាញធ្ងន់ធ្ងរ ។
៥. ភក្សស៊ីផ្លែម្ទេស (Pepper weevil)
អាចសម្គាល់ឃើញ
ភក្សពេញវ័យ ស៊ីស្លឹក ផ្កា និងឆោមរួចទៅក្នុងផ្លែម្ទេស។ សញ្ញាបំផ្លាញដំបូង គឺមើលឃើញមានរន្ធតូចទៅក្នុងផ្លែម្ទេសខ្ចី និងមានរន្ធតូច។ ប្រព្រលាងមួយ
(មានអង្កត់ផ្ចិតប្រវែង ២-៥ម.ម) នៅលើស្លឹក។ អាចសង្កេតឃើញថា ជាការបំផ្លាញដោយដង្កូវរមាស់ (Caterpillar)។ ដង្កូវស៊ីផ្លែ និងដង្កូវមានវែងនៅ
ដែលកំពុងលូតលាស់ទៅជាផ្លែ ដើម្បីក្រុយជាដង្កើរ។ ការបំផ្លាញនេះ បណ្តាលឱ្យគ្រាប់ពូជបាត់ ផ្លែ និងដុំម្ទេសរាបស្មើ ។
ជាមួយ ភក្សពេញវ័យ ស៊ីស្លឹក ផ្កា ខាងក្រៅ ដុំម្ទេសរាបស្មើ។ ផ្លែទាន្ទរបាងមុខសូនធម្មតា ត្រូវម្ទេសរាបស្មើ មានដំបៅ។ មានស្នាមរន្ធស៊ីជាក់ស្តែងនៅថ្នែក
ខាងក្រៅ និងក្នុងផលិសម្បូរ។
វិធានការបង្ការ និងព្យាបាល
ក្នុងការទេសវែងមានការរាតត្បាត ចំណែកភ្លូជម្ទេសវែងពេញនិយមគេ មិនត្រូវទាំមកដាំតំបន់វែងមានបញ្ហាសត្វល្អិតទៀតទេ។ ហើយមិនត្រូវដាំផ្លា
និងផ្លែវែងមានសមាសភាពច្រៃមកជាមួយ។ កន្លែងវែងសមាសភាពត្រូវតែបំផ្លាញគ្រប់ដាច់ដាច់ដើម្បីបុ ដើម្បីការពារកុំឱ្យមានសត្វល្អិតទៅច្រៃ
ទេនៅមានជីវិត ។
៦. ដង្កូវស៊ីរបៀ (Leafminers)
អាចសម្គាល់ឃើញ
ស្លឹកត្រូវបំផ្លាញ មានការលេចធ្លោរបៀបជាលូបបាតបត់បែរបង្កើតជាផ្លូវវែងបែរ និងវិកការខ្លែតជំនៅ។ ក្នុងករណីស្លឹកមានដង្កូវច្រើន សកម្មភាពស៊ីសំយោគត្រូវ
ថយចុះ បន្ទាប់មកស្លឹកក៏ស្ងួតហើយជ្រុះ។ វាច្រើនតែធ្វើការបំផ្លាញស្លឹកពីក្រោមដៅញុះធ្លើរទៅលើ ។
វិធានការបង្ការ និងព្យាបាល
បេះស្លឹកណាវែងរបៀបស៊ីបំផ្លាញចោលដោយដុត ឬត្រាំឱ្យរលួយក្នុងទឹក។
៧. ទងច់ភ្នក់ ឬត្និប (Thrip)
អាចសម្គាល់ឃើញ
ក្នុងទឹបនឹងញាស់ និងសត្វពេញវ័យ ទាក់ទឹបជញ្ជក់យកក្រូសសើតត្រួយថ្នា និងស្លឹក ដែលបណ្តាលឱ្យវាក្លាយជាសណ្តែសស្លក ហើយវាក៏ជាក្រុមដែលនាំមេរោគមួយជម្ងឺវីរុស
(Leaf Curl Virus) ដែលពេលហៅថា Transmitted insect ។
វិធានការបង្ការ និងព្យាបាល
ប្រើវិធីធ្វើស្លឹកដែលមានជាតិអាសុយទឹកញ្ជក់ ត្រូបលើថ្នាលមុនដាំបេះដើរធ្វើឱ្យវាមិនអាចជ្រក និងរស់នៅបាន ព្រោះដើម្បីរបស់ពៅស៊ីអាចកាត់បន្ថយ
ផ្លូវវិត្តអាយុរបស់វាបានយ៉ាងខ្លាំង។ ចាត់ទឹកសាប៊ូដែលមានក្លិនឆ្អួន ដើម្បីធ្វើការកំចាត់មេម៉ដ៏ជាក់។
៨. រុយស (Whitefly)
អាចសម្គាល់ឃើញ
ក្នុងទឹបនឹងញាស់ និងសត្វពេញវ័យ ចុចជញ្ជក់យកក្រូសពីផ្នែកខាងក្រោមរបស់ស្លឹកបន្តែម ដែលបណ្តាលឱ្យ
ស្លឹកលេចធ្លោជូចពណ៌ផ្ទុះ ឬធ្វើឱ្យស្លឹកក្រៀមវាជាពណ៌ឆៀងជាងមុន។ ហើយចាប់។
វិធានការបង្ការ និងព្យាបាល
ចាក់ទឹកសាប៊ូដើម្បីកំចាត់រុយស។ ក្រដាសរឹងពណ៌ឆៀងលាបជាមួយសារធាតុប្រេងស៊ីត ហើយព្យួរនៅលើ
ដើមក្រូចជាតិ អាចនឹងទាក់ទាញសត្វពេញវ័យបានយ៉ាងល្អ។ ត្រូវធ្វើការត្រួតពិនិត្យក្នុងដំណាំនៅក្នុងវាល
បណ្តុះឱ្យបានទាន់ពេលវេលា។
ការប្រើប្រាស់ថ្នាំកសិកម្ម ជាជម្រើសចុងក្រោយបំផុត ត្រូវពិចារណាយ៉ាងយកចិត្តទុកដាក់មុនអ្នកបង្ហាញលេងជាមុនសិន
មុនមើលសម្រេចចិត្តយកថ្នាំកសិកម្ម។ ថ្នាំកសិកម្មដែលសមស្របសម្រាប់កំចាត់សត្វល្អិតទៀបមានដូចនេះ យើងអាច
ប្រើប្រាស់ថ្នាំទឹកប្រភេទ Cypermethrin ឬ Diazinon ក្នុងកំរិតប្រើ ១-១,៥លីត្រ ក្នុងមួយហិកតា លាយជាមួយទឹក
ចំនួន ៤០០-៥០០លីត្រ។ ការប្រមូលផលអាចប្រើបានវាងៗ បន្ទាប់ពីចាក់ថ្នាំហើយក្នុងរយៈពេល ៥-៧ ថ្ងៃ។
អភិរក្សដោយ : អគ្គនាយកដ្ឋានកសិកម្ម
អាសយដ្ឋាន ៥៤-៥៦ បុ ផ្លូវលេខ ៦២៦
សង្កាត់ ទឹកល្អក់ ពា ខ័ណ្ឌ ទួលគោក រាជធានីភ្នំពេញ
ទូរស័ព្ទ : ០២៣ ៨៨ ៥៤ ៣២/ ទូរសារ : ០២៣ ៨៨ ៣២ ៦៧
ជាមួយកម្មវិធី : HORT/2003/045: Improvement of vegetable production and postharvest management systems in Cambodia and Australia Project
Australian Government
Australian Centre for International Agricultural Research
NSW DEPARTMENT OF PRIMARY INDUSTRIES


ក្រសួងកសិកម្ម រុក្ខាប្រមាញ់ និងនេសាទ
អគ្គនាយកដ្ឋានកសិកម្ម
សត្វល្អិតចង្រៃលើដំណាំម្ទេចម្ទេះ
១. រុយស (Whitefly)
អាចសម្គាល់ឃើញ
កូនចៅមានស្លាស់ និងសត្វពេញវ័យ ចូចជញ្ជក់យកភ្នក្រសពីផ្នែកខាងក្រោមរបស់ស្លឹកម្ទេចម្ទេះ ដែលបណ្តាលឱ្យស្លឹកលេចឡើងចុះពណ៌ស្លាំង។ ប្តូរឱ្យស្លឹកប្រែទៅជាពណ៌លឿងជាដុំៗ ហើយងាប់។
វិធានការព្យាបាល
ចាស់ទឹកសាប៊ូដើម្បីកំចាត់រុយស។ ក្រដាសរឹងពណ៌លឿងដាក់ជាមួយសារធាតុប្រេងសឹត ហើយព្យួរនៅលើដើមរុក្ខជាតិ អាចនឹងចាក់ចាញ់សត្វពេញវ័យបានខ្លះនៅពេលយប់។ ត្រូវធ្វើការត្រួតពិនិត្យក្នុងដំណាំនៅក្នុងផ្ទាល់បណ្តុះឱ្យបានម៉ត់ចត់ជាប្រចាំ។
២. មមង់ឥស្រាក់ ឬទ្រីប (Thrip)
អាចសម្គាល់ឃើញ
កូនចៅមានស្លាស់ និងសត្វពេញវ័យ ចាក់បឺតជញ្ជក់យកភ្នក្រសពីត្រួយផ្កា និងស្លឹក ដែលបណ្តាលឱ្យវាក្លាយជាពណ៌ស្លេក ហើយវាក៏ជាភ្នាក់ងារចម្លងជម្ងឺវីរុស (Leaf Curl Virus) ដែលពេហោរ៉ា Transmitted insect។
វិធានការព្យាបាល
ប្រើផ្ទាំងស្លឹកដែលមានជាតិអាល្កុយមីក្នុងដី ត្របែលថ្នាលបន្ទាយដើម្បីបង្កើនប្រសិទ្ធិភាពមិនអាចជ្រាត និងរស់នៅបាន ព្រោះជើងរបស់កៅស៊ូអាចកាត់បន្ថយនូវវត្តមានរបស់វាបានយ៉ាងខ្លាំង។ ចាស់ទឹកសាប៊ូដែលមានកូនដូច ដើម្បីធ្វើការកំចាត់មមង់ជញ្ជក់។
៣. ដង្កូវចោះផ្លែ (Budworm)
អាចសម្គាល់ឃើញ
ដង្កូវចោះចំលុះធ្វើបង្គោះដោយប្រអប់មាត់ ហើយវាស៊ីបំផ្លាញផ្កាដំបូង ទៅលើពោត ផោតផ្លែ និងស្លឹក ត្រមាំងផ្លែសណ្តែកផងដែរ។ ជារការបង្កភាពីស្លឹតទៅលើដំណាំពោត និងសណ្តែកដែរ។
វិធានការព្យាបាល
ប្រើសារធាតុប្រេងម្យាំង ដើម្បីធ្វើការកំចាត់ដង្កូវចោះផ្លែ។ ថ្នាំពពួក Bacillus thuringiensis អាចបង្កជម្ងឺលើដង្កូវចោះផ្លែបណ្តាលឱ្យវាងាប់តែម្តង។ ការធ្វើអនាម័យចំការ បំផ្លាញប្រមូលស៊ីក្នុងរយៈពេល ៧-១០ថ្ងៃ ជាវិធីដ៏ល្អ ត្រមាំងផ្នាស់ប្តូរមុខដំណាំ។
៤. ដង្កូវកាត់ដើម (Cutworm)
អាចសម្គាល់ឃើញ
ដង្កូវរស់នៅក្នុងដីក្បែរគល់ម៉ដ្ឋចេះ វាស៊ីដើមម៉ដ្ឋចេះដែលដេរខ្ជិនដោយកាត់ដើមឱ្យរលំ។ វាមានសកម្មភាពស៊ីបំផ្លាញត្រួយស្លឹក និងផ្លែផងដែរ។
វិធានការព្យាបាល
ប្រើប្រាស់ក្រដាសរឹង ឬក្រដាសកាតុង ដាក់ជុំជិញ ដើម្បីការពារកូនម៉ដ្ឋចេះ។ ក្រោយពេលសូងកូនហើយ ត្រូវប្រើកៅស៊ូធ្វើស្លឹកដែលមានជាតិអាល្កុយមីក្នុងដាក់ជុំជិញដើមដើម្បីការពារកុំឱ្យដង្កូវស៊ីបាន។ ការប្រមូលស៊ីអាចសម្លាប់ពីការឡើងដង្កូវកាត់ដើមដែលយ៉ាងខ្លួនក្នុងដី។
៥. មែះម៉ដ្ឋចេះ (Aphid)
អាចសម្គាល់ឃើញ
ស្លឹកម៉ដ្ឋចេះដែលចូលរងការរាតត្បាតក្លាយទៅជាខ្ទះរួញមូល មែកគោងមូល ផ្កា និងក្រឹបជ្រុះតាមកាល។ ទៅកន្លែងរាតត្បាតវាបញ្ចេញទោលផ្សែងមកស្អិត។ ដែលបង្កើតឡើងនូវទិដ្ឋភាពគ្រិចសមស្របសម្រាប់ការលូតលាស់ពពួកផ្សិត។ ផ្នែកដែលចូលរងការរាតត្បាតបណ្តាលឱ្យក្រិន មិនលូតលាស់ មានសភាពជ្រីញជ្រួញក៏ពីកកំពក និងផុតបង់ណា។ ការបឺតជញ្ជក់យកភ្នក្រសរបស់សាច្រិតបណ្តាលឱ្យម៉ដ្ឋចេះចុះខ្សោយការលូតលាស់។ កូនម៉ដ្ឋចេះ ដែលរងការបំផ្លាញបណ្តាលឱ្យខ្ជះខ្ជយ បើរស់ក៏ចូលបានមិនផុលបានដែរ។
វិធានការព្យាបាល
ភ្ជួរដីឱ្យបានជ្រៅ សំអាតស្មៅ និងកំចេកចំទីរុក្ខជាតិ ក្រោយពេលប្រមូលផល។
៦. ដង្កូវស៊ុះស្លឹ (Leafminers)
អាចសម្គាល់ឃើញ
ស្លឹកត្រូវបំផ្លាញ មានការលេចឡើងជាបូបរាងបត់បែនដូចតំណូសដែនទី និងរីកកាន់តែធំទៅៗ។ ក្នុងករណីស្លឹកមានដង្កូវច្រើន សកម្មភាពស៊ីសំយោគត្រូវបានចុះ បន្ទាប់មកស្លឹកក៏ស្ងួតហើយជ្រុះ។ វាធ្វើអតីតធ្វើការបំផ្លាញស្លឹកពីក្រោមដោយឡើងទៅលើ។
វិធានការព្យាបាល
បេះស្លឹកណាដែលស៊ីបំផ្លាញធ្ងន់ដោយដុត ឬត្រាំឱ្យលុងក្នុងទឹក។
ចំនាន់ការកេះត្រួតសាស្ត្រ
ការការពារដំណាំដោយវិធីសាស្ត្រនេះ ផ្នែកលើចំនាក់ចង្កេះនៃអាំពើរវិញ្ញាណទៅមក រវាងរុក្ខជាតិ សត្វល្អិត និងមជ្ឈដ្ឋានរុក្ខជាតិជីវិញ។ វិធីសាស្ត្រនេះ ឃើងអាចបង្កលក្ខណៈមិនសមស្របមួយចំនួនដល់ការលូតលាស់ និងការបង្កើតរបស់សត្វល្អិតទន្លែ និងបង្កលក្ខណៈសមស្របដល់ការលូតលាស់របស់ដំណាំ និងសត្វមានប្រយោជន៍។ ការប្រមូលផ្តុំត្រូវ អាចសម្គាល់ដើមរឿងរបស់ដង្កូវកាត់ដើមដែលណាក់ខ្លួនក្នុងដី។ ការប្រមូលផ្តុំត្រូវបានឱ្យធានាច្រើនសារ និងលុនឱ្យធានាច្រើនសារ និងធានាសារពេលវេលាមួយរយៈ ការកាត់មែក និងកាត់ស្លឹករបស់ដើមម៉ដ្ឋចេះអាចជួយមិនឱ្យមានវត្តមានដង្កូវហួងកើនឡើងបាន។ ត្រូវធ្វើការត្រួតពិនិត្យក្នុងដំណាំនៅក្នុងរងឱ្យបានម៉ត់ចត់ជាប្រចាំ បើបង្ខែសជុតពីការបំផ្លាញរបស់ប្រសព។ គេអនុវត្តវិធានការក្បែត្រសាស្ត្រដ៏មានប្រសិទ្ធភាព ដើម្បីកំចាត់ដង្កូវស៊ីញ៉ែ ដូចជាការដុតស្មៅ ឬស្លឹកដែលជ្រុះក្រោយពេលប្រមូលផល និង ការបំផ្លាញចោលដូវតក្អកជាតិដែលដុះឯង ដែលជាជម្រកបស់សត្វល្អិតទន្លែ។
ការប្រើប្រាស់ថ្នាំកសិកម្មក្នុងការកំចាត់ជាដំបិសមុនក្រោយបំផុត ។ យើងអាចប្រើថ្នាំកប្រភេទ Abamectin ឬ Diazinon ក្នុងអ៊ីតប្រើ ១ - ១.៥ លីត្រ ក្នុងមួយហិកតា ដាយជាមួយទឹក ៤០០ - ៥០០ លីត្រ ។ ការប្រមូលផលអាចប្រព្រឹត្តទៅបាន បន្ទាប់ពីបានថ្នាំថ្នាក់ក្នុងរយៈពេល ៧ - ៩០ ថ្ងៃ ។
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