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Integrated crop management practices to enhance value chain outcomes for the mango industry in Pakistan and Australia

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Mango Research Station, Shujabad, Punjab

Mango Research Institute, Multan, Punjab

Bahauddin Zakariya University, Multan, Punjab

The Fruit and Vegetable Project, government of Punjab.

Sindh Agricultural University, Tandojam, Sindh

Agriculture Research Institute, Tandojam, Sindh

Sindh Horticulture Research Institute, Mirpur Khas, Sindh

Agriculture Training Institute, Sakrand, Sindh

Asim Agriculture Farm (AAF), Tando Allahyar, Sindh

Nestlé Limited

We acknowledge the many individuals from the above mentioned institutions who made the project successful. Project contributors are listed in table 10, Appendix 5.

2 Executive summary

The project, '***Integrated crop management practices to enhance value chain outcomes for the mango industry in Pakistan and Australia***' (HORT/1201/006) is the second phase of the mango production component of the Australia/Pakistan Agriculture Sector Linkage Program (ASLP). The project that ran from 1 October 2010 to 30 September 2015 and followed the ASLP Phase 1 project '***Development of integrated crop management practices to increase sustainable yield and quality of mangoes in Pakistan and Australia***' (HORT/2005/135).

The overall aim of the project was to enhance the profitability of small landholder mango growers in Pakistan by sustainably improving their yields and fruit quality through improved orchard production, pest and disease management. This was achieved by the coordinated engagement of over 30 researchers from 10 research and extension institutions with guidance from Australian researchers who worked with 41 smallholder mango grower clusters in villages across Punjab and Sindh to address several key issues in mango production that were having significant impact on the livelihood systems of the rural poor in Pakistan.

Mango yields were significantly increased between 111% and 204% in the first two seasons corresponding to an increase in net value of the crop between 11% and 130% (Average 65%) where best orchard management practices were adopted. These practices improved canopy management and the control of pests and diseases, resulting in higher returns to farmers. Much of the success of the best orchard management practices was due to improved canopy pruning and nutrition resulting from research undertaken on local mango cultivars.

Management of the tree killing disease 'Mango Sudden Death' that was identified in the first phase of ASLP was refined. A macro infusion technology to deliver fungicides in to the trunk of the tree was developed, tested and incorporated in to the disease management recommendations. Tree losses were reduced from up to 10% tree/year prior to the project to almost nil in orchards following ASLP project recommendations.

The epidemiology of another significant yield reducing disease 'Mango Malformation Disease' was investigated and ways of reducing its spread were identified after reviewing traditional nursery practices. Although it may not be possible to completely eradicate these diseases and pests from the Pakistan mango industry, they can be now be managed to minimize their impact on production and fruit quality.

'Gall Midges' were identified as a widespread pest of mango with over 80% of farms infested. Of these, 89% of the farmers were unaware of the problem and only 11% were actively managing the pest. Project research staff developed integrated monitoring and management practices to manage the pest that included timely irrigation and pesticide use.

Postharvest diseases in fruit from Pakistan domestic markets and from farms operating different management practices were identified and the pathogen species profiled to understand the effects of pre-harvest growing conditions on post-harvest rots. Improved postharvest fruit quality was seen in orchards in which the ASLP best orchard management practices were adopted.

The traditional nursery sector of the Pakistan mango industry was identified as the major source of disease spread to new orchards. Practices and protocols were developed to establish a modern clean nursery sector for the Pakistan mango industry including suitable potting media using locally available ingredients. During the project six new research nurseries and six new commercial nurseries were established that adopted best practice nursery management enabling them to grow high health grafted trees for sale in

half the time, with significantly lower rates of transplant loss, compared to traditional nurseries. Nursery practices were published in a joint citrus and mango nursery manual.

The project built capacity in the Pakistan research, extension and farming sectors of the mango industry. Prior to the project, there was poor collaboration between research institutions in the Government and University sectors and between Punjab and Sindh. By the end of the project research teams of University, Government and leading farmers were commonly collaborating on major issues in the Pakistan mango industry such as nursery development, orchard management and field diseases. The scientific capacity of project researchers was boosted through specialised discipline training, active attendance at conferences and symposia and international study tours.

The project provided extensive postgraduate training with eight PhD theses and 19 MSc (Hons) theses completed. For farmers, over 100 training events were held reaching 6233 participants to assist adoption of the orchard best management practice. Additional grower capacity was undertaken by other non ASLP projects sponsored by USAID, UNIDO and Pakistan governments.

Communication of the project outputs to both scientific, government and grower stakeholders was achieved by attendance of over 27 specialist Pakistani scientists at 5 international conferences and symposia, a range of grower oriented pamphlets in English and local languages, demonstration on 41 cluster sites across Pakistan, and 22 peer reviewed papers published.

All these achievements were made possible by the collaboration of 13 Pakistan research and training organisations being led by the Queensland Department of Agriculture and Fisheries and coordinated in Pakistan by the National Agricultural Research Centre, with Dr Iftikhar Ahmed, Chairman NARC as leader and Mr Faisal Fateh as the project coordinator. The other Pakistan project partners were:

Bahauddin Zakaraya University, Multan, Punjab

Mango Research Institute, Multan, Punjab

Mango Research Station, Shujabad, Punjab

Fatima Jinnah Women's University, Rawalpindi, Punjab

The Punjab Fruit and Vegetable Project, Punjab

Sindh Agricultural University, Tandojam, Sindh

Agricultural Research Institute, Tandojam, Sindh

Singh Horticultural Institute, Mirpur Khas, Sindh

The Agricultural Training Institute, Sakrand, Sindh

Asim Agricultural Farm, Tando Allahyar, Sindh

This project addressed 5 specific objectives:

Objective 1: To facilitate the establishment of "clean" mango nurseries and good tree husbandry so that high quality planting material would be widely available to the industry

Objective 2: To develop improved orchard management practices for the sustainable production of quality fruit for domestic and export markets.

Objective 3: To investigate and develop integrated strategies for the management of field diseases and pests affecting fruit productivity

Objective 4: To determine the prevalence and impact of postharvest diseases and develop management strategies to address them.

Objective 5: To facilitate the enhancement of extension and capacity building capabilities for the mango industry to improve value chain benefit flows.

3 Background

3.1 Justification

Pakistan is a strategically important country in which development challenges are considerable. It is ranked 146th of 187 countries in the 2013 UN Human Development Index, which estimates that more than one-fifth of the population live on less than US\$1.25 per day with limited access to basic services. Currently, two-thirds of people live in rural areas, with approximately 68% of rural households employed in agriculture and related enterprises. High-value horticultural crops such as mangoes are an important source of farm income for small and larger growers alike; however, crop management practices are often suboptimal and losses along the value chain are high.

Pakistan is an important global agricultural producer and increasingly a mango exporter. Recent annual statistics for mangoes indicate production has increased from 0.9 million tonnes in 1995-96 to around 1.75 million tonnes in 2008 from 166,223 ha (FAO STAT 2010), making mango one of the country's largest horticulture industries. Production has increased by 113 % from the 1.06 million tonnes recorded just four years previously (FAOSTAT 2010, COMSTAT 2010). See Table 1 and Table 2. Between 1999 and 2005, production had grown at c. 13 % per year. Between 2004 and 2005, production jumped by 37 % (corresponding to a 32 % jump in area harvested), and has subsequently grown at c. 4.5 % per year, corresponding to growth of 8.8 % per annum in area harvested. This reflects the increasing importance of the mango industry to Pakistan and suggests that production increases are mainly due to growth in planting area. Given the low productivity levels and the large post-harvest losses (around 40%); there is significant scope to increase the value of the mango industry throughout the value chain.

Table 1. Mango Statistics 2003-2009 for Pakistan (Area harvested, Yield, Production, Trade Value and Quantity)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Area harvested (000 ha)	102.79	103.11	151.54	156.57	171.98	166.22	na	na	na	na	na
Yield (t/ha)	10.06	10.24	11.05	11.20	10.44	10.55	10.15	10.62	10.98	95.55	96.83
Production (m t)	1.035	1.060	1.674	1.754	1.719	1.754	1728	1846	1888	1680	1659
Export volume (000 t)	60.44	82.06	48.86	105.60	62.06	69.32	73.58	85.92	105.13	101.16	98.93
Export Value (US\$ m)	21.90	23.61	27.67	16.66	29.28	26.79	33.18	na	na	na	na
Export Value (US\$ per t)	298.98	284.83	325.72	304.13	349.48	426.93	407.36	na	na	na	na

Source: FAOSTAT 2015 and COMSTAT, 2015.

Table 2. Provincial Mango Production Level (Area*in 000 hectares, Production**in 000 tonnes)

Province	*Area **production	2007-8	2008-9	2009-10	2010-11	2011-12	2012-13
Punjab	Area	112.3	112.4	112.3	111.9	111.4	109.1
	Production	1373.1	1324.9	1455.7	1503.2	1304.2	1280.2
Sindh	Area	52.1	55.8	59.5	59.2	60.1	60.4
	Production	368.1	390.5	379.0	381.3	391.8	396.1
Khyber Pakhtun Khwah	Area	0.40	0.40	0.50	0.30	0.30	0.30
	Production	4.0	4.0	3.90	2.90	2.90	3.0
Balochistan	Area	1.40	1.50	1.40	0.50	0.50	0.60
	Production	8.50	8.50	6.90	1.10	1.20	1.10
Pakistan	Area	166.2	170.1	173.70	171.90	172.40	170.40
	Production	1753.70	1727.90	1845.50	1888.50	1700.10	1680.40

Source: Fruit, Vegetable and Condiments Statistics of Pakistan (2012-13)

Many factors contribute to sub-optimal mango yields in Pakistan. Dust storms (52.2%) were the leading environmental factor damaging mango orchards. Major mango orchard diseases were also important including die back (48.9%) and malformation (34.5%). The major influences on grower incomes were less profit (41.1%) and less amount of production (36.7%). About 26.6% of small growers earned an income of 100,000-200,000 PKR and 47.8% growers earned 200,000-400,000 PKR. Mango losses greatly reduced grower's income, with 26.6% of growers facing losses of 20,000-25,000 PKR and 47.8% of growers 50,000-70,000 PKR annually. Due to these losses, 25.6% growers were facing difficulties of proper household management, 23.3% were troubled to fulfil domestic and social needs. As a result, 70% of growers had adopted alternative sources of income, with the chief source being personal business (49.3%) (Mohsin et al, 2014).

3.2 Key issues

Many researchable issues impact or limit the productivity and fruit quality of mango in Pakistan. Orchard productivity is severely limited by several diseases and pests, poor tree canopy management and poor understanding of orchard establishment, irrigation and nutrition management.

Disease management

The predominant mango diseases limiting productivity are mango sudden death (MSDS), estimated at an incidence of more than 30% in most production areas, (based on survey data from the initial scoping study under SRA HORT/2005/154, and mango malformation disease (MMD) caused by *Fusarium mangiferae* (Akhtar, 2006; Iqbal, et al., 2006). Significant pests include fruit flies (*Diptera tephritidae*) and the emerging pest problem mango midge (*Procontarinia* spp).

The causes of mango sudden death had not been identified prior to the inception of the ASLP 1 project (HORT/2005/153) and had remained a source of conjecture among researchers in Pakistan. Previously the pathogen *Lasiodiplodia theobromae* (Khanzada, et al., 2004) syn. *Botryodiplodia theobromae* (Akhtar, 2006) was suggested as the major pathogen responsible for this disease. Research from outside Pakistan, especially in



Figure 1. Mango tree killed by mango sudden death syndrome disease (MSDS)

Oman, had shown that the fungus *Ceratocystis manginecans* was involved in the syndrome (Van Wyk, et al. 2005; Al-Subhi, et al. 2006). From the initial scoping studies carried out in Pakistan (SRA/HORT/2005/154), the research team isolated *Ceratocystis* sp. from diseased samples from Punjab and Sindh orchards, reinforcing the findings of Malik et al (2005) that *C. fimbriata* or a related species was causing the disease. In follow-up research under ASLP 1 on the detection of MSDS, it

was clearly established that this fungus is playing a major role in the phenomenon of mango sudden death syndrome. At the beginning of this project (ASLP 2), effective management of mango sudden death had not been established although preliminary research into potential management options had begun in ASLP1.

Another production limiting fungal disease of importance to Pakistan is mango malformation disease (MMD) caused by *Fusarium mangiferae* (Akhtar, 2006; Iqbal, et al., 2006 and 2011). This disease affects both vegetative and floral growth of mango. In floral growth it deforms the flowers preventing them setting fruit and thus reducing yields. The disease is endophytic (living within the tissue of the mango trees) and cannot be eradicated once a tree has been infected. Much of the infection of Pakistan mango orchards with mango malformation disease occurs in the early growth of the tree, often when nursery trees are grown under the canopy of infected trees. Mango malformation has been found in over 14 different locations in Pakistan (Iqbal et al., 2006).

Pest management



Figure 2. Leaf galls caused by mango midges, *Diptera cecidomyiidae*

Mango midges, *Diptera cecidomyiidae* are significant pests of mango in Pakistan and other parts of the world (but not in Australia) and infestation can decrease yield by up to 65%. There are 16 known species of gall midges that infest mango throughout Asia. Midge symptoms include curling and drying of leaves, galling of leaves, shrivelling of new growth and fruit drop. At the beginning of this project (ASLP2) little was known of the different species of gall midges and their lifecycles in Pakistan making management of the pest difficult.

Orchard management



Figure 3. Traditional orchards that have never been pruned, exclude light and have low yields

The impact on productivity of poor canopy management is also a significant constraint to farm productivity and profitability. Little or no pruning of trees has caused long term yield decline due to poor flowering and insufficient light penetration through the outer canopy. Better tree management in conjunction with improved plant nutrition and irrigation linked to tree phenology cycles are critical components of an improved orchard management system. Research station trials were initiated during ASLP 1 to develop better management practices and to demonstrate to farmers that these practices can lead to increased productivity, quality and profitability.

Continued refinement of management practices and their integration as a management package for farmers was demonstrated in ASLP 2.

Nursery sector

Another major aspect of disease management is the production of nursery stock free of diseases such as mango malformation, sudden death and bacterial black spot. Nursery trees are generally produced by the private sector in Pakistan with little care for tree quality. Traditional mango nurseries operate well below best-practice and are contributing to low productivity in these industries. They frequently use poor quality, diseased propagating materials and plant these in local soils that are also infected with diseases that reduce tree health and lower tree productivity. Many traditional nurseries are responsible for spreading and perpetuating tree diseases such as mango malformation and for spreading infections to previously clean orchards.



Figure 4. Traditional mango Nurseries are grown under the canopy of orchard trees and are exposed to soil borne and areal diseases such as mango sudden death and mango malformation.

During ASLP phase 1, the need for clean nurseries was introduced to growers and selected commercial growers were trained on clean nursery propagation techniques. Activities under ASLP 2 have built on these achievements and spread the information to other small holder nurseries through new production manuals and more training sessions. Nursery stock transmission of malformation which was observed in high proportions in orchard nurseries during the scoping study, is also a critical disease issue that was addressed through the

establishment of clean nurseries during ASLP 2.

The continued persistence of the issues outlined above has been attributed to the existence of relatively few professional horticulturists, pathologists, entomologists and extension workers with a sound up-to-date knowledge of mango agronomy and associated disciplines to research and develop improved management practices for the Pakistan mango industry. This project has expended considerable effort into training professionals, semi-professionals, and extension workers on the latest science within their disciplines and in providing them with a scientific framework to work with each other and with farmers and private industry to solve issues. The project has also trained farmers, nursery operators and students on best practices developed during this and the previous project (HORT/2005/153) to assist the uptake of best practices by the small mango farmers of Pakistan.

Australian research - Dendritic Spot

Dendritic spot is a relatively new postharvest disease of mango that has emerged in Australia, in recent years. It was identified by more than 60% of growers in a 2007 survey as a major constraint to Australian mango industry development. The sporadic and unpredictable nature of this disease has resulted in a decrease in market confidence because the disease symptoms only manifest themselves as the fruit ripens, at which time nothing can be done to address the problem. A John Allwright Graduate Student Fellowship was secured to research dendritic spot disease to understand more about its causes and the conditions for spread of this disease.



Figure 5. Symptoms of Dendritic spot disease on ripening fruit

Australia has comparative strengths in horticulture in general and mangoes in particular. This spans the entire production system and supply chain. The value chain approach and integration of end-users in the planning, execution and evaluation of research, and development of effective strategies to engage and support less efficient and marginalised producers, are unique attributes that were used in Pakistan. The collaborative engagement around the production issues outlined above has provided significant opportunities to impact the productivity and efficiency of Pakistan mango value chains for poor farmers as well as medium and larger farmers. This project has capitalised on these strengths through direct linkages between the Australian and Pakistan research teams and the extension and mango agribusiness sector as well as targeting small-holder farmers, harvest contractors and marginalised sectors of the industry in a participatory mode with underpinning from HORT/2010/003 (Fostering Effective Collaboration and Strengthening Pro-Poor Benefit Flows) and linked to the activities of HORT/2010/001 (Mango Value Chains).

4 Objectives

The Pakistan-Australia Agriculture and Rural Development Strategy (PAARDS) for 2010-2014 provides the framework for strategic collaboration to improve livelihood systems for the rural poor in Pakistan. Under PAARDS, the Agricultural Sector Linkages Program (ASLP) Phase 2 was implemented through three components – Pro-Poor Value Chains, Agricultural Capability and Enabling Policy. This is in keeping with the overarching goal of PAARDS to improve livelihood systems for the rural poor in Pakistan. This project, HORT/2010/006 – *Integrated crop management practices to enhance value chain outcomes for the mango industry*, extended the collaboration and support initiated under the ASLP1 project HORT/2005/153 to smaller farmers to enhance pro-poor value chains for mango agri-enterprises in Pakistan. This approach complemented the efforts of another ASLP2 Mango project HORT/2010/001 (*Mango value chain improvement*) that also extended collaboration to smaller farmers to enhance pro-poor value chains for mango agri-enterprises in Pakistan.

This project (HORT/2005/153) focused on sustainable yield of high quality fruit through pre-harvest factors with the aim of “improving integrated crop management practices to enhance value chain outcomes for the mango industry in Pakistan and Australia”.

This project achieved this aim by establishing and spreading clean nurseries, developing integrated orchard and disease management approaches, improving the management of postharvest diseases and by building up the capacity to deliver on-farm research and extension within the mango industry. All of this contributed to enhanced benefit flows to the poor and marginalised. Analytical activities and staff exchanges were also an important learning component of the project.

The project had five sub objectives:

Objective 1: To facilitate the establishment and spread of “clean” mango nurseries and general good tree husbandry so that high quality planting material is widely available to the industry

Objective 1 activities:

- Assist in extending the model commercial nurseries to other commercial operators in different production districts using participatory and training of trainer (ToT) approaches.
- Identify, test and maintain cultivars with resistance or tolerance to different abiotic stresses.
- Source and evaluate dwarf and semi-dwarf germplasm for new orchard development and establishment.

Objective 2: To develop improved orchard management practices for the sustainable production of quality fruit for domestic and export markets.

Objective 2 activities:

- Evaluate the role of tree nutrition on fruit productivity, quality and disease severity.
- Continue with investigations on the role of canopy management through timed pruning on tree productivity and fruit quality.

Objective 3: To investigate and develop integrated strategies for the management of field diseases and pests affecting fruit productivity

Objective 3 activities

- Evaluate options for the integrated management of mango sudden death.

- Link to current projects to screen local and exotic germplasm for resistance to the sudden death pathogen.
- Review and investigate the epidemiology of the mango malformation disease and evaluate management options.
- Study the biology, determine the economic impact and investigate options for the management of the mango gall midge.

Objective 4: To determine the prevalence and impact of postharvest diseases and develop management strategies to address them.

This sub-objective was implemented in tandem with complementary activities under HORT/2010/001 (*Mango Value Chain Achievement*).

Objective 4 activities:

- Identify and characterise the major pathogens impacting on postharvest rots and the factors accelerating their development under Pakistani production and marketing conditions.
- Investigate field and postharvest management options to reduce postharvest rots.
- Study the epidemiology of dendritic spot under Australian conditions to enable the development of management options for the disease.

Objective 5: To facilitate the enhancement of extension and capacity building capabilities for the mango industry to improve value chain benefit flows.

Objective 5 activities:

- In collaboration with HORT/2010/003 identify case study options for poverty mapping and pro-poor benefit flow initiatives in mango production systems.
- Increase capacity of project teams to deliver training and develop information.
- Facilitate individual, short and long term training needs to enhance pro-poor integrated crop management research and extension.
- Develop pro-poor training programs and information resources for adoption on various aspects of mango production and postharvest handling.
- Investigate (with HORT/2010/003) the use of Web 2.0 technologies to deliver pro-poor training and information and facilitate project collaboration and co-ordination.

5 Methodology

5.1 Overview

The work in this project was primarily undertaken in the two main mango producing provinces of Pakistan, Punjab and Sindh. Some activities were also conducted in Pakistan's capital Islamabad and in Australia.

In Punjab research activities were centred on the extended Multan district where the project's partner research and extension institutions were based and where mango growing districts were made up of small to medium land holders. The institutions included the Mango Research Station at Shujabad, the Mango Research Institute in Multan and Bahauddin Zakaraya University in Multan. These partner institutions were also involved in the first phase of the ASLP mango production project.

In Sindh the research activities were centred on the Tandojam and Mirpurkhas districts where the Sindh Agricultural University, the Sindh Horticultural Research Institute and the Agricultural Research Institute are based. These areas also have some of the highest numbers of small to medium sized mango farms that are practising traditional orchard management. The project also worked with the Agricultural Research Training Institute in Sacrand, Sindh. These sites and institutions were chosen as they had research and extension staff already engaged with the mango growers of these districts.

Objective 1: To facilitate the establishment and spread of “clean” mango nurseries and general good tree husbandry so that high quality planting material is widely available to the industry.

Activity 1: Assist in extending the model commercial nurseries to other commercial operators in different production districts using participatory and training of trainer (ToT) approaches.

Nurseries established

Training in nursery technologies to new and existing traditional commercial nurseries occurred in both the Punjab and Sindh provinces as traditional mango nurseries are common in both provinces. Emphasis was placed on encouraging fully independent commercial nurseries to adopt the new technologies as demonstration businesses because they often had a more entrepreneurial business outlook and were prepared to manage the investment in new technology. A considerable lack of understanding of the principles behind containerised nursery production and nursery hygiene was recognised in both government and university research and teaching institutions. As such, emphasis was also placed on developing model nurseries at various research and teaching institutions, that were used as focal points for teaching and training. The eight nurseries which were established on research training institutes and the five commercial nurseries established using high health containerised technologies are listed in Table 3.

The earliest private commercial nursery established in this project was MAK Nursery at Sadiqabad in Punjab. This nursery has produced 40000 containerised grafted mango trees each year for over four years and has managed to get a premium price for their trees.

Refinement of mango potting media

This work was undertaken at the Mango Research Station, Shujabad by Mr Inam Ul Haq, Mr Abdul Ghaffar and Mr Muhammad Ikhlaq and in Sindh by Dr Noor un Nisa from Sindh Agricultural University and Mr Noor Muhammad Baloch at Sindh, Horticultural Research Institute. The aim of this research was to develop a soil-less medium that is suitable for growing mangoes in pots from locally available ingredients. The activity was undertaken by an experimental approach where mango seedlings were grown in 12 different combinations of media ingredients and their growth rates and the media physical and chemical properties recorded to determine the most suitable potting media. Two sites were chosen to conduct the media development as ingredients such as sand differ between sites. Also the process of developing and testing a range of mango potting media served as a training opportunity for academics and students that were not familiar with the discipline of potting media.

Joint Citrus and Mango Pakistan Nursery Manual

The Nursery manual was a joint activity between this project and the ASLP 2 Citrus project (HORT/2010/002). The aim of the manual was to provide a detailed operational guide for mango and citrus nursery growers, researchers, and extension workers in Pakistan. The manual was written and edited by Australian team members (Dr Nerida Donovan, Dr Ian Bally, Mr Tony Cooke and Mrs Susan House) with input from the Pakistan project teams. Pakistan inputs included latest information from Pakistan research, photos depicting nursery activities in Pakistan and editing of drafts to improve suitability for Pakistan nurserymen. The manual will become a reference authority for developing training curriculum and extension literature for the Nursery sector as well as a how-to guide for nursery operators wishing to produce clean, true-to-type containerised mango trees for the citrus and mango sectors.

Training of nursery sector scientists, extension workers and growers

Training of people in all sectors of the mango nursery sector was a significant part of this project and was undertaken at many levels, including:

Nursery training in Australia– Training was a joint activity between the Mango and Citrus components of the ASLP2 program. It was conducted between 1 and 12 November 2012 with the aim of developing skills in Pakistani personnel in the establishment and management of high health containerised nurseries. The training was sponsored by the Agricultural Capability Support fund for the Australia Pakistan Agricultural Sector Linkage program and coordinated by Dr Ian Bally, Queensland Department of Agriculture and Dr Nerida Donovan of NSW Department of Primary Industries. Placements were conducted at Victoria Citrus Nursery in the Sunraysia district and Birdwood nursery in south east Queensland district.

Four citrus nurserymen, two mango nurserymen and one mango advisory horticulturist undertook the nursery training. A mango nursery researcher who could not get a visa in time for the training was trained at a later date (12 to 27 May 2013). The training consisted of a two-day introductory workshop in Sydney followed by a week placement at Victoria Citrus Nursery and a week at Birdwood Nursery for practical hands-on training of nursery day-to-day operations. After the hands-on training the trainees travelled back to Sydney for a debriefing workshop before travelling back to Pakistan. An additional 8 Pakistani delegates from this project attended the International Horticultural Congress in Brisbane in August 2014 where they participated in a pre-congress nursery training activity organised in conjunction with the Crawford Fund, ACIAR and the IHC.

Nursery training workshops in Pakistan – Nursery training seminars and workshops were conducted for the nursery sectors in Punjab and Sindh throughout the project. The seminars aimed to inform the nursery sector of the disease and quality issues of current traditional nursery technologies, the benefits of improved nursery management and new management techniques. The seminars have predominantly been run by the Pakistan

project officers with some guest seminars from Australian project staff during their Pakistan visits. In the Punjab, the nursery training was coordinated by Prof. Dr Nazim Labar Husain from Bahauddin Zakariya University in Multan. In the Sindh, the training was coordinated by Dr Kazi Memon and Mr Ismail Kumbhar, Assistant Professor of Sindh Agricultural University.

Nursery plant nutrition

Separate experiments were conducted at the Mango Research Station in Shujubad and at the Sindh Agricultural University to determine the best form of nutrition for nursery grown mango trees. Experiments were conducted to investigate different combinations of nutrients at different rates and application methods to determine which combination resulted in highest plant growth.

Nursery grafting

The best grafting techniques for mangoes grown in containers in plant houses were evaluated by Mrs Humara Inam at the Mango Research Station in Shujubad and by Dr Noor un Nissa at Sind Agricultural University. This was done by experimental comparison between the common Pakistan methods and several methods used in other countries.

Activity 1.2. Identify, test and maintain cultivars with resistance or tolerance to different abiotic stresses.

And

Activity 1.3. Source and evaluate dwarf and semi-dwarf germplasm for orchard new development and establishment

Local and imported polyembryonic germplasm evaluated

This activity was divided into separate activities in Punjab and in Sindh. At the Sindh Agricultural University, a PhD student Mr Rasool Bux Khaskhely and his supervisor Dr Inaytuallah Rajpar conducted a series of experiments with the aim of

- i) identifying salinity tolerance through a systematic evaluation of mango seedlings,
- ii) developing a salinity tolerance assay for mango based on shoot and root growth responses to salts and
- iii) testing the compatibility of mango scions with identified salinity tolerant cultivars as commercial rootstock.

The experiments were conducted as field experiments using natural saline conditions.

Mr Abdul Ghaffar Grewal had been evaluating 48 polyembryonic varieties that were imported from Australia in ASLP 1 at the Mango Research Station in Shujubad. The purpose for importing these mango varieties was to establish a genebank of polyembryonic cultivars with potential for becoming rootstocks for Pakistan varieties. The current rootstocks used in Pakistan are monoembryonic, 'desi' varieties which are not genetically uniform and do not have any particular biologic or abiotic stress tolerances. Fourteen of the imported varieties died during the acclimatising process leaving 29 varieties for testing. The trees have been grown in the field on the research station and were evaluated for their growth characteristics. Seeds from some of these trees were distributed to other project partners for salinity research and to develop further copies of the genebank.

Objective 2: To develop improved orchard management practices for the sustainable production of quality fruit for domestic and export markets

Activity 2.1 and 2.2. Evaluate the roles of canopy management through timed pruning and of tree nutrition on tree productivity and quality

Evaluation of pruning techniques and timing of mango trees in Pakistan was undertaken at the Mango Research Station in Shujabad, by Mr Abdul Ghaffar Grewal. The work was undertaken as experimental research on 'Chaunsa Sammar Bahisht', the dominant mango variety of the Punjab (37% of the area). Similar experiments were conducted in the Sindh Horticultural Research Institute at Mirpurkhas by Dr Atta Soomro. This work was started in ASLP 1 and continued in ASLP 2 to integrate pruning, nitrogen and growth regulator applications. Results from this experiment and earlier experiments were incorporated in to the ASLP best mango orchard management recommendations that were demonstrated on farms, incorporated into training packages and were integral to developing the codes of practice and training courses produced by other aid organisations such as USAID and UNIDO.

Orchard management techniques extended to model orchards across districts and adoption of techniques by small holders.

Improved orchard management techniques were extended to 12 Pakistan mango growing districts through farm demonstrations, and farmer training sessions on the demonstration farms. This was achieved by including project personnel in the farm activities. The project employed a project officer in Punjab and in Sindh to coordinate and organise demonstration and training activities. Implementation of on farm management was the responsibility of the project officers who collaborated with discipline experts brought in to demonstrate specific orchard management practices to farmers on the demonstration farms at the specific stage of the cropping cycle they were needed. This approach led to the correct implementation of the ASLP orchard management practices, provided training for farmers in the vicinity of the demonstration farms and provided an opportunity for farmers to talk with the research experts advocating the changes.

Activity 2.3. Recommendation on improved nitrogen fertiliser applications to maintain canopy health and maintain fruit quality.

Mango orchard nutritional status.

A survey of mango orchard nutrition was undertaken in Sindh by Dr Mehrun un Nisa of the Sindh Agricultural University. This survey sampled ASLP Best orchard management demonstration sites and surrounding traditional farms for macro and micronutrient concentrations in different districts of Sindh.

Activity 2.4. Improve Irrigation efficiency

Optimum of soil moisture levels in the root zone at different stages of mango growth.

Investigations for improved irrigation efficiency were undertaken at several stages of the project. The first approach was to improve the soil management within mango orchards by ceasing under tree cultivation and building bund walls within the orchard to direct water to trees and away from inter row spaces. The second approach was undertaken by Mr Muhammad Ikhtlaq, Assistant Horticulturist, Mango Research Station at Shujabad, who conducted a replicated field experiment to standardise the water requirement under each phenological stage of mango development in the cultivar "Sindhri". This research looked at saving water by irrigating at a set and optimal level of soil moisture in the orchard.

Objective 3: To investigate and develop integrated strategies for the management of field diseases and pests affecting fruit productivity.

Activity 3.1. Evaluate options for the integrated management of mango sudden death (PC)

Identify all control options for the disease, developed from ASLP-1 and National Project on Etiology and Management of MSD.

Control options were identified through research activities undertaken in the Phase 1 project and through monitoring of the international literature.

Evaluate other options such as efficacy of more systemic fungicides, natural plant extracts and plant activators.

Replicated field experiments were used to evaluate systemic fungicide management options for the control of mango sudden death disease. Separate experiments were conducted in Punjab and Sindh. In Punjab Mr Muhammad Tariq Malik of the Mango Research Institute in Multan undertook the research. In Sindh, Mr Leemon Kumar of the Agricultural Research Institute, Tandojam, undertook the research. In both regions the experiments were conducted on farmers' orchards and served as demonstration and training sites for disease management.

Assemble the effective options into integrated packages and evaluate in selected model farm across the production region including brochures.

Effective management options were assembled and added to the ASLP Mango Orchard Best Management Guide. Mango sudden death management practices were implemented in the selected model farm clusters in Multan, Muzaffargarh, Rahim Yar Khan, and Khanewala. Brochures on the causes and management of MSD were initially developed in ASLP Phase 1. These were improved and others developed for small holders in local languages. These brochures were distributed among growers.

Activity 3.2. Screen local and exotic germplasm for resistance to the sudden death pathogen (PC)

3.2.1. Source resistance from local germplasm identified through linked projects

Mr Muhammad Tariq Malik and Mr Muhannad Ammar of the Mango Research Institute in Multan undertook two pathology screening experiments to identify any mango varieties with resistance or tolerance to MSD. An *in-vitro* mycotoxin method and an *in-vivo* stem inoculation method were used. The *in-vitro* mycotoxin method was not found to be reliable and will need refining before the technique can be applied.

2.2.2. Undertake the molecular characterisation of strains of *Ceratocystis* spp. affecting mangoes in Pakistan

Mr Leemon Kumar, of the Agricultural Research Institute, Tandojam, Sindh undertook a study of mango sudden death in Sindh mango orchards. He collected 21 isolates of the mango sudden death causal pathogen *Ceratocystis fimbriata* for genetic identification by Dr Shazia Iftkhar, Associate Professor Department of Environmental Sciences of Fatima Jinnah Women's University, Rawalpindi. A series of aggressiveness experiments were conducted on 18 month old potted trees using disease isolates from Punjab and Sindh. Trees were infected using a flap inoculation method and disease responses recorded for 45 days. Dr Shazia used molecular markers to identify each of the pathogen isolates.

3.2.3. Links established with external collaborators to tap from their findings

Links with external collaborators were not developed formally in the project however several informal opportunities arose for linkages with external parties during the project. These occurred when Pakistan scientists attended training, conferences and symposia.

Activity 3.3. Review and investigate the epidemiology of the mango malformation disease and evaluate management options (PC)

3.3.1. Review the mango malformation literature conducted in Pakistan and elsewhere

A review of the epidemiology of mango malformation disease was written using Pakistan and International literature by Mr. Muhammad Tariq Malik of the Mango Research Institute, Multan.

3.3.2. Investigate the epidemiology of the mango malformation and possible management options explored

An experiment was conducted to monitor the inoculum of mango malformation disease in traditional and improved orchards. It aimed to evaluate different management strategies in improved and traditional orchards, to determine distant dispersal of spores, to monitor the inoculum load in different mango phenological phases, to correlate spore dispersal with climatic factors, and to develop a disease prediction model.

A survey of the incidence and severity mango malformation disease was undertaken of mango growing districts in Punjab and Sindh by Mr Muhammad Tariq Malik of the Mango Research Institute, Multan and Mr Leemon Kumar, Agricultural Research Institute, Tandojam. Twenty one Isolates of *Fusarium spp.* collected during the survey were characterised using molecular markers by Dr Shazia Iftkhar, Associate Professor Department of Environmental Sciences of Fatima Jinnah Women's University, Rawalpindi.

3.3.3. Assess the role of current nursery practices on the spread of mango malformation disease and recommend ways of reducing its spread

With the knowledge of the epidemiology of mango malformation disease Pakistan and Australian pathologists examined traditional nursery practices and developed several management practices to overcome some of the disease infection pathways. Recommended nursery management practices to reduce the risk of spreading the disease have been incorporated into the Mango and Citrus Nursery Manual and into all nursery training and extension literature.

Activity 3.4. Study the biology and determine the economic impact of gall midge (cecidid flies) (PC)

3.4.1. Identify the species prevalent in mango orchards in Pakistan and compare with species from other countries of interest such as the Philippines

Surveys of mango orchards throughout the year were used to collect gall midges and to attribute the damage they cause. Identification of the different species of gall midges was undertaken by Dr Shafqat Saeed of Bahauddin Zakaraya University, Multan in consultation with Dr Ian Newton, Department of Agriculture and Fisheries, Mareeba.

3.4.2. Link up with the Philippines project (HORT/2007/067/4) on the biology and ecology of the mango gall midge.

Linkages between the Pakistan and Philippines ACIAR project activities on the biology and ecology of mango gall midge was initially organised by Dr Ian Newton, Department of Agriculture and Fisheries, Mareeba, the Australian entomologist who was active in both projects. Linkages between the groups were strengthened when entomologists from the Philippines and Pakistan attended the International Midge Conference held in south-east Queensland, Australia in 2013 with support from the Crawford Fund in Australia. After this

meeting, midge samples were shared between the Pakistan and Philippines team for identification.

3.4.3. Evaluate the economic impact of gall midge on mango productivity across locations.

Evaluation of the economic impact of gall midges on mango farms was undertaken by Dr Shafqat Saeed, Bahauddin Zakayara University. Dr Shafqat undertook a survey of 28 mango orchards in different districts of the Punjab. Gall midge losses were recorded based on the galls on leaves.

3.4.4. Examine integrated options for managing the pest if shown to have a significant impact on productivity, with a linked national project on the pest.

Potential integrated management options were examined for their suitability by experimental application within mango orchards as individual techniques and then integrated with current best practice management recommendations.

Activity 3.5. Study the factors affecting occurrence and prevalence of mango stem end rots (A)

Activity 3.6. Study the epidemiology of Dendritic spots of mango – Field development focus (A)

The fungi which cause anthracnose and stem end rot such as *Colletotrichum gloeosporioides* and *Neofusicoccum parvum* are also responsible for causing the dendritic spot of mango. However, a number of other fungi such as *Fusicoccum sp.*, *Alternaria sp.* and *Lasiodiplodia theobromae* have also been isolated from the dendritic spot symptoms from time to time. The isolates of different dendritic spot fungi were also tested by pathogenicity test. Market surveys were carried out to collect the dendritic spot, stem end rot and anthracnose pathogens. The purpose of this activity was to determine the geographical distribution of the dendritic spot pathogens. The fruit from Northern Territory, north Queensland and southeast Queensland was collected and isolations were carried out from the diseased fruit. All the *Colletotrichum* isolates collected from anthracnose were identified as *C. gloeosporioides* but different species of *Colletotrichum* such as *C. gloeosporioides*, *C. tropicale* and *C. asianum* and *N. parvum* were identified by using the Internal Transcribed Spacer (ITS) and Trans elongation Factor (TEF) 1- α .

The fruit bagging experiments were carried out on Kensington Pride (KP) and R2E2 cultivars of mango. The fruit of these cultivars were bagged at four different growth stages. The results of this study showed that the fruit which were bagged at the very early stage of growth and then remained bagged throughout the season until harvest resulted in low incidence of dendritic spot and stem end rot.

The effect of conventional and improved orchard practices on the management of anthracnose and stem end rot was also studied. The experiment was carried out in Pakistan. Three districts of Punjab province of Pakistan were selected for the study. The fruit of 'Chaunsa' cultivar of mango were collected from farmers' conventional practices block and ASLP improved practices block.

Activity 3.7. Extend pest and disease management recommendations to growers (PC)

Pest and disease management results were extended to growers using a similar approach for the delivery of other orchard management and nursery information. This consisted of information pamphlets on the specific diseases and pests with recommendations, through

training events scheduled around the phenological stage of the crop where the pests and disease occur, and through visits by ASLP staff to farms.

Objective 4: To determine the prevalence and impact of postharvest diseases and develop management strategies to address them.

Activity 4.1. Identify and characterise the major pathogens of postharvest rots and determine the factors accelerating the development of these losses (PC)

4.1.1. Determine the likely causes of fruit diseases in domestic and export market fruit.

The causes of the common post-harvest mango diseases occurring in Pakistan's markets was studied by Dr Shazia Iftikhar of Fatima Jinnah Women's University, Rawalpindi. The studies surveyed Pakistan's domestic city markets for diseased mango fruit and then used laboratory isolation, growth and identification of the pathogens associated with disease symptoms from each market. The studies also looked at the difference in virulence between isolates of each disease and mango varieties susceptibility the disease pathogens. In the third year of these studies, molecular identification of the mango disease pathogens was also undertaken in the laboratory of Dr Shazia Iftikhar.

4.1.2. Evaluate other options such as efficacy of more systemic fungicides, natural plant extracts and plant activators.

Evaluation of the efficacy of systemic fungicides on postharvest rots was not undertaken in this project. Investigations of natural plant extracts and botanicals against postharvest diseases was undertaken in the laboratory by testing the toxic effects of several leaf extracts on postharvest pathogens in petri dishes in the laboratory.

In Australia, experimental evaluation of several fungicides for their ability to control stem-end-rot rot (*Neofusicoccum parvum* and *Lasiodiplodia theobromae*) and anthracnose (*Colletotrichum gloeosporioides*) were tested over two seasons (2013/14 and 2014/15) on the mango cultivars Kensington Pride and Keitt. Four fungicide treatments (i) fludioxonil (Scholar®), (ii) azoxystrobin (Amistar®) and (iii) fludioxonil + azoxystrobin (Graduate +)) applied as a hot (52°C) or ambient dip while (iv) prochloraz (Sportak®) was only applied as an ambient treatment. Check treatments were also included: untreated, ambient water and hot water treatment. Following treatment, fruit were ripened at 24°C and assessed for disease development (% area infected) and ripeness. The work was done at the Mareeba DAF site using a purpose built dipping tank for the chemical treatments. Personnel involved in the trials were: Mr Tony Cooke, DAF, Brisbane, Mr Peter Trevorrow, DAF, Mareeba and Ms Kathy Grice DAF, Mareeba. Data were statistically analysed using ANOVA by Mareeba based biometrician Dr Carole Wright, DAF.

Activity 4.2. Investigate field management and postharvest options to reduce postharvest rots (PC&A).

Surveys of fruit and postharvest rots were undertaken in orchards practising both traditional and the ASLP mango best management practices in Punjab and Sindh, by the projects field officers Mr Muhammad Asif Arif and Mr Gul Bahar Pusiod. Diseases were identified and numerated by Dr Shazia Iftikhar.

Activity 4.3. Study the epidemiology of dendritic spots of mangoes – postharvest focus (A)

The epidemiology of the postharvest disease dendritic spot was studied by Ms Arslan Quershī as part of her PhD research undertaken through the University of Queensland and supervised by Dr Victor Galea.

Objective 5: Increase extension and capacity building capabilities in the mango industry to improve value chain benefit flows.

Activity 5.1. Increase capacity of the project team and extension group to deliver training and develop information and to understand and extend poverty mapping and benefit flows (PC) (with HORT/2010/003).

Methods to increase the capacity of the project team to deliver information were achieved through a series of specialised training activities.

5.1.1. Identify individuals to become trainers of wider extension group

Partner-country organisations in the Punjab and Sindh regions were screened, with a total of 50 Field Assistants and 150 Agriculture Extension Officers identified for extension training activities.

5.1.2. Conduct skills audit and prioritise areas for capacity building

A skills audit of the project team and extension group was conducted with the following priority training areas identified: canopy management, budding and grafting and identification of field diseases of mango.

5.1.3. Set up and evaluate a curriculum of individuals, project team and the wider extension group in the development and delivery of extension training programs

A mango curriculum development workshop was organised at Multan, with 40 participants including, 20 extension workers from provincial governments, 15 researchers from institutes/universities and five progressive growers. The outcome was the identification and development of a series of best orchard management practice guidelines.

Training of Field Assistants and Agriculture Extension Officers was undertaken in the Punjab via the In-Service Agriculture Training Institute (IATI) Rahim Yar Khan. In the Sindh training was undertaken via the Agriculture Research Institute, Tandojam and the Agriculture Training Institute (ATI), Sakrand. More than 50 Field Assistants and 150 Agriculture Extension Officers were trained and have benefitted from these training activities that have focused mainly on canopy management, budding and grafting and identification of field diseases of mango.

5.1.4. Deliver specialised extension training to project officers in Pakistan

Specialised extension training was delivered to project officers in Pakistan on several occasions:

Dr Greg Johnson organised a workshop on the diagnosis and management of mango postharvest diseases, at the National Agricultural Research Council (NARC) in Islamabad on 26-28 August 2012. The workshop had 24 participants from 10 research institutions in Pakistan. This workshop provided speciality skills to pathologists and other postharvest researchers on disease identification and control.

Dr Bally gave specialised training to nurserymen and nursery staff on grafting methods at MAK Nursery, Rahim yak khan, Punjab.

Mr Mathew Weinert, Extension Officer, DAF and Jenny Metcalfe (E Connect, a private Extension Services Consultant), coordinated and delivered a four day intensive communication skills workshop held at the Pearl Continental Hotel Bhurban, Punjab between 28 September to 1 October. This workshop was supported by the ASLP agricultural communication fund as a program-wide activity that involved 27 personnel from the ASLP Mango production, Mango Value Chain, Citrus, Dairy and Social projects. 2014. The training workshop “Presenting Science” taught the core knowledge and skills required for communicating science and technology to a range of audience types.

Dr Geoff Dickinson, Extension Officer DAF (who replaced Mr Weinert in early 2015) met with ASLP research and extension at locations including Islamabad, Bhurban, Multan and TandoJam from the 23/08/15 – 07/09/15. Dr Dickinson delivered an extension training workshop at the Bahauddin Zakariya University, Multan, Punjab State. Attendees included 35 agricultural extension and research personnel from the Punjab State Provincial Extension service and Bahauddin Zakariya University, as well as some key growers. The workshop was titled “Mango Communication Technology” and included latest trends in the electronic delivery of information and training packages.

Activity 5.2. Facilitate individual, short and long term training needs to deliver project outcomes (PC) (with HORT/2010/003)

5.2.1. Review training needs in areas of mango production and extension to reduce poverty

A skills audit of the project team and extension group was conducted in early 2012 with the following priority training areas identified: canopy management, budding and grafting and identification of field diseases of mango. Nursery hygiene and the management of containerised stock was identified as another high priority.

5.2.2. Prioritise training needs and facilitate through individual and group formal and informal programs. Including graduate degree, certificate and short courses

Project team and extension group individuals undertook field training within the priority training areas of canopy management, budding and grafting and identification of field diseases of mango.

Activity 5.3. Develop training programs and information resources for adoption of integrated mango crop management, harvest and post-harvest handling.

5.3.1. Document extension and capacity building information supply within the mango industry including individuals and organisations and their rolls

Over the life of the project, advisory and information literature for developed for growers. The list of trainings, pamphlets, seminar, numbers of farmers trained are in Appendix 3.

5.3.2. Review and prioritise training activities and information based on outcomes from the production and postharvest research activities.

Training activities prioritised and organised on the basis of the ASLP Best Orchard Management Practice Protocols.

5.3.3. Collaboratively develop training programs and information resources to be delivered by trainers from 5.1

Training programs were developed in Sindh and in Punjab by the focal people in each state and using discipline experts associated with the project.

5.3.4. Establish Farmer facilitation services using participatory approaches in conjunction with the Fruit and Vegetable Development project.

This activity was not undertaken by the project as Mr Khalid Chauhdary, director of the fruit and vegetable project was moved from the fruit and vegetable project to several other institutions.

5.3.5. Use ongoing projects to strengthen week extension links through positioning of local champions

Appointed Mr Khalid Chauhdary as ASLP Extension Focal person, however, after becoming Director extension Punjab, his time on the ASLP project was limited.

- Appointed Professor Nazim Labar Hussain as nursery coordinator in Punjab.
- Appointed Mr Yousaf Channa as Extension Focal Person in Sakrand, Sindh
- Appointed Dr Kazi Sulamon Memon, SAU as Focal Person to coordinate research and extension in Sindh, when he retired Mr Ismail Kumbar was appointed in the roll.

5.3.6. Train groups of farmers in orchard management

Many groups of farmers were trained throughout the project in farmer field schools associated with the ASLP best orchard management practice demonstration cluster groups.

5.3.7. Develop written and video materials for Pakistan Extension Services

During the final year of the project regular radio and internet broadcasts for farmers on ASLP best practice in mango orchards and in nurseries were conducted – by Nazim L. Hussain. All extension activities were directed towards both growers and a broader audience including provincial extension officers, nurserymen, contractors etc. and are listed in Appendix 3.

No video materials were produced for Pakistan due to the resignation of the Australian extension personnel and replacement staff not appointed until the end of the project.

5.3.8. Develop mango picking video and mango problem solver App for the Australian industry.

The video “Mango Picking – How to do it right” was completed in November 2013 and loaded to YouTube for public access. The video has been viewed over 1500 times (01/11/2015). The video has also been used as a communication tool for grower extension activities in Australia and Pakistan.

An updated “Mango pests, beneficials, diseases and disorders field guide” was developed in collaboration with the NTDPIF, for Australian mango growers in October 2015. The guide will be released electronically and is currently being reformatted for upload to the NTDPIF website.

Activity 5.4. Investigate the use of Web 2.0 technologies to deliver training and information

5.4.1. Develop an interactive project website using Web 2.0 technologies and train project team in their use.

Feedback from Australian mango growers at industry workshops in 2012 and 2013, was that many Web 2.0 technologies (blogs, grower facebook or other social networking sites and apps) had very little use by growers at present and that generally growers were unlikely to utilise these technologies in the near future. A similar, if not greater negative response was measured from the Pakistan mango growers.

5.4.2. Identify and develop information resources for development using Web 2.0 and multi media

Lack of industry support for Web2.0 resources, resulted in a refocused approach to adapt and enhancing other web based information resources. Feedback from Australian mango growers at industry workshops in 2012 and 2013 identified that a “One-stop website” for grower information, preferably based on the Australian Mango Industry Association website would be the most desirable electronic information delivery tool. The development of videos on mango management systems was considered a high priority for the Australian and Pakistan mango growers.

5.4.3. Set up and evaluate online training packages for trainers, growers, and the wider mango industries in Pakistan and Australia.

In Australia a “One-stop website” for grower information, located on the Australian Mango Industry Association website was developed throughout 2012 and 2013. Many useful mango extension resources were uploaded to the AMIA website over this time. A complete redesign of the AMIA website in early 2014, resulted in a loss of much of this information, but these have been progressively reloaded throughout 2015. Current training packages include pest and disease, nutrition management, picking, packing and post-harvest management. In Pakistan this activity was not undertaken as emphasis was placed on training on farms.

5.4.4. Evaluate the effectiveness of Web2.0 for information use and online learning to develop generic guidelines.

In Australia Web 2.0 technologies have slowly gained some uptake by the mango industry. The AMIA Aussie Mangoes Facebook site is primarily a consumer site, but does have some very minor grower content. The site has 52,000 followers (1/12/15). The Aussie Mangoes Facebook site also has links to content on Instagram and YouTube.

6 Achievements against activities and outputs/milestones

Objective 1: To facilitate the establishment and spread of “clean” mango nurseries and general good tree husbandry so that high quality planting material is widely available to the industry

outputs/ milestones	Date due	date complete	Comments
Activity 1.1 Assist in extending the model commercial nurseries to other commercial operators in different production districts using participatory and training of trainer (ToT) approaches.			
Development of nursery technologies			Potting media experiments initiated in Phase 1 were continued into phase 2 (this project) with a recommendation for a suitable potting media for Mango as 65% bagasse, 30% silt, 5% coir and fortnightly sprays of 2% NPK mix.
Extend model nurseries to commercial operators.			By September 2015 there were 5 private nurseries producing containerised mango plants using ASLP methodologies producing more than 35,000 trees/yr. The number of trees is expected to increase in the coming year. One of these nurseries is producing nursery trees exclusively for their own farm and for export to UAE.
Distribute completed nursery manual to all production districts and make freely available through the internet	Initially Y1 M6 2014 -15 Project extension Y5 M12	August 2015	The Pakistan Mango nursery manual was a joint activity with the ASLP 2 Citrus project. The delayed completion was due to changes in Australian project staff and its complexity. The nursery manual reflects Pakistan research undertaken in this project on potting media and international standard practices for clean nurseries management. The nursery manual was launched by the Pakistan Federal Minister for Food Security, Mr Bosan on the 29th August 2015 at Bahauddin Zakaraya University, Multan. The joint citrus and mango nursery manual was distributed to all project teams as hard copies and to extension departments, nurseries and farmers as PDF electronic version. An electronic version is available for download from the National Agricultural Research Council (NARC) website. The manual is also being reformatted as an ACIAR Publication and will be available through ACIAR publications. This manual will provide information of mango and citrus nursery practices on which pamphlets and seminars and practical training can be based. Several extension pamphlets have been developed using materials and content from the Nursery manual or from other Australian training. These extension pamphlets are listed in Appendix 1.
Activity 1.2 Identify, test and maintain cultivars with resistance or tolerance to different abiotic stresses.			
Local and imported polyembryonic germplasm evaluated	Y1 M12	2015	Sindh Agricultural University PhD student Mr Rasool Bux Khaskhely and Dr Inaytuallah Rajpar of Sindh Agricultural University have found several local rootstock varieties with partial salinity tolerance and the imported variety 13-1 was highly tolerant to saline soils in some stock scion combinations. The PhD thesis is in the process of being written up. Summary of results: <ul style="list-style-type: none"> No local varieties survived in EC 9 dSm⁻¹, except for the imported cultivar “13-1”. At lower EC’s of 3 dSm⁻¹ or medium 6 dSm⁻¹ grafted Sindhri & Fajri survived and performed well. Among indigenous (desi) varieties, rootstock of Meho & Sheedi were found to be tolerant to low & medium salinity; whereas the other three varieties (Totapuri, Khatmithro and Sawro) were found to be sensitive to medium salinity levels. Scions of variety “Sindhri” performed well on all tolerant rootstocks

			<p>45 local mango varieties were evaluated at the mango research station in Shujabad for their seed embryony to determine if they were suitable as rootstocks. All 45 varieties were monyembryonic in mature and would not make true-to-type rootstocks.</p> <p>43 polyembryonic varieties were imported from Australia in ASLP phase 1. Of these 14 died, during the acclimatising process leaving 29 varieties for testing. Establishing the imported trees to the point where they are cropping has taken longer than expected and as such much of the evaluation of material has been delayed.</p> <p>By 2015, 29 of the introduced surviving varieties are growing well in the gene bank of MRS Shujabad, Punjab. 11 of these varieties have cropped by end of 2015 and will undergo embryonic testing and graft compatibility testing in the future as seed are available for propagating. Out of these 29 varieties; 4 are vigorous, 14 show medium growth, while 11 are showing poor growth. All the Polyembryonic varieties will be tested as rootstock for salinity, drought, frost, heat etc. under commercial scion varieties in the future. Some of the Polyembryonic varieties, R2E2, 13-1 and Kensington Pride have reverted to Monoembryonic under the Punjab high temperature growing conditions.</p> <p>Fifteen plants of each variety that have already cropped are ready for transfer to germplasm collections around Pakistan.</p>
Clean rootstocks and scions made available for GPU's	Y3 M6	2015	<p>Budwood of imported cultivars has been shared with Sindh Horticultural Research Institute and the mango Research Institute, Multan for pathology and salinity testing. The mango varieties imported in to Pakistan by this project have been used to re-establish the mango gene bank at the Sindh Horticultural Research Institute at Mirpurkhas after the loss of all trees following the flooding in 2010 and 2011.</p> <p>Rootstocks and scions have not yet been made available to germplasm production units as the varieties have only just begun to crop and they have not been fully tested for their suitability for Pakistan conditions. This work is planned to continue after the end of the ASLP project with other sources of funding from the Punjab government.</p>
1.3 Source and evaluate dwarf and semi-dwarf germplasm for orchard new development and establishment			
Local collections assessed	Y2 M6		This activity was not undertaken in Punjab as research teams have concentrated on assessing the imported germplasm
Review and import any material identified	Y3 M10	On going	Growth rates are being evaluated in current imported polyembryonic varieties; however, assessment of combining ability as scions or rootstocks of the imported varieties has begun but has not been completed. This activity can only begin after the imported cultivars begin to produce sufficient seed. This started in 2015 and will be completed after the ASLP II project has finished.

Objective 2: To develop improved orchard management practices for the sustainable production of quality fruit for domestic and export markets.

outputs/ milestones	Date due	date complete	comments
2.1 Evaluate the role of canopy management through timed pruning on tree productivity (PC)			
Pruning trials completed, brochures on procedure produced	Y2 M6	2013 and ongoing	Mango Pruning experiments at the Mango Research Station at Shujabad, Punjab were completed in 2013 showing annual pruning of trees is possible without reducing the subsequent years cropping. The results have been incorporated in to the ASLP mango management recommendations, training packages and in to other extension materials prepared by the Mango Research Station in conjunction with UNIDO. Changes in Tree pruning and Canopy management have been one of the most widely adopted management practices to come out of this project and have led to increasing yields in orchards that have adopted the recommended pruning practices.
Techniques extended to model orchards across districts and adoption of techniques by small holders	Y3 M10		<p>Model orchard techniques for pruning and canopy management, were demonstrated to small holders on 21 farms in 4 clusters in Punjab and on 12 farms in 3 clusters in Sindh. Pruning was adopted by many growers outside demonstration clusters with other orchard management practices sometimes slower to be adopted adopt. Many farmer field school sessions have been delivered in association with scheduled management practices on demonstration farms. In addition to demonstrations on small holder cluster farms pruning techniques have been taught through practical demonstrations to farmer field schools at all demonstration sites</p> <p>In Punjab 24 Integrated research sites were established in farm clusters in the districts of Multan, M.Z. Garh, Khanewal, and Rahim Yar Khan and ASLP improved practices implemented as demonstration sites and as research sites.</p> <p>Growers who adopted postharvest pruning, postharvest nitrogen application and used paclobutrazol in the Multan, Muzaffargarh and Vehari districts increased their yields by 59% and 65% in 2009/10 and 2010/11 respectively.</p> <p>The mango orchard management practices developed from the Mango Research Station experiments were also extended to over 2000 farmers through the USAID training program between 2011 and 2014.</p> <p>Another 250 growers participated in hands on training in paclobutrazol application, in larger farms under the TRTA-II COP's development program. The COP's and CCP's have also been demonstrated in UNIDO cluster farms and have published in UNIDO operational manuals.</p> <p>In Sindh established Integrated research sites at Latif farm SAU, Syed Ali Gogar Farm, Mr Umer Bughio farm in Mirpurkhas and Rahoki farm, and Dost Muhammad farm Hyderabad. In late 2015 40% of growers surrounding the cluster demonstration farms had adopted all the ASLP mango orchard best practices, and 20% had partly adopted ASLP best orchard management practices.</p>
Activity 2.2 Evaluate the role of tree nutrition on fruit productivity and quality			
The role of nitrogen on tree productivity demonstrated (PC)		Early 2015	<p>An experiment on the effects of different doses of nitrogen on yield and fruit quality in annually pruned mango trees cv. Chaunsa Sammar Bahisht to determine the optimum nitrogen level for a mango tree after the post harvest pruning found that:</p> <ul style="list-style-type: none"> • Post harvest nitrogen application increases flowering terminals and yield, • Post harvest nitrogen application does not affect the fruit quality and shelf life. and

			<ul style="list-style-type: none"> Nitrogen application at flowering contributes in yield but negatively affects the shelf life. These findings have been incorporated in to current nutrition management recommendations for Pakistan. <p>A further experiment to determine optimum rates of nitrogen and the plant growth regulator paclobutrazol found:</p> <ul style="list-style-type: none"> 40- 50 ml per tree Paclobutrazol with 500 to 1000 g N improved flowering to between 63 and 77%, gave a regular yields of 256 – 306 Kg per tree over a 4 year period Paclobutrazol restricted the number of flushing periods during the year from 3 to 1 allowing the canopy to settle down for the subsequent years cropping.
FFS linked to the activity to appreciate nutrition role (PC)			<p>Findings from the Experiment above have been incorporated in to current nutrition management recommendations for Pakistan and have been taught in Farmer Field schools in Sindh and Punjab. The ASLP best orchard management practices were also taught to 10 cluster farm groups in the UNIDO project that included practical training every month.</p> <p>Dr. Mehrun Nisa Memon from Sindh Agricultural University, Tandojam and her students have sampled the nutritional status of the projects integrated research sites at Mirpurkhas and Tandoallahyar as well as in neighbouring traditional orchards to compare postharvest fruit quality between improved and traditional nutrition management. The results to date have clearly indicated that project sites using ASLP recommendations for nutrition and other orchard management practices had a lot lower incidence of postharvest diseases as compared to traditional practices</p>
Timing of nitrogen fertiliser and effects of fruit quality and post harvest canopy growth (A)			<p>The effect of timing of application of nitrogen to mango trees was investigated over 3 years to determine if pre-harvest applications of N affected fruit quality, canopy growth, flowering and tree yield in 8 year-old Kensington Pride (KP) and R2E2 mango trees growing in Far North Queensland. The study found that pre-harvest applications of N did not significantly affect tree or orchard yield, fruit weight, size or number, nor did it negatively influence background skin colour or disease incidence at eating ripe in either variety, when compared to the control (100% N added post-harvest) in the season the fertiliser was applied. Preharvest application of nitrogen positively influenced postharvest vegetative growth and early floral development. This work has shown that earlier application of nitrogen to mangoes can raise biennial bearing without affecting fruit quality. This research was presented at the XI International Mango Symposium in Darwin, 28 September to 2 October 2015.</p>
Investigate the use of Fulvic acid to improve fertiliser uptake and fruit quality (A)			<p>The effect of fulvic acid as a supplement to potassium (K) applications on mango fruit quality, flower synchronisation and yield were investigated in an 8 year-old Kensington Pride orchard at Southedge Research Station, in Far North Queensland, over two seasons. Results showed that neither K fertiliser nor fulvic acid increased average fruit number or yield. However, there was a slight increase in fruit size from the K application.</p>
Nutrient management practices			<p>A nutrition survey of mango farms in districts of Nausharoferoze, Shaheed Benazeerabad, Sanghar, Hyderabad, Matari, Tando Allahyar and Mirpirkhas district was conducted to determine the status of soil and tree nutrition in traditionally managed orchards. The Survey found that phosphorus (P), Zinc (Zn), and boron (B) were generally low in mango orchards of these Sindh districts and application of these elements was recommended.</p>
Activity 2.3 Recommendation on improved nitrogen fertiliser applications to maintain canopy health and maintain fruit quality			
Forms and timing of fertiliser application rated completed (PC)	Y2 M12		<p>Alternate bearing and low yields of mangoes was a significant constraint in Pakistan orchards severely reducing the income of small and larger farmers. Experiments on nitrogen application in Punjab mango orchards found that 500-1000g of nitrogen applied after harvest in combination with 40-50ml Paclobutrazol per tree, produced regular fruiting with average production of 265-306Kg per tree over the period of 4-years and controlled the alternate bearing habit of plants.</p>
Demonstration trials		2009- 2011	<p>Mango nutrition experimental results and the integrated canopy management recommendations were extended at one location each, in</p>

with grower participation			<p>3 districts i.e. Multan, Muzaffargarh and Vehari in Punjab, where orchard yields increased by 59% and 65% in 2009-10 and 2010-11 respectively.</p> <p>In addition to ASLP demonstration cluster farms, the recommendations were extended to over 2000 farms under USAID training Program 2011-2014 in leading mango growing districts of Punjab and Sindh.</p> <p>Over 250 mango growers received practical training on pruning, nutrition management & PBZ application over the period of two year in rich mango clusters in TRTA-II (COPs development program).</p> <p>COPs and CCPs have been published on mango orchard management to produced sustainable yield of quality fruits.</p> <p>The Demonstration plots of UNIDO are working as hub for spreading the developed modern production technology.</p> <p>As s a result of grower training in the Punjab. Many growers now use nitrogen on their trees after harvest, use nitrogen on the basis of tree responses and not flat rates and medium and larger farmers are using soil and leaf nutrition to when planning orchard nutrition.</p>
Activity 2.4 Improve Irrigation efficiency			
Optimum of soil moisture levels in the root zone at different stages of mango growth			<p>Experimental testing of tree performance over two seasons concluded that irrigating trees when the soil dropped to 15% soil moisture in the upper 100 to 600 cm was sufficient to develop sufficient postharvest vegetative growth, set maximum numbers of flowers, and fruit and maximise yield. This irrigation regime also saved between 40 % of annual water usage</p>

Objective 3: To investigate and develop integrated strategies for the management of field diseases and pests affecting fruit productivity.

outputs/ milestones	Date due	date complete	comments
Activity 3.1 Evaluate options for the integrated management of mango sudden death (PC)			
Identify all control options for the disease, developed from ASLP-1 and National Project on Etiology and Management of MSD	Y1 M12	2014	<p>Comprehensive studies on mango sudden death (MSD) were initiated in ASLP phase 1 and other National projects. These studies included: disease assessment, symptoms characterization, cultivars susceptibility, predisposing factors, aetiology and physiology of pathogenic fungus. From this work the following integrated management options were identified:</p> <p>Host Resistance</p> <ul style="list-style-type: none"> Resistant/tolerant rootstock may provide some protection against MSD. Polyembryonic rootstocks may provide a more consistent barrier to MSD as local monoembryonic varieties such as Langra and Sindhri are variable and not resistant. <p>Cultural Management</p> <ul style="list-style-type: none"> Avoid intercropping in mango orchards Do not over irrigate and restrict irrigation water moving between blocks Avoid root damage from hoeing and plough under and between trees Follow ASLP canopy management Add organic matter annually in mango orchards Avoid prolonged water contact trunk by formation of ring or slope around the trunk <p>Biological Management</p> <ul style="list-style-type: none"> There is a lack of biological management information on MSD. The antagonistic organisms against pathogenic fungus of MSD (<i>Ceratocystis fimbriata</i>) may be evaluated in future. <p>Chemical Management</p> <ul style="list-style-type: none"> Control the infestation of bark beetle and termites in mango orchards through application of appropriate insecticides <p>The fungicides named Topsin-M (Thiophanate Methyl) or Carbendazim may be used to inject into the main trunk of diseased as well as healthy plants.</p>
Evaluate other options such as efficacy of more systemic fungicides, natural plant extracts and plant activators			<p>Experiments to induce host plant resistance to MSD were conducted on sick orchards. The most effective treatment that reduced symptoms by 59.2% was trunk injection of the plant activator Bion @ 2g/tree and fungicide Topsin-M @ 20g/tree simultaneously, using a macro infusion system, specifically developed by this project.</p> <p>In Sindh a similar experiment to screen new fungicides for the management of MSD tested four fungicides either alone or in conjunction with each other. The result indicated that Nativo10 + Aliette40 proved to be the most effective in reducing the fresh gumation symptoms, followed by the fungicides Cabrio top, Topsin M & Control. The Nativo/Alliate treatment also yielded the highest in the year of treatment. (3000 kg per tree as compared to 1200 kg per tree in the untreated control treatment. Subsequent to the experiment local growers. The Punjab and Sindh experiments indicate that MSD can be managed and trees prevented from death if treatments are applied early in the disease development.</p> <p>A study was conducted to determine the prevalence of the MSC causal pathogen <i>Ceratocystis fimbriata</i> in potting media from nurseries. Samples of media were taken from pots from the nurseries at Multan, Shujabad, Sadiqbald, and Tandojam where trees were</p>

			growing with no apparent symptoms of the disease. <i>Ceratocystis</i> was found in 77.8% of the potting mixes tested. This finding is of great concern as it points to nursery stock as a significant cause of the spread of the disease and highlights the importance of adequate media pasteurisation and nursery hygiene.
Assemble the effective options into integrated packages and evaluate in selected model farm across the production region including brochures.			Effective management options were assembled and added to the ASLP Orchard Best management guide. MSD management practices were implemented in the selected model farms in farm clusters in Multan, Muzaffargarh, Rahim Yar Khan, and Khanewal. Brochures on the causes and management of MSD were initially developed in ASLP Phase 1. These have been improved and others developed for small holders in local languages. These brochures were distributed among growers.
Activity 3.2 Screen local and exotic germplasm for resistance to the sudden death pathogen (PC)			
Source resistance form local germplasm identified through linked projects			Several pathological screening trials were conducted to see if any mango varieties has resistance or tolerance to MSD. Two methods of screening were undertaken: An <i>in vitro</i> mycotoxin method and an <i>in vivo</i> method stem inoculation method. The <i>in vitro</i> mycotoxin method did not find any resistance or tolerance to 6 varieties tested. The methodology may need refining before the technique is reliable. The <i>In vivo</i> method evaluated 20 imported polyembryonic cultivars grafted on to monoembryonic local Desi varieties. Variation in tolerances was observed amongst the tested cultivars. With the cultivars "Bullocks Heart" and Carabao Lamao" being the most tolerant. It was recommended to evaluate these two cultivars as rootstocks when sufficient seed are available from the Mango Research Station at Shujabad.
Undertake the molecular characterisation of strains of <i>Ceratocystis</i> spp affecting mangoes in Pakistan			A study of mango sudden death undertaken at ARI, Tandojam collected 21 isolates of <i>Ceratocystis fimbriata</i> for genetic identification. Mango sudden death disease status was found to be higher in traditional farmed orchards as compared to those using ASLP Best Practice Orchard Management. Based on nuclear ribosomal DNA, detailed molecular identification found disease isolates from Pakistan grouped within the <i>Ceratocystis fimbriata</i> species complex and were most closely related to <i>C. manginecans</i> . <i>Ceratocystis manginecans</i> is the actual pathogen responsible for mango sudden death in Pakistan.
Links established with external collaborators to tap from their findings			In August 2014 Pakistani pathologists attended the International Horticultural Congress in Brisbane where they met other mango pathologists. A similar opportunity to meet international pathologists was the XI International Mango Symposium, Darwin, 28 September to 02 October 2015. From these meetings formal consulting visits by the Brazilian pathologies Dr Carlos Rosetto is being arranged outside this project. Mango sudden death disease status was found to be higher in traditional farmed orchards as compared to those using ASLP Best Practice Orchard Management. Based on nuclear ribosomal DNA, detailed molecular identification found disease isolates from Pakistan grouped within the <i>Ceratocystis fimbriata</i> species complex and were most closely related to <i>C. manginecans</i> . <i>Ceratocystis manginecans</i> is the actual pathogen responsible for mango sudden death in Pakistan.
Activity 3.3. Review and investigate the epidemiology of the mango malformation disease and evaluate management options (PC)			
3.3.1. Review the mango malformation literature conducted on Pakistan and else ware	Y1 M6	2012	A review of the epidemiology of mango malformation disease was written using Pakistan and International Literature. The review document is attached in the Appendix (Review on the epidemiology of mango malformation.doc)

<p>3.3.2. Investigate the epidemiology of the mango malformation and possible management options explored</p>			<p>An experiment was conducted to monitor the inoculum of mango malformation disease in traditional and improved orchards with the aims of evaluating different management strategies in improved and traditional orchards and to find out distant dispersal of spores, to monitor the inoculum load in different phenological phases of mango, to correlate the spore dispersal of with climatic factors, and to develop disease prediction model. Spore numbers were highest within an infected orchard, gradually reducing with distance from the orchard, however 150 meters from the orchard there were still enough spores to cause infection of trees. Spore release was highest during the fruit development stage followed by the vegetative phase and lowest during flowering. Spore liberation was not greatly affected by temperature or wind, however relative humidity did affect spore liberation with maximum release at 55% RH. The ASLP recommended improved orchard management practices reduced the incidence of mango malformation symptoms by 83.3% and increased yields by 33.3%.</p> <p>A survey of mango diseases and insect pests was undertaken during the 2012 flowering season to determine the prevalence of diseases and pests at flowering in Punjab, growers awareness of them and what management practices are being used to manage them. The survey found:</p> <ul style="list-style-type: none"> • most growers were unaware of the annual growth cycle of mango and did not prune their trees, however they were aware of the new recommendations to prune and were thinking of trying it. • most growers were using old chemicals and were not aware of new chemistry • most growers and managers could not distinguish between insect and disease damage to trees • intercropping was practised in most orchards with wheat and berseem. • most growers applied nitrogen at the incorrect time (after fruit set) which negatively affected fruit quality • most growers were still cultivating and hoeing under and around trees. Less MSD was found in no-till orchards <p>The results of the survey were published in a short report 'Survey Report For The Assessment of Mango Insects & Diseases During Flowering Season, 2012".</p> <p>A separate survey of the incidence and severity of Mango Malformation disease in the Sindh was conducted in 2012/13, and included old mango orchards, orchards under 5 years old and nurseries. The survey found:</p> <ul style="list-style-type: none"> • MMD was present in All mango growing districts of Sindh • The incidence MMD ranged from 34% to 70% between districts of Sindh • MMD was present in all commercial mango cultivars with the common (Desi) varieties having the highest incidence of 63% and the cultivar Bombay having the lowest incidence of 29% • Three fungal pathogens were isolated from survey samples, <i>Fusarium nivalea</i>, <i>F. oxysporum</i> and <i>F. mangiferae</i> <p>Genetic characterization of mango malformation disease (<i>Fusarium</i> sp.) from 21 isolates collected from the district surveys of Punjab and Sindh, found that isolates from Pakistan grouped within the <i>Fusarium mangiferae</i> species, confirming that <i>Fusarium mangiferae</i> is the actual pathogen of mango malformation in Pakistan.</p>
<p>3.3.3. Assess the role of current nursery practices on the spread of mango malformation disease and recommend ways of reducing it's spread</p>			<p>A comprehensive survey to explore management options for Mango Malformation Disease (MMD) was undertaken in 20 mango orchards of Punjab and Sindh with the following objectives:</p> <ul style="list-style-type: none"> • To compare the incidence of MMD, inoculum loads under different management control options. • To examine the inoculum load of the pathogenic fungus through spore trapping technique. • To collect the different isolates of pathogenic fungus for molecular studies. • The maximum incidence (35%) of MMD was found in orchards that did not prune trees. <p>Maximum disease, while minimum disease incidence (3.0%) and minimum no of colonies (10) were noted in the orchard where malformed panicles were pruned off and two sprays of fungicide applied after harvest and after new isolates of <i>Fusarium mangiferae</i></p>

			from 20 different orchards were purified and sent to Fatima Jinnah Women University, Rawalpindi for molecular studies.
Activity 3.4. Determine the Importance of gall midge and investigate integrated control options. (PC)			
3.4.1. Identify the species prevalent in mango orchards in Pakistan and compare with species from other countries of interest such as the Philippines	Pest Biology understood Y2 M12	2012	<p>Literature review on gall midges in mango completed and included in the report: Saeed, S., Saeed, Q., Amin, M.A., Rizwan, M. 2012, Identification, monitoring and damage assessment of cecid flies of mango, Department of Entomology, Faculty of Agricultural Science and Technology, Bahauddin Zakariya University, pp 79.</p> <p>Four species of mango midge and two parasitoid species were found to attack mango leaves and inflorescences. Four of the midge species identified on the basis of damage pattern on leaf, blossom and fruits of mango. Monitoring techniques of mango midge adults and larvae were devised. The activity period of different species on different phenological stages of mango tree were studied throughout the year for their management. The species identified were:</p> <p>a) <i>Procontarinia mangiferae</i>, leaf gall midge b) <i>Procontarinia Spp.</i>, leaf and blossom gall midge c) Unidentified species 1, leaf gall midge d) Unknown species 2, leaf gall midge e) <i>Synopeas mangiferae</i>, parasitic species f) <i>Synopeas temporale</i>, parasitic species</p> <p>Blossom midges are active from January to May on buds, blossom, leaves and pea-size fruits. From March-September midge activity can reduce fruit yield on different varieties ranging from 30-100% (blossom midge) and indirect yield loss 4-60% (leaf gall midges)</p> <p>Three gall midges, (<i>Procontarinia mangicola</i>, <i>Procontarinia robusta</i>, Psyllid Gall midge) and one blossom midge (<i>Procontarinia mangiferae</i>) have been identified as pests of mango. The blossom midge can damage buds, leaves, blossoms, and pea size fruits. These species are different from the species present in the Philippines, which only has the one major species <i>Procontarinia frugivora</i>, which can damage mature fruit of mango.</p>
3.4.2. Link up with the Philippines project (HORT/2007/067/4) on the biology and ecology of the mango gall midge		2013	An International Midge Conference held in O'Reilly's Rainforest Resort Australia in 2013, included a training programme arranged by Dr Ian Newton, Queensland DAF, with the funding of Crawford Fund Australia. Philippines mango midge experts also participated in the conference. Midge samples were shared between the Pakistan and Philippines team for identification. Midges of Pakistan and Philippines were found to be totally different as mentioned in 3.4.1.
3.4.3. Evaluate the economic impact of gall midge on mango Productivity across locations			<p>A survey, an economic assessment of galls and blossom midges experimentation was carried out to determine the extent of the pests in the Punjab. The economic losses of midges were calculated by surveying 28 farms in different mango growing areas of Punjab, i.e. Multan, Shujabad and Rahim Yar Khan. The survey found that:</p> <ul style="list-style-type: none"> more than 10% blossoms of fruits were affected at Shujabad and lowest damage was observed at Rahim Yar Khan (6.7%). There was 80-90% loss of fruit yield of these affected blossoms. 82% of farmers were unaware of inflorescence midges and 89% were unaware of leaf midges only 11% of farmers applied spray to control gall midges. the mango Cultivar Sindhri was the most susceptible (59 symptoms /1m³) compared to Anwar Ratol (16.00 symptoms /1m³)

3.4.4. Examine integrated options for managing the pest if shown to have a significant impact on productivity, with a linked national project on the pest.			Early midge population can be managed by installing orange/yellow coloured sticky traps to identify their presences in the orchard. Usually mango growers irrigate mango trees after flowering with interval of 20-25 days during fruiting stage. Midges can be managed by more frequent irrigation at an interval of 15 days to suppress the larvae of midges present in the soil by flood irrigation. Several insecticides were tested by foliar application and Movento, Bifenthrin, Squadron, and Imidachloprid, Pyramid were found effective for management of midges during February to April. Whereas Furadon and Cartap can be used as soil treatment for long term mango midge management but its residual effect on non-target organisms needs to be studied.
Activity 3.7. Extend pest and Disease management recommendations to growers (PC)			
3.7.1. Pest and disease management recommendations incorporated in to ASLP orchard management recommendations			P&D recommendations have been imported into ASLP extension literature, including pamphlets and manuals.
3.7.2. Incorporate Pest and disease management in to all farmer training			All farmer training on best orchard management practices included recommendations on the management of pests and diseases

Objective 4: To determine the prevalence and impact of postharvest diseases and develop management strategies to address them

outputs/ milestones	Date due	date complete	Comments
4.1 Identify and characterise the major pathogens of postharvest rots and determine the factors accelerating the development of these losses (PC)			
4.1.1. determine the likely causes of fruit diseases in domestic and export market fruit		2011	In the Pakistan city fruit markets a survey of the prevalence, severity and incidence of postharvest diseases of mango found the most common diseases to be stem-end-rot (<i>Lasiodiplodia theobromae</i>) and anthracnose (<i>Colletotrichum gleosporides</i>). These diseases were found in all markets. <i>Alternaria (Alternaria alternata)</i> and <i>Aspergillus (Aspergillus niger)</i> rot diseases were other major post harvest diseases that were identified.
		2102	During 2012, studies were focused on pathological and genetic characterization of predominant post-harvest fungal pathogens (<i>Lasiodiplodia theobromae</i> , <i>Colletotrichum gloeosporioides</i> , <i>Aspergillus niger</i> and <i>Aspergillus flavus</i>) of mango. The aggressiveness of these fungal isolates were tested through artificial inoculations under controlled conditions and all proved to be pathogenic with varying degree of virulence on the mango varieties Sindhri and White Chounsa. Pathological studies indicated that White Chounsa was more resistant to environmental factors than Sindhri.
		2013	In 2013, a study of the distribution, molecular and pathological characterization of post-harvest fungal pathogens associated with stem end rot of mango fruits, found that stem-end-rot was emerging as a major disease problem in mango orchards and domestic markets. This survey was conducted in traditional farms and in farms using ASLP best orchard management practices in six districts of Punjab (Multan, Muzaffar Garh, Rahim Yar Khan) and Sindh (Matiyari, Mirpur Khas, Tando AllahYar). Stem end rot was prevalent in all the locations. The causal pathogens of stem end rot were isolated by tissue segment method. A pair of ITS primers were used to amplify the obtained DNA. The amplified products from ITS-5.8S-rDNA were sequenced and compared with previously identified sequences in Genbank which showed 96-100% similarity with <i>Lasiodiplodia theobromae</i> and <i>Botryosphaeria dothidea</i> . Two species of <i>Botryosphaeriaceae (Lasiodiplodia theobromae</i> and <i>Botryosphaeria dothidea</i>) were detected by molecular sequencing analysis. Isolates from Punjab were shown to be more aggressive as compared to isolates of Sindh. The incidence of stem and rot was higher in traditional farmer fields because of poor management practices.
		2014	In 2014 molecular ((ITS1 & ITS2) and 5.8S rDNA gene sequencing) and pathological identification of fungi responsible for postharvest mango diseases, found the opportunist pathogens (<i>Fusarium solani</i> and <i>Fusarium oxysporum</i>) to be present. These pathogens are known to infect mangoes through wounds and injuries, indicating poor fruit handling practices during harvest and marketing.
4.2 Investigate field management and postharvest options to reduce postharvest rots (PC&A)			
4.2.1. Model orchards used to study options of Field management.		2013	In Pakistan postharvest rots in fruit from traditional farms and from ASLP best practice farms were evaluated in 2011, 2012 and 2013. In the first two seasons, fruit from improved practice blocks were variable in disease susceptibility, however by 2013 disease incidence was lower in the demonstration blocks using ASLP best practice.
4.3. Evaluate other postharvest options to reduce postharvest rots options (PC)			
4.3.1. Evaluate other options such as efficacy of more systemic fungicides,			Leaf extract of three plant species <i>Datura stromium</i> , <i>Eucalyptus camaldulensis</i> and <i>Aloe barbadensis</i> were used as a bio-control against the stem-end-rot pathogen <i>Lasiodiplodia theobromae</i> . Three plant species <i>Azadirachta indica</i> , <i>Moras alba</i> , <i>Citrus lemon.L.</i> were used as anti-fungal botanicals (AFB) to control the growth of <i>Fusarium</i> spp. <i>Moras alba</i> controlled 100% of the growth of <i>Fusarium</i> spp.

natural plant extracts and plant activators 4.3.2. Evaluate alternative fungicides for postharvest control of fruit rots (A)			and <i>Azadirachta indica</i> also showed satisfactory results. <i>Eucalyptus camaidulensis</i> and <i>Datura stromium</i> were very effective against the growth of <i>Lasiodiplodia theobromae</i> ,
4.4 Study the epidemiology of dendritic spots of mangoes – postharvest focus (A)			
4.4.1. Effect of bagging on the incidence of dendritic spot and stem-end-rot of mango		2014	In Australia the effect of bagging on the incidence of dendritic spot and stem-end-rot of mango was investigated as part of the PhD studies of Ms Arslan Jabeen Quershi on the field and postharvest biology of dendritic spot and stem end rot of mango, University of Queensland (submitted). The study found that fruit bagged at the golf ball stage of development had lower incidence of both dendritic spot and stem end rot, suggesting that bagging of fruit on the tree early in their development, was an effective way of reducing the incidence of postharvest dendritic spot and stem end rot during post-harvest storage.
4.4.2. Causes and Conditions that favour postharvest diseases known			This activity was part of the PhD studies of Ms Arslan Jabeen Quershi on the field and postharvest biology of dendritic spot and stem end rot of mango, University of Queensland (submitted). Although several experiments were conducted to elucidate the epidemiology of dendritic spot, the role of field environmental factors on the disease were not forthcoming.
4.5 Study the factors affecting occurrence and prevalence of mango stem end rots (A)			
4.5.1. Determine the viability of anthracnose populations across different production areas in Australia to understand the variable spray responses from fungicides for field management of the disease.			This activity was part of the PhD studies of Ms Arslan Jabeen Quershi on the field and postharvest biology of dendritic spot and stem end rot of mango, University of Queensland, (submitted). This study found that postharvest hot fungicidal dipping followed by exogenous ethylene gas, was an effective way of controlling dendritic spot disease. A survey of mango growing districts was carried out to determine the fungal pathogens associated with dendritic spot, stem-end-rot and anthracnose symptoms. No major differences in pathogens were associated with the Australian growing districts. Several pathogenic fungi were identified as being able to cause dendritic spot disease (<i>C. gloeosporioides</i> , <i>N. parvum</i> , <i>L. theobromae</i> , <i>Altenaris</i> sp.). However <i>C. gloeosporioides</i> , <i>N. parvum</i> were the most common and virulent pathogens of dendritic spot in Australia.
4.6 Evaluate fungicide alternatives for their efficacy as postharvest treatments in disease control			
4.6.1. Identification and sourcing of fungicide alternates with potential for use as postharvest treatments based on efficacy in other systems and evaluate the selected compounds for efficacy in the management of postharvest diseases under ambient hot water treatment conditions.			In Australia, it was confirmed that the use of heated fludioxonil (Scholar®) as a post-harvest option is still best practice (lowest disease rating in all three experiments conducted) for management of both stem end rot and anthracnose. Differences in the efficacy of products depended on the organism being assessed. For example: unheated fludioxonil was more effective at managing anthracnose compared to stem end rot, whereas heated fludioxonil provided control of anthracnose and stem end rot. Symptoms of dendritic spot which can be caused by either <i>Colletotrichum gloeosporioides</i> or <i>Neofusicoccum parvum</i> was also recorded in these experiments. The incidence was extremely low which may reflect the geographic distribution (of the causal organisms) or the environmental conditions are not conducive to symptom expression.

PC = partner country, A = Australia

Objective 5: Increase extension and capacity building capabilities in the mango industry to improve value chain benefit flows.

outputs/ milestones	Date due	date complete	comments
Activity 5.1 Increase capacity of the project team and extension group to deliver training and develop information and to understand and extend poverty mapping and benefit flows (PC) (with HORT/2010/003)			
5.1.1. Identify individuals to become trainers of wider extension group	Yr1 m8	2012	Partner-country organisations in the Punjab and Sindh regions were screened, with a total of 50 Field Assistants and 150 Agriculture Extension Officers identified for extension training activities.
5.1.2. Conduct skills audit and Prioritise areas for capacity building	Yr1 m8	2012	A skills audit of the project team and extension group was conducted with the following priority training areas identified: canopy management, budding and grafting and identification of field diseases of mango.
5.1.3. Set up and evaluate a curriculum of individuals, project team and the wider extension group in the development and delivery of extension training programs.	Yr1 m12	2012	<p>A mango curriculum development workshop was organised at Multan, with 40 participants including, 20 extension workers from provincial governments, 15 researchers from institutes/universities and five progressive growers. The outcome was the identification and development of a series of best orchard management practice guidelines.</p> <p>Training of Field Assistants and Agriculture Extension Officers was undertaken in the Punjab via the In-Service Agriculture Training Institute (IATI) Rahim Yar Khan. In the Sindh training was undertaken via the Agriculture Research Institute, Tandojam and the Agriculture Training Institute (ATI), Sakrand. More than 50 Field Assistants and 150 Agriculture Extension Officers were trained and have benefitted from these training activities that have focused mainly on canopy management, budding and grafting and identification of field diseases of mango.</p>
5.1.4. Deliver specialised extension training to project officers in Pakistan		<p>2012</p> <p>2014</p>	<p>Specialised extension training was delivered to project officers in Pakistan on several occasions:</p> <p>2012. Dr Greg Johnson organised a workshop on the diagnosis and management of mango postharvest diseases, at the National Agricultural Research Council (NARC) in Islamabad on 26-28 August 2012. The workshop had 24 participants from 10 research institutions in Pakistan. This workshop provided speciality skills to pathologists and other postharvest researchers on disease identification and control.</p> <p>2014. Dr Bally gave specialised training to nurserymen and nursery staff on grafting methods at MAC Nursery, Rahim yak khan, Punjab</p> <p>2014. Mr Mathew Weinert, Extension Officer, DAF and Jenny Metcalfe (E Connect, a private Extension Services Consultant), coordinated and delivered a four day intensive communication skills workshop held at the Pearl Continental Hotel Bhurban, Punjab between 28 September to 1 October. This workshop was supported by the ASLP agricultural communication fund as a program-wide activity that involved 27 personnel from the ASLP Mango production, Mango Value Chain, Citrus, Dairy and Social projects. 2014. The</p>

		2015	<p>training workshop "Presenting Science" taught the core knowledge and skills required for communicating science and technology to a range of audience types.</p> <p>2015. Dr Geoff Dickinson, Extension Officer DAF (who replaced Mr Weinert in early 2015) met with ASLP research and extension at locations including Islamabad, Bhurban, Multan and TandoJam from the 23/08/15 – 07/09/15. Dr Dickinson delivered an extension training workshop at the Bahauddin Zakariya Univesity, Multan, Punjab State. Attendees included 35 agricultural extension and research personnel from the Punjab State Provincial Extension service and BZUniversity, as well as some key growers. The workshop was titled "Mango Communication Technology" and included latest trends in the electronic delivery of information and training packages.</p>
Activity 5.2 Facilitate individual, short and long term training needs to deliver project outcomes (PC) (with HORT/2010/003)			
5.2.1. Review training needs in areas of mango production and extension to reduce poverty			A skills audit of the project team and extension group was conducted in early 2012 with the following priority training areas identified: canopy management, budding and grafting and identification of field diseases of mango. Nursery hygiene and the management of containerised stock was identified as another high priority.
5.3.1 Prioritise training needs and facilitate through courses.			Project team and extension group individuals undertook field training within the priority training areas of canopy management, budding and grafting and identification of field diseases of mango.
Activity 5.3 Develop training programs and information resources for adoption of integrated mango crop management, harvest and postharvest handling (PC & A)			
5.3.1. Document extension and capacity building information supply within the mango industry including individuals and organisations and their rolls			Over the life of the project, advisory and information literature for developed for growers. The list of trainings, pamphlets, seminar, numbers of farmers trained are in appendix 3.
5.3.2. Review and prioritise training activities and information based on outcomes from the production and postharvest research activities.			Training activities prioritised and organised on the basis of the ASLP Best Orchard Management Practice Protocols

5.3.3. Collaboratively develop training programs and information resources to be delivered by trainers from 5.1			Training programs were developed in Sindh and in Punjab by the focal people in each state and using discipline experts associated with the project
5.3.4. Establish Farmer facilitation services using participatory approaches in conjunction with the Fruit and Vegetable Development project.			This activity was not undertaken by the project as Mr Khalid Chaudry, director of the fruit and vegetable project was moved from the fruit and vegetable project to several other institutions
5.3.5. Use ongoing projects to strengthen week extension links through positioning of local champions			Appointed Me Khalid Cahudry as ASLP Extension Focal person, however, after becoming DG extension Punjab, his time on the ASLP project was limited. Appointed Professor Nazim Labar Hussain as nursery champion in Punjab. Appointed Mr Yousaf Chenna as Extension Focal Person in Sacrand, Sindh Appointed Dr Kazi Sulamon Memon, SAU as Focal Person to coordinate research and extension in Sindh, when he retired Mr Ismail Kumbar was appointed in the roll.
5.3.6. Train groups of farmers in orchard management	2014-2015	Sep 2015	Many groups of farmers were trained throughout the project in farmer field schools associated with the ASLP best orchard management practise demonstration cluster groups
5.3.7. Develop written and video materials for Pakistan Extension Services (PC)	2014-2015	Sep 2015	During the final year of the project regular radio and internet broadcasts for farmers on ASLP best practice in mango orchards and in nurserues – by Nazim L. Hussain. All extension activities directed towards growers and broad audiences including provincial extension officers, nursery men, contractors etc. alre listed in Appendix 3. No video materials were produced for Pakistan owing to the resignation of the Australian extension personnel.
5.3.8. Develop mango picking video and Mango problem solver for the Australian mango industry (A)	2014-2015		The video “Mango Picking – How to do it right” was completed in November 2013 and loaded to YouTube for public access. The video has been viewed over 1500 times (01/11/2015). The video has also been used as a communication tool for grower extension activities in Australia and Pakistan. An updated “Mango pests, beneficials, diseases and disorders field guide” was developed in collaboration with the NTDPIF, for Australian mango growers in October 2015. The guide will be released electronically and is currently being reformatted for upload to the NTDPIF website.
Activity 5.4 Investigate the use of Web 2.0 technologies to deliver training and information (With HORT/2010/003)			
5.4.1. Develop interactive website using Web2.0 technologies and train			Feedback from Australian Mango growers at industry workshops in 2012 and 2013, was that many Web 2.0 technologies (blogs, grower facebook or other social networking sites and apps) had very little use by growers at present and that generally growers were unlikely to utilise these technologies in the near future. A similar, if not greater negative response was measured from the Pakistan mango growers.

the project team in their use			
5.4.2. Identify and develop web 2 resources			Lack of industry support for Web2.0 resources, resulted in a refocused approach to adapt and enhancing other web based information resources. Feedback from Australian mango growers at industry workshops in 2012 and 2013 identified that a "One-stop website" for grower information, preferably based on the Australian Mango Industry Association website would be the most desirable electronic information delivery tool. The development of videos on mango management systems was considered a high priority for the Australian and Pakistan mango growers.
5.4.3. Set up and evaluate online packages for trainees, growers, and the wider mango industry in Pakistan and Australia			In Australia a "One-stop website" for grower information, located on the Australian Mango Industry Association website was developed throughout 2012 and 2013. Many useful mango extension resources were uploaded to the AMIA website over this time. A complete redesign of the AMIA website in early 2014, resulted in a loss of much of this information, but these have been progressively reloaded throughout 2015. Current training packages include pest and disease, nutrition management, picking, packing and post-harvest management. In Pakistan this activity was not undertaken as emphasis was placed on training on farms
5.4.4. Evaluate the effectiveness of web 2			In Australia Web 2.0 technologies have slowly gained some uptake by the mango industry. The AMIA Aussie Mangoes Facebook site is primarily a consumer site, but does have some very minor grower content. The site has 52,000 followers (1/12/15). The Aussie Mangoes Facebook site also has links to content on Instagram and YouTube.

PC = partner country, A = Australia

7 Key results and discussion

7.1 Objective 1: Mango nurseries

To facilitate the establishment and spread of 'clean' mango nurseries and general good tree husbandry so that high quality planting material is widely available to the industry

Recognising the need for an improved nursery sector in the Pakistan mango industry has been one of the key outcomes of this project. Traditional mango nurseries in Pakistan were producing trees infected with mango malformation disease and mango sudden death disease and were responsible for much of the transmission of these diseases to clean orchards. Traditionally grown mango nursery trees also take up to 3 years to be ready for field planting and when planted often experience losses of up to 70%.

This project has initiated improvements in the Pakistan mango industry nursery sector by:

1. Raising awareness of the problems associated with traditional nurseries.
2. Developing modern high health nurseries that grow trees in containers with soilless media.
3. Undertaking research to customise nursery technologies for Pakistan conditions and varieties

Training researchers, extension workers, nursery owners and workers and farmers.

4. Developing a nursery operational manual
5. Developing training materials

Recognition of nursery issues

Awareness of the issues within existing mango nurseries has been increasingly recognised by some farmers, nurserymen, researchers and students through 20 training sessions and seminars for over 1500 people (Appendix 2, Table 9.) However, a lot more awareness of the problems associated with traditional nurseries and the benefits of high health trees grown in soil-less media is needed.

Nursery establishment

The project established modern containerised nurseries at the major mango research stations in the Punjab (Mango Research Station, Shujabad, Bahauddin Zakaraya University, Multan and Mango Research Institute, Multan) and Sindh (Sindh Agricultural University, Tandojam, Sindh Horticultural Research Institute, Mirpurkhas, the Agricultural



Figure 7a. Research Nursery at Sindh Agricultural Research Institute prior to the ASLP project.



Figure 7b. New Research Nursery at Sindh Agricultural Research Institute built to ASLP nursery guidelines.

Training Institute, Sacrand and the Agricultural Research Institute, Tandojam).

These nurseries on research institutes are being used for horticultural, entomological and pathological research and for training. In addition to these research and training nurseries, two research institutes have also established commercial production nurseries to replace their traditional nurseries.

In addition to nurseries on government and university research and training institutions this project has supported the development of several independent commercial nurseries in conjunction with private owners. These private commercial nurseries represent industry adoption of improved nursery practices and are an example of this project working with private industry to integrate new technologies in to the private sector. The private mango nurseries that have developed with technical assistance from this project are listed in Table 4. By September 2015, the oldest commercial nursery had produced approximately 35,000 trees over four seasons. Another commercial nursery has exported approximately 35,000 trees to the United Arab Emirates (UAE). Trees from these nurseries are achieving almost 100% survival during field planting as compared to up to 70% transplant losses from traditional nurseries.

Introducing new nursery production techniques to existing commercial nursery businesses has not been as successful as originally expected. All the new best practice commercial nurseries are new businesses with entrepreneurial managers. The traditional businesses that have engaged with the project have had training from the project but have not adopted all the technologies. Often traditional mango nursery businesses in Pakistan are run by families and the business models are strictly managed by the elders in the family who are very conservative and not open to change. Traditional nurseries can also produce trees cheaper than the high health containerised nurseries and price is still an important factor for farmers. Before the benefits of clean nursery trees can be realised by the majority of farmers, a significant education program will be needed to inform them of the benefits over and above trees from a traditional nursery.

During the project, considerable effort was given to supporting the new nursery businesses in their early years resulting in strong Government and private industry linkages.



Figure 8. MAK Nursery, Sadaquabad was one of the first privately owned commercial mango nurseries growing containerised trees using ASSLP guidelines.

ASLP research officers working in the nursery management field were encouraged to regularly visit (monthly) the developing commercial nurseries to assist them with any technical problems they were having with potting media, plant growth, plant nutrition and pest and diseases. While this gave the nurseries the technical support they needed, it was also immensely helpful for the research staff to be exposed to real-world issues experienced by commercial operators. For the first time in Pakistan, high health, grafted mango trees are available to farmers, providing them the ability to establish new mango orchards with a very low risk of contamination with mango malformation and mango sudden death diseases.

Nursery research

The nursery management research in ASLP 1 continued in to this project ASLP 2. The research activities centered around developing suitable potting media from locally available components, assessing plant growth in the media, looking at the best ways to fertilise nursery trees and evaluation of the disease stats of traditional and new nursery techniques.

Potting media - One of the early successes of the nursery research in the Phase 2 project was the development of a suitable potting medium for growing mangoes in 5 litre polyethylene bags. The research was initially carried out by Mr Inam ul Haq of the Mango



Research Station in Shujabad, Punjab. The potting medium he developed that gave maximum plant growth consisted of: 65% Bagasse, 30% silt, and 5% coir. This medium has been adopted by most of the commercial nurseries associated with the project. Similar research was undertaken in the Sindh by Dr Noorun Nisa Memon of Sindh Agricultural University, Tandojam who repeated the work to confirm its efficacy using Bagasse, silt and coir sourced in the Sindh.

Figure 9. Researcher Mr Abdul Ghaffar Grweal discussing potting media experiments with the proprietor of the commercial MAK nursery, Mr Wiaz Mujeeb at the Mango Research Station Shujabad.

Nutrition management- Nutrition management of nursery trees was also researched to determine the best way to keep the tree growing rapidly and healthily. Regular foliar sprays of 2% NPK mix was found the best and avoided fertiliser burn that is often experienced when solid fertilisers are added to the pot.

Nursery hygiene - A research activity to assess the role of current nursery practices on the spread of mango malformation and other diseases was undertaken by Mr Tariq Malik of the Mango Research Institute in Multan, Punjab. The experiment tested soil and potting media from healthy mango seedlings from seven nurseries in Punjab and Sindh and used an agar slants technique to isolate the fungal pathogen *Ceratocystis frimbriata* (MSDS) from the media. Microscopic studies of the contaminated agar colonies revealed 6 pathogenic fungi, *Ceratocystis sp.*, *Fusarium sp.*, *Nattrassia sp.*, *Cladosporium sp.*, *Penicillium sp.* and *Aspergillus sp.*

A total of 78% of the potting mixes from commercial nurseries were infected with the pathogen for mango sudden death, *Ceratocystis sp.* No other pathogen infected more than 10% of the mixes tested.

This research has highlighted the fact that mango sudden death is a soil borne pathogen and can be easily spread through nursery potting media. It is essential that commercial nurseries pasteurise their potting media adequately and observe all recommended nursery hygiene management rules.

Nursery Training

Nursery training was an important component of the project to assist the transition from traditional inefficient, unhealthy nursery practices to modern high health containerised efficient nurseries. Training was conducted for research staff, extension staff, nursery owners, nursery workers and students. Training activities included overseas visits and internships with commercial nurseries in Australia, seminars on nursery practices, hands on training on potting media preparation, grafting and tree nutrition and one-on-one mentoring of new nursery managers developing new nursery businesses.

Nursery Manual

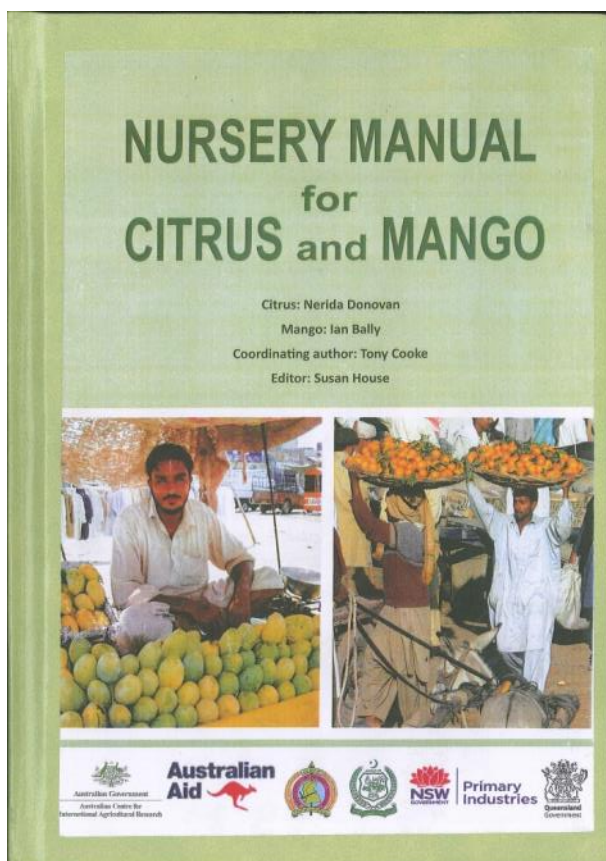


Figure 10. Joint citrus and mango nursery management manual was developed as a guide for nursery operators, teachers and researchers in the raising of healthy true-to-type nursery stock.

A joint citrus and mango nursery management manual was developed by a collaboration between the ASLP mango and citrus production projects.

The nursery manual was launched by the Pakistan Federal Minister for Food Security, Mr Bosan on the 29th August 2015 at Bahauddin Zakaraya University, Multan. The joint citrus and mango nursery manual was distributed to all project teams as hard copies and PDF electronic version distributed to extension departments, nurseries and farmers. The electronic version is available for download from the National Agricultural Research Council (NARC) website.

The manual is also being reformatted as an ACIAR Publication and will be available through ACIAR publications. This manual will provide information of mango and citrus nursery practices on which pamphlets and seminars and practical training can be based.

Several extension pamphlets have been developed using materials and content from the Nursery manual or from other Australian training. These extension pamphlets are listed in Appendix 1.

Table 3. New high health containerised mango nurseries developed during the project on research and teaching institutions and in the private sector.

Nursery name and Location	Comments
Research and training nurseries	
Mango Research Station (MRS), Shujabad, Punjab	two nurseries, one for research and demonstration, the other to demonstrate simple nursery construction for small growers.

Bahauddin Zakaraya University (BZU), Multan, Punjab	for research and teaching under-grad students
Sindh Agricultural University (SAU), Tandojam, Sindh	two nurseries, one for research and teaching under-grad students, the second for research
Sindh Horticultural Research Institute (SHRI), Mirpurkhas, Sindh	for research and demonstration to growers
Agricultural Training Institute (ARI), Sacrand, Sindh	for training students, growers and nursery staff
Mango Research Institute (MRI), Multan, Punjab	for research

Private Nurseries

MAK Nursery, Sadiqabad, Punjab	capacity 40000 plants/yr
Bandor Nursery Farm, Rahim-yaar-Khan, Punjab	capacity 20000 Pts/yr., Plans to export trees to Dubai, UAE
Naseem Nursery Sadiqabad, Punjab	capacity 20000 Pts/yr
YAM Nursery Kabirwala, Punjab	capacity 3000 Pts/yr
New Leaf Age Nursery, Multan, Punjab	capacity 12000 Pts/yr
Khurshid Nursery, Hyderabad, Sindh	

Rootstocks

The project engaged in a search for more suitable rootstocks for the Pakistan mango industry. Traditionally mangoes have been grafted on to 'desi' varieties (small fruited local varieties) or on to the major commercial varieties. All of these rootstocks have monoembryonic embryos and have no specific abiotic tolerance. Seedlings grown from monoembryonic cultivars will not be genetically uniform and as such be unpredictable on their effects on scion varieties. To overcome the lack of polyembryonic cultivars available in Pakistan, 43 polyembryonic cultivars were imported from Australia in ASLP Phase 1 project. Fourteen of the imported cultivars did not survive the acclimatisation process, leaving 29 for evaluation. By late 2015, 11 of the imported polyembryonic varieties had cropped and were undergoing embryo, graft compatibility and tree vigour evaluation.



Figure 11. Imported monoembryonic rootstock growing in the field at Mango Research Station, Shujubad, with winter frost protection.

Some cultivars have reverted back to monoembryony when grown under the Punjab conditions making them unsuitable for use as rootstocks. Eleven of the 29 polyembryonic cultivars are displaying dwarf or slower growing habits which has the potential to also reduce scion vigour. Evaluation of the suitability of these cultivars for rootstocks on Pakistan scion varieties will continue beyond the ASLP 2 project by Mr Ghaffar Grewal and his team at the Mango Research Station at Shujubad, Punjab.

Saline resistance - In a separate experiment Mr Rasool Bux Khaskhely (PhD student) and his supervisor Dr Inaytuallah Rajpar of Sindh Agricultural University have found

several local rootstock varieties with partial salinity tolerance and found the imported variety '13-1' was highly tolerant to saline soils in some stock scion combinations. They found:

- No local varieties survived in EC 9 dSm⁻¹, except for the imported cultivar "13-1".
- At lower EC's of 3 dSm⁻¹ or medium EC 6, dSm⁻¹, grafted 'Sindhri' & 'Fajri' scions survived and performed well.
- Among indigenous ('desi') varieties, rootstock of 'Meho' & 'Sheedi' were found to be tolerant to low & medium salinity; whereas the other three varieties ('Totapuri', 'Khatmithro' and 'Sawro') were found to be sensitive to medium salinity levels. Scions of variety 'Sindhri' performed well on all tolerant rootstocks.



This work has identified potential rootstocks for Pakistan mangoes that are growing in mild saline conditions or are being irrigated with high EC water.

Figure 12. Ian Bally (project leader, Australia) discussing salinity resistant rootstock with Prof. Kazi Memon Suleman, PhD student Mr. Rasool Bux Khaskelly, and Prof Inayatullah Rajpur (SAU) and Mr Faisal Fateh (Project coordinator NARC).

Disease resistance - Mr Muhammad Tariq Malik and Mr Hafiz Muhammad Ammar of the Mango Research Institute in Multan, Punjab conducted mango sudden death disease (*Ceratosystis frimbriata*) resistance screening on 20 imported polyembryonic rootstocks and on local cultivars. No local varieties were found to have resistance or tolerance to *Ceratosystis frimbriata*. Two of the imported cultivars ('Bullocks Heart' and 'Carabao Lamao') did not display any disease symptoms during the screening experiment and may be potentially useful rootstock for with some tolerance to mango sudden death.

7.2 Objective 2: Orchard management

To develop improved orchard management practices for the sustainable production of quality fruit for domestic and export markets.

Mango Orchard Management Protocols - The key finding associated with the orchard management component of the project was the demonstration of effectiveness of the integrated orchard management practices in increasing yields, reducing biennial yield fluctuations and improving fruit quality.

Various components of orchard management were researched in phase one and were refined in phase two of the ASLP mango production project. These included: pruning practices,

Figure 13. ASLP Mango orchard best management protocols- Urdu version.

nutrition, disease and pest management, orchard floor management and irrigation. In this project integrated mango orchard management protocols were developed for the Punjab and Sindh and implemented on 28 sites in Punjab and 13 in Sindh. Farms using the ASLP integrated mango management protocols had yield increases of approximately 59% in the first year of practice and further increases in subsequent years. The biggest impact on yield was on yield consistency (reduction of biennial bearing). This was achieved through pruning and canopy management that ensured maximum numbers of terminals flowered each year. The tree disease mango sudden death that was killing up to 10 % of trees in orchards each year was now able to be recognised in its early stages and treated to bring trees back to full health and production. Other pests and diseases such as mango malformation, gall midge and nutrient disorders were managed to minimise their impact on yield and fruit quality. The postharvest and general fruit quality improved in terms of lower number of postharvest fruit rots and larger sized fruit.

Table 4. Increase in Productivity and value of one acre of ASLP best practice demonstration plots over traditional farming practices for three farmers over the first two seasons of implementation. Improved practices included, pruning, fertilising and application of the plant growth regulator, paclobutrazol .

Farmer	Year	Traditional farming practices (1 acre)		ASLP best practice (1 acre)		Additional costs per acre (Rs)	Difference in net value (Rs)	Increase in value (%)
		Yield (kg)	Fruit value (Rs)	Yield (kg)	Fruit value (Rs)			
M. A. Khokhar	2009/10	4,800	7,200	9,800	147,000	9,000	66,000	44
	2010/11	3,100	45,000	5,400	108,000	5,000	58,000	130
Z. K Tareen	2009/10	5,700	85,500	11,350	170,250	10,000	74,500	87
	2010/11	9,100	182,000	14,200	284,000	25,000	98,520	54
M. N. Khichi	2009/10	6,100	91,500	8,850	132,750	-	41,250	45
	2010/11	10,300	257,000	11,450	286,250	900	27,850	11

Table 5. Changes in orchard values for four farms over 5 years after adopting ASLP best orchard management practices

Growers	2009 Millions (Rs)	2010 Millions (Rs)	2011 Millions (Rs)	2012 Millions (Rs)	2013 Millions (Rs)	2014 Millions (Rs)
Dr. Zafar-ullah Tareen, Muzaffargarh (75 acres)	4.8	7.5	8.0	10.0	9.5	9.2
Muhammad Nawaz	2.6	4.0	6.5	9.3	9.6	10.2

Khichi, Vehari. (55 acres)						
Azhar Khan Khichi, Mailsi, Vehari. (84 acres)	4.0	7.5	9.3	14.0	15.5	17.0
Saith Javaid, Khan Bella Rahim Yar Khan (220 acres)	8.9	12.0	23.5	36.5	40.2	50.0

Third party publications - The success of the ASLP Mango Orchard Management Protocols was recognised by other international aid organisations such as USAID and UNIDO who used the research findings from this and the previous ASLP project to develop codes of practice, operational manuals and training curricula with the help of the same scientists working on this project. These third party documents are listed in Appendix 3.

Nitrogen and plant growth regulators - A key finding from the orchard management research undertaken by Mr Ghaffar Grewal, of the Mango Research Station, Shujabad, Punjab during this project was the optimal rate and timing of nitrogen and the plant growth regulator paclobutrazol to mangoes to ensure tree canopies renew and are ready for flowering every year. Prior to this research work most Pakistan farmers applied nitrogen to their trees during the fruit development. This practice had negative effects on the fruit quality and subsequent vegetative flushing and flowering. The research work of this project found that application of nitrogen in the postharvest period increased the number of flowering terminals and yield in the following season, without negatively affecting fruit quality or shelf life. The research also confirmed that nitrogen application at flowering reduced fruit shelf life by increasing the fruit's susceptibility to postharvest rots. The research found that paclobutrazol applied at 40-50 ml per tree with 500 to 1000 g N improved flowering to between 63% and 77% and gave a regular yields of 256 – 306 Kg per tree over a 4 year period. The extension pamphlet “Use of paclobutrazol (PBZ) in mango orchards” was developed to outline the procedure of PBZ to for farmers (Appendix 3).



Figure 14. Application of plant growth regulator paclobutrazol as a trunk drench. A.) applying the paclobutrazol in 1 litre of water and B.) watering-in after application.

7.3 Objective 3: Field diseases and pests

To investigate and develop integrated strategies for the management of field diseases and pests affecting fruit productivity.

Mango Sudden Death - field management

Prior to ASLP mango production projects the tree disease Mango Sudden death (MSD) was a significant threat to the Pakistan mango industry. The disease was found in all mango growing districts with incidences up to 30% in the worst districts based on survey data from a 2015 scoping study (SRA HORT/2005/154). At that time there was no consensus amongst Pakistani plant pathologists on the causes, the epidemiology and the control of the disease. In ASLP1 project (HORT2006/153), much of the epidemiology was investigated and by the end of the project the causal organism was known (*Ceratocystis frimbriata*), the disease development within the tree was described and several management options proposed. In this project (ASLP2) a range of proposed MSD management practices were tested in the field on farm demonstration plots. These tests evaluated the efficacy of chemical and cultural options and how they integrated with other mango management operations.

The preferred management options developed by the project were to identify the disease early in its infection of a tree and to treat the tree with fungicide injections directly into the tree trunk. We also recommend the pruning and removal of dead wood reducing the size of the canopy to reduce the demand on the healing root system. Recovering trees should also have all pests controlled and have adequate fertiliser and irrigation. In addition to these curative measures the project also recommended that orchard sod culture be adopted where no cultivation occurs under trees and that irrigation be directed into individual canopy flood zones to prevent over watering and under watering in different parts of the orchard.

The most effective fungicide combination for the control of mango sudden death when applied early in the infection cycle was a combination of Topsin-M™ (Thiophanate methyl) @ 20g/tree with Bion™ @ 2g/tree injected in to the trunk h)just above ground level. In Sindh a combination of the fungicides Nativo™ (Trifloxystrobin and Tebuconazole) and Alliate™ (Fosetylye aluminum) were also found to be effective in controlling the disease.

A unique fungicide delivery system was developed by Mr Muhammad Tariq Malik, Pathologist from the Mango Research Institute in Multan, Punjab. This was a simple pressurised macro injection system that enabled injection of fungicide in to 4 or 5 injection points in the tree trunk simultaneously, speeding up treatment time and the time the tree needs to absorb the fungicide. The macro infusion system is now used in both Punjab and Sindh mango growing districts.



Figure 15. A simple pressurised macro injection system to apply fungicides in to the trunk of the tree to control mango sudden death. First holes are drilled in to the tree trunk, then nozzles inserted and the pressurised fungicide is applied through the nozzles.

Where these recommended treatments were applied tree death has ceased and sick trees have come back to full production.

After the 2010 and 2011 floods in Sindh where many mango orchards were inundated with flood water for several months, many trees died, Mango sudden death disease infected the majority of flooded trees. Many farmers gave up on these trees and cut them down for fire wood. One farmer provided his orchard as a demonstration site for this project to demonstrate and test the optimum fungicide injection treatment. The farmer claimed he had “nothing left to lose”. The treatment worked and his orchard is back in production. That farmer is now advocating the ASLP mango management protocols in his region with many visitors coming to see the success story.

Genetic resistance. The project also looked for genetic resistance to mango sudden death by screening rootstock and scion varieties for their tolerance to the disease. No significant tolerance was found in any Pakistani mango varieties, however two cultivars ‘Bullocks Heart’ and ‘Carabao Lamao’ imported from Australia showed some promise. We recommend further testing and development of these varieties as rootstocks when sufficient seed are available from the Mango Research Station at Shujabad.

MSD in the nursery - A study was conducted to determine the prevalence of the MSC causal pathogen *Ceratocystis fimbriata* in potting media from nurseries. Samples of media was taken from pots from the nurseries at Multan, Shujabad, Sadiqbald, and Tandojam where trees were growing with no apparent symptoms of the disease. *Ceratocystis* infected 77.8% of the potting mixes tested. This finding is of great concern as it points to nursery stock as a significant cause of the spread of the disease and highlights the importance of adequate media pasteurisation and nursery hygiene.

Mango Malformation Disease (MMD)

MMD prevalence - in 2012 a survey of the incidence and severity of mango malformation disease was undertaken in mango growing districts in Punjab and Sindh by Mr Muhammad Tariq Malik of the Mango Research Institute, Multan and Mr Leemon Kumar, Agricultural Research Institute, Tandojam, who surveyed orchards less than 5 years old the survey report is listed in appendix3 as pest and disease survey_tariq_march_2012_(1).



Figure 16. Mr Tariq Malik, Mango Research Institute, Multan conducting a survey of the incidence and severity of mango malformation and other diseases.

The survey found that:

- Mango malformation disease was widespread throughout all mango growing districts with incidences ranging between 34% to 70% between districts.
- MMD was present in all commercial mango cultivars with the common (‘Desi’) variety having the highest incidence of 63% and the cultivar ‘Bombay’ having the lowest incidence of 29%.
- Most growers were unaware of the annual growth cycle of mango and did not prune their trees, however they were aware of the new recommendations to prune and were thinking of trying it.

- Most growers were using old chemicals and were not aware of new chemistry.
- Most growers and managers could not distinguish between insect and disease damage to trees.
- Intercropping was practised in most orchards with wheat and berseem.
- Most growers applied nitrogen at the incorrect time (after fruit set) negatively affecting fruit quality.
- Most growers were still cultivating and hoeing under and around trees.
- Less MSD was found in no-till orchards that practiced sod culture.

The survey has highlighted just how wide spread this disease is, the inadequate control measures being used and with other evidence from Phase 1 project that a primary source of the disease in new orchards is traditional nurseries.

Spore dispersal - An experiment was conducted to see how far and from where, disease spores can spread. A comparison of traditional and improved orchards was undertaken with the aims of evaluating different management strategies effects on MMD spore dispersal, to monitor the inoculum load at different phenological growth phases of mango, to correlate the spore dispersal of with climatic factors, and to develop disease prediction model.

The experiments found:

- Spore numbers were highest within an infected orchard, gradually reducing with distance from the orchard, however 150 meters from the orchard there were still enough spores to cause infection of trees.
- Spore release was highest during the fruit development stage followed by the vegetative phase and lowest during flowering.
- Spore liberation was not greatly affected by temperature or wind; however relative humidity did affect spore liberation with maximum release at 55% RH.
- The ASLP recommended improved orchard management practices reduced the incidence of mango malformation symptoms by 83.3% and increased yields by 33.3%.

Species identification - Internationally there are many *Fusarium Spp.* associated with



Figure 17. Mango Malformation

malformation like symptoms with some being more pathogenic than others. During the survey of farms in Punjab and Sindh MMD samples were taken for pathogen species identification. Samples were sent to Dr Shazia Iftkhar, Associate Professor Department of Environmental Sciences of Fatima Jinnah Women's University, Rawalpindi for molecular identification. Isolates from Pakistan grouped within the *Fusarium mangiferae* species, confirming that *Fusarium mangiferae* is the actual pathogen of mango malformation in Pakistan.

Management of MMD – the impact of various orchard management practices on the incidence of mango malformation disease was studied:

- The maximum incidence of MMD in an orchard was 35% in unpruned orchards.

- The minimum incidence (3.0%) found in 10 colonies was found in orchards where malformed panicles were pruned off and two sprays of fungicide applied after harvest and after new.

Gall midge

The insect pest known as gall midges were a target of this project as they were widespread in Pakistan mango orchards and there was little known of their identification, life cycles, economic impact and control and management. Dr Shafqat Saeed, Entomologist from Bahauddin Zakaraya University in Multan and his students investigated the impact of gall midges on mango.

A Literature review on gall midges in mango was undertaken as part of the studies and published in the report: "Saeed, S., Saeed, Q., Amin, M.A., Rizwan, M. 2012, Identification, monitoring and damage assessment of cecid flies of mango, Department of Entomology, Faculty of Agricultural Science and Technology, Bahauddin Zakariya University, pp 79." as listed in the Appendix 3.

Species identification - The project identified six different species of gall midges in



Figure 18. Leaf gaul midge, IProcontarinia spp.

mango orchards of the Punjab. Four of the midge species were identified on the basis of damage pattern on leaf, blossom and fruits of mango. Two parasitoid species of gall fly were also identified. Three gall midges, (*Procontarinia mangicola*, *Procontarinia robusta*, and psyllid gall midge and one blossom midge (*Procontarinia mangifera*) were identified as pests. The blossom midge can damage buds, leaves, blossoms, and pea size fruits. These species are all different from the species present in Philippines where they only have one major species *Procontarinia frugivora*, which can damage mature fruit of mango. Blossom midges were found to be active from January to May on buds, blossom, leaves and pea size fruits. From March-September midge activity can reduce fruit yield on different varieties ranging from 30-100% (blossom midge) and indirect yield loss 4-60% (leaf gall midges).

Economic importance – An economic assessment of gall and blossom midges in the Punjab was undertaken by a survey of 28 farms in different mango growing areas of Punjab, i.e. Multan, Shujabad and Rahim Yar Khan. The survey found that:

- more than 10% blossoms were affected at Shujabad and lowest damage was observed at Rahim Yar Khan (6.7%). There was 80-90% loss of fruit yield of these affected blossoms.
- 82% of farmers were unaware of inflorescence midges and 89% were unaware of leaf midges
- only 11% of farmers applied spray to control gall midges.
- The mango Cultivar 'Sindhri' was the most susceptible (59 symptoms /1m³) compared to 'Anwar RatoI' (16.00 symptoms /1m³).

Gall Midge management–Gall midge management protocols to come out of the project recommend that midges be managed early in the season and the population size be monitored by using orange/yellow coloured sticky traps to identify their presence in the orchard. Usually mango growers irrigate mango trees after flowering with intervals of 20-

25 days during fruiting. However, more frequent irrigation on a 15 day interval will suppress midge larvae in the soil by flood irrigation. Several insecticides were tested and foliar application using Movento™, Bifenthrin™, Squadron™, Imidachloprid™, and Pyramid™ were found effective for controlling midges during February to April. Insecticides, Furadon™ and Cartap™ can be used as soil treatment for long term mango midge management but its residual effect on non-target organism need to be studied.

7.4 Objective 4: Postharvest diseases

To determine the prevalence and impact of postharvest diseases and develop management strategies to address them.

Identify postharvest pathogens – Pathogens in fruit from Pakistan’s domestic markets and from farms practising different management practices were identified to profile the species prevalent in Pakistan and to understand the effects of preharvest growing conditions on postharvest rots. Mangoes from Pakistan’s domestic city markets were surveyed for the severity and incidence of postharvest rots. In the 2011 season the most common diseases were stem-end-rot (*Lasiodiplodia theobromae*) and anthracnose (*Colletotrichum gloeosporioides*) that were found in all markets. Alternaria rot (*Alternaria alternata*) and Aspergillus rot (*Aspergillus niger*).

In the second season (2012) studies were focused on pathological and genetic characterization of these post-harvest fungal pathogens (*Lasiodiplodia theobromae*, *Colletotrichum gloeosporioides*, *Aspergillus niger* and *Aspergillus flavus*) and their aggressiveness. All fungi were found to be pathogenic with varying degrees of virulence. the pathogens were less virulent on the mango variety ‘White Chunsa’ as compared to ‘Sindhri’.

The molecular and pathological characterisation of postharvest fungal pathogens was studied in the 2013 season. This study compared traditional farms and farms using ASLP best orchard management practices in six districts of Punjab (Multan, Muzaffar Garh, Rahim Yar Khan) and Sindh (Matiyari, Mirpur Khas, Tando AllahYar).

Stem-end-rot was found to be the major disease in mango orchards and domestic markets. Fungal pathogens associated with stem end rot of mango fruits were prevalent in all locations and were predominately 96-100% by *Lasiodiplodia theobromae* and *Botryosphaeriadothidea*. In the Punjab, two species of *Botryosphaeriaceae* (*Lasiodiplodia theobromae* and *Botryosphaeriadothidea*) were detected in stem-end-rot lesions. These isolates proved to be more aggressive than in the Sindh. The incidence of stem and rot was higher in traditional farmer fields because of poor management practices.

Field management and postharvest control options - In Australia experiments led to a confirmation that heated fludioxonil (Scholar®) as a post-harvest dip option was still best practice (lowest disease rating in all three experiments conducted) for management of both stem end rot and anthracnose. Differences in the efficacy of products depended on the organism being assessed. For example: unheated fludioxonil was more effective at managing anthracnose compared to stem end rot, whereas heated fludioxonil provided control of anthracnose and stem end rot.

Symptoms of dendritic spot which can be caused by either *Colletotrichum gloeosporioides* or *Neofusicoccum parvum*, both were recorded in these experiments. The incidence was extremely low, which may reflect the geographic distribution (of the causal organisms) or the environmental conditions that were not conducive to symptom expression.

In Pakistan postharvest rots in fruit from traditional farms and from ASLP best practice farms were evaluated and In 2011, 2012 and 2013. In the first two seasons fruit from improved practice blocks was variable in its disease susceptibility due to the best practices not being fully practices or trees settling down after their first pruning. However, by 2013 disease was lower in the demonstration blocks using ASLP best practice. This has shown that systematic application of ASLP best practices that include disease management have had a large fruit quality benefit.

Epidemiology of dendritic spot and stem end rot diseases in Australia. Dendritic spot of mango proved to be a difficult disease to study as it was rarely seen during the 3 years of the PhD studies by Ms Arslan Jabeen Quershi on the field and postharvest biology of dendritic spot and stem end rot of mango. However when fruit were bagged at an early stage of fruit development, protecting them from the outside elements, they had lower incidence of both dendritic spot and stem end rot.

A survey of mango growing districts in Queensland, Australia was carried out to determine the fungal pathogens associated with dendritic spot, stem-end-rot and anthracnose symptoms. No major differences between pathogens were associated with the Australian growing districts. Several pathogenic fungi were identified as being able to cause dendritic spot disease (*C. gloeosporioides*, *N. parvum*, *L. theobromae*, *Altenaria sp.*). however *C. gloeosporioides*, *N. parvum* were found to be the most common and virulent pathogens of dendritic spot in Australia.

7.5 Objective 5: Capacity building

Increase extension and capacity building capabilities in the mango industry to improve value chain benefit flows.

This objective planned to increase the human capacity throughout the mango industry in Pakistan from the landless farm workers, small farmers, extension staff researchers in government research institutions and in universities and students that represent the next generation of teachers and researchers in Pakistan.

Several key methods were developed to improve the way horticultural pathological entomologists, extension workers and molecular biologists undertake their work.

Collaborative and research approach

Prior to ASLP it was very uncommon for professionals to work together and share their data for a higher goal. During this project, research teams consisted of personnel from a range of university and government institutions and not only did they work together as a team, but they also regularly visited each other and made presentations to scientific groups and grower groups from other districts. This collaborative approach to industry issue solving was also extended to growers, with research plots and experiments on farmer's orchards and the research staff visiting farmers regularly for training and to learn the real farm practices being used in their industry. Collaboration and coordination within this project was encouraged and driven by the project coordinator Mr Faisal Sohail Fateh and his federal research organisation National Agricultural Research Council (NARC).

The project has adopted a research approach to developing better mango management practices in Pakistan, engaging with Pakistan research scientists to conduct experiments and research trials under local conditions rather than merely demonstrating international practices. The benefit of this approach is that researchers gain valuable training in research methodology and they generate local data that they can use to justify new mango management recommendations. Local growers and mango industry have more faith in locally generated proof of concepts. An example of the success of this method was seen with the research staff of the Mango Research Station at Shujubad, Punjab, where

their research activities gave them the skills and standing with in the Pakistan mango research and extension community to attract funding and projects outside ASLP. They have worked as consultants for USAID and UNIDO.

Specialised extension training

Specialised training in extension and communication for project personnel as a four-day intensive communication skills workshop run by the Australian company E-connect at the Pearl Continental Hotel Bhurban, Punjab between 28 September to 1 October. This workshop was supported by the ASLP agricultural communication fund as a program-wide activity that involved 27 personnel from the ASLP Mango production, Mango Value Chain, Citrus, Dairy and Social projects.

The project also increased the capacity of researchers and extension personnel to extend their messages to growers and others in the mango industry by seminars on extension methods.

- Mr Matthew Weinert, Extension Officer, DAF presented a seminar on modern technology adoption by growers to boost quality and production on 7 March 2012
- Dr Geoff Dickinson, Communications specialist, DAF presented a seminar on extension theory and methods to extension personnel at Bahauddin Zakaraya University, Multan on 29 August 2015.

Developed training curriculum

Local Champions

Appointment of local champions for specific project sectors helped to deliver the outcomes and value chain benefit flows. The project employed two project officers to coordinate activities in Punjab and in Sindh and to lease with regional project personnel and the project coordinator in Islamabad.

Mr Muhamma Asif Arif, ASLP Project Officer Punjab was based at BZU in Multan to coordinate all demonstration sites.

Mr Gul Bahar, ASLP Project Officer Sindh was based at the Agricultural Research Institute in Tandojam, Sindh to to coordinate all demonstration sites and training.

Prof, Nazim Labar, of Bahuddin Zakaraya was appointed as the nursery sector champion in the Punjab. In this roll he coordinated all nursery all nursery training.

Mr Khalid Chaudry, Punjab government extension, was appointed as the extension champion. His appointment helped the project link with the various levels of the Punjab governments extension personnel.

Dr Kazi Sulamon Memon was appointed as the Sindh Agricultural University coordinator. In has roll he coordinated research officers from the university and government with demonstration plots on farms and at the university and with all ASLP training in the Sindh.

Mr Yousif Channa, Agricultural Training Institute, Sakrand was appointed as the training champion for the Sakrand district of Sindh, where he organised orchard management and nursery training.

Extension materials

A series of extension pamphlets and brochures on specific management practices and technologies were developed to assist the communication with growers. These were produced in both English and in local languages that targeted illiterate, poor farmers using photos with ticks and crosses to deliver the messages. A list of the extension pamphlets is given in Appendix 3.

Cluster model demonstration orchards

The benefits to growers and others in the value chain of ASLP management recommendations was enhanced by adopting a cluster approach with demonstration orchards. The cluster approach uses collaborating farmers' orchards as demonstration plots. The demonstration farms are usually village based and surrounded by other similar sized farms. The cluster farms become the focal point for ASLP training and the site for research and surveys. This approach uses the natural social interactions within a village to disseminate information as well as formal training of farmers in the farmer field school style. There have been several successful clusters in the project with clusters considered ideal for studying and understanding adoption pathways.



Figure 19. Farmer field school on pruning of mango orchard held on a Sindh farm cluster.

8 Impacts

8.1 Scientific impacts – now and in 5 years

One of the major scientific impacts of this project has been the way scientific research and extension is undertaken in Pakistan. Prior to the ASLP projects many government and university scientific research institutions were far more competitive than collaborative. It was very rare for University and Government institutions to work together. This project and the previous project (ASLP1) has introduced a new collaborative approach to research and extension in Pakistan where researchers and extension officers are working together on industry issues. The project was Pakistan-wide and an international project with research teams from Pakistan provincial governments (Punjab, and Sindh), Federal agencies (NARC), the university sector (BZU and SAU), private consultants (Hadi Laghari), businesses (Nestle and MAK Nursery) and international (Australia) working on single issues. Practicing this type of collaborative science has improved scientific rigour and increased replication leading allowing discoveries and results to be combined into integrated recommendations for farmers. Many Pakistan researchers have commented that this new approach of working with each other and with industry has changed their mindset to work with modern scientific approach.

Within scientific disciplines there are other scientific impacts that will change the way the science and farming is done in the future. Observing the growth of trees as a continuous cycle of phenological (growth) events with each event setting up the way the following event unfolds has been a significant insight for many researchers, and farmers. Current and future research and recommendations will be undertaken and communicated on tree phenological basis. Tree phenology as a basis for all management actions is being taught in all farmer field schools.

A comment from one Pakistan researcher involved with both ASLP1 & 2 was “The research carried out in the mango sector during the ASLP project carries more value than the work done in the previous 50 years”. With this sort of scientific impact being experienced by researchers and growers, it is likely that the approach will continue into the future and continue to provide improved benefits to Pakistan’s mango industry.

For Mango Sudden Death disease, the causal pathogen has been identified, and systems to recognise the diseases in it’s early stages have been developed. An innovative macro trunk injection method was developed to infuse fungicides in the trees with early stage symptoms to control the disease and cure the disease. In addition to Fungicidal management of the disease, guidelines have been developed to minimise the spread of the disease between trees and to new orchards. These guidelines include ceasing the cultivation under and in between trees to limit root damage where the disease can enter the plant. As a result, the incidence of new trees dying from mango sudden death has reduced in recent years.

Another sector where scientific research and science based management will have a significant impact is in the mango nursery sector. The nursery sector is currently based on methods practiced for hundreds of years with no improvements that manage disease, speed up production or reduce field transport losses. In the ASLP scientific research and evaluation of the nursery sector has identified where traditional nursery practices are failing the industry. Issues such as early disease infection, poor root development, poor branching structure and unknown rootstock genetics were identified. The new nursery management recommendations as laid out in the joint citrus and mango nursery manual and being practiced by a handful of new nurseries who will for the first time give Pakistani growers the choice of buying disease-free, true-to-type, high-health trees with almost no transplant losses.

The other major disease that has spread throughout mango growing regions of Pakistan is mango malformation disease. Prior to the project, mango malformation was known about and was only controlled by flower pruning in the field after the symptoms became apparent. This management technique on its own was unable to eradicate the disease from orchards, reduce the disease's impact on yields or stop it spreading. During the project a lot more knowledge has been acquired about the aetiology of the disease through a literature review of international literature on the disease, through experimental testing of disease spores and how they spread and management options for its control. The primary spread of the disease to new orchards was through infected seedlings from traditional nursery operators. The capacity of the mango nursery sector to contain the disease and produce clean true-to-type plants has greatly improved through basic nursery hygiene and isolation of nursery operations from orchards. Mango malformation disease management strategies were also developed and pruning of all malformed growth from the tree and fungicide sprays after harvest and at the time of any new growth have been recommended.

8.2 Capacity impacts – now and in 5 years

The capacity of the Pakistan project scientists has greatly improved specifically their ability to assess industry needs and develop collaborative projects to undertake targeted research and deliver the outputs and outcomes to industry. The project activities that led to the increase in the capacity of scientists are many and include: improvements targeting specific discipline areas, study tours, practical mentoring by Australian project scientists and interactions between scientists from different institutions and disciplines. Project funded travel of scientists on study tours and conference tours in Australia and outside Pakistan has exposed them to, and encouraged them to work at international scientific standards.

Conferences such as the ICCP 3013 on August 25-30 in Beijing, China, the International Horticultural Congress in Brisbane in August 2004, the XI International mango Symposium in Darwin in September 2015 and the International Society for Plant Pathology Symposium in May 2011 gave Pakistan delegates a chance to network with leading scientists in their fields as well as attend symposia associated training. Examples of such training include the “New frontiers in plant pathology for Asian and Oceania” and the Mango disease workshops between 2nd and 4th May 2011. Other workshops attended by Pakistani project scientists were in the disciplines of molecular biology, entomology, plant physiology, statistical analyses and remote sensing. These conferences and associated training have given Pakistan scientists an appreciation of the level of international science within their discipline areas and enabled them to develop international networks that they can use in their future research.

The collaborative link between government research scientists and private industry is of particular significance as it has demonstrated how these types of arrangements can be a win-win situation that builds capacity in both parties. For example, this project linked the nursery research scientist Mr Inam-ul-Haq, Mango Research Station, Shujabad with several developing commercial nurseries (MAK Nursery, Naseem Nursery and Amir Nursery in Rahim-Yar-Khan district) to visit and provide advice on a monthly basis. These visits not only give the nursery management and workers the chance to get advice from a leading expert, but the researcher also gets an appreciation and experience in the real-world problems being experienced by commercial operators and allows him to see how experimental ideas developed on a research station can be adopted and scaled up in commercial nurseries.

The success of the research science associated with the ASLP2 project and the increased capacity of the scientists involved has already been recognised by other parties in Pakistan. Individual scientists are being recognised by attracting increased research and extension grants. An example of this is the increase in demand for scientific research staff from the Mango Research Station, Shujabad and the Mango Research Institute, Multan. Since undertaking fundamental research in areas such as mango canopy pruning and nutrition, Nursery potting media and mango sudden death disease, they have been requested to develop management protocols, deliver guest lectures and write training curriculums by organisations such as UNIDO, USAID, and other projects such as ASLP the citrus nursery project.

In the next five years the capacity impacts on scientists working on the mango nursery and orchard production is likely to increase as they use the skills they learnt in the ASLP on new projects to continue to develop the Pakistan mango industry. Students working on their degrees during ASLP 2 will be in the workforce in the next 5 years and applying their skills to horticultural research and extension in the private Government and University sectors.

The capacity of farmers and farm workers has increased greatly during the ASLP 2 project with extensive hands-on training of farmers in and around the clustered farms used for demonstration sites of the ASLP best orchard management practices. These farmers are now more aware of the annual growth cycle of mango and how to manage canopy pruning, nutrition, irrigation, pest and diseases in relation to the annual growth cycle to get more consistent higher yields of high quality fruit. The net value increase of their crop was on average 59% in the first season and 65% in the second season.

An example of a small farmer improving his capacity to derive an income from his farm through improving farm management is the young farmer Mr Sadaqat Sheikhan from Multan district who after adopting ASLP best practices has not only increased yields, but has also improved fruit quality resulting in a 77% increase in his average income. Mr Sadaqat has assembled a group of 10 smallholder farmers who now market their high quality fruit in cardboard trays that are delivered directly to customers in the city who order fruit through the internet. These farmers have used the quality of their fruit to develop a small scale marketing enterprise that avoids the normal commission agents that do not currently recognise quality in their payments to farmers. The group also employs two young men to undertake deliveries of fruit. The group sold 31 tons of top quality mangoes packed into cardboard trays in 28 days at a retail price of AUD\$5.00 per 5kg tray compared to AUD3.50 for the same weight of traditionally packed mangoes.

The capacity of the Pakistani mango industry to manage significant diseases and pests that limit yield and kill trees has been greatly improved by the project. Prior to the ASLP projects Mango Sudden Death and Mango Malformation Diseases were killing trees and greatly reducing crop yields. Little was known about the causes and management of these diseases. Many of the traditional nursery and orchard management practices were actively spreading the diseases. The project has developed and tested comprehensive management strategies that have been integrated in to a workable whole of orchard management program.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

Several economic impacts have arisen from this project. They have mainly come from the farmers implementing new orchard and nursery management recommendations that were developed from integrating results from several different research projects undertaken in the project.

The ASLP Mango orchard best management practices, where adopted, have led to increased yields and increased fruit quality that has, in some case, trippled the income from the orchards (111% - 174%). Some of the smaller land holders have still not yet completely adopted all the ASLP mango orchard best management practices due to their ability to afford some of the practices such as spraying. Despite this, they have all been able to adopt the basic pruning recommendations which have improved yield and yield consistency within one or two seasons. In these situations, the sale of pruned wood from the trees as firewood, has enabled them to afford the pruning.

Management of mango sudden death and malformation diseases recommendations also have positive economic impact on grower's incomes. The macro infusion technologies, developed in the project, that link new chemicals with a delivery system has, for the first time, provided a method of stopping the disease from killing trees and restoring them to full production. Prior to the ASLP project it was not uncommon for growers to lose between 7 and 10% of their trees from MSD. If trees are treated early the losses can be reduced to 0%. As an example, one small grower Mr Syed Ali Gohar Shan from Mirpurkhas was about to remove all of his trees due to poor performance and MSD after inundation for weeks after the 2010 floods. He was convinced to delay his tree removal by project researchers and allow them to demonstrate ASLP disease management practices. After treatment with macro infusion fungicides, pruning of canopies and fertilisation of the trees the orchard was nursed back to full health. The farmer has kept the trees and is now advocating the ASLP orchard management protocols to all farmers that will listen to him.

Improvements in fruit quality from adopting the ASLP best practice management has been slower to attract an improvement in the value of their crop. One small grower (Sadaqat Sheikhana) has managed to gain extra value from his improved fruit quality by changing from selling his orchard crop while still on the tree to a commission agent, to direct selling to customers looking for high quality fruit through the internet.

Larger growers, that are exporting mangoes, have already understood the economic advantage from improved fruit quality due to better orchard management and have recognised the traditional timing of nitrogen applications (during fruit development) has a significant detrimental effect on fruit shelf life.

In the future additional economic benefits are likely to arise from other changes in orchard management practices such as irrigation. Research undertaken in this project has shown that by irrigating mango trees more often with a trigger when the soil moisture reached a 15% of field capacity, up to 50% of water can be saved without affecting the tree performance. These research results have come late in the project and have not yet been incorporated into recommendations. Other recommended orchard management practices such as dropping the use of older out-of-date chemicals and using new more effective chemicals to control pests and diseases will improve crop productivity.

8.3.2 Social impacts

Economic benefits achieved from the project will flow on to the farming communities through higher family incomes. The benefits are likely to be in the areas of improved health and education. The cluster demonstration approach has acted as a communal focal point for many villages, stimulating discussions on agricultural practices.

Another social impact of the project has been the interest by some of the larger businesses in Pakistan in the way food is produced. An example of this is the link

between Nestlé and the ASLP project where Nestle has supported demonstration of ASLP best practices through funding of additional demonstration blocks. Nestlé are now able to source fruit for juice from farmers who are undertaking best practise and delivering best quality as well as tell the world of their work to support the livelihoods of small farmers in Pakistan.

8.3.3 Environmental impacts

Environmental impacts of the project will flow from more efficient use of natural resources such as land and water. Traditional irrigation practices on mango flood the whole orchard with little or no directional management of the flood water. This results in overwatering in some parts of the orchard and under watering in others. The ASLP Best Mango Orchard Practice encourages sod culture and bunding to direct water under the canopy and leaving the inter-rows dry, to save water. Scheduling irrigation on a 15% soil moisture in the upper 100 to 600 cm of soil can save up to 50% of the water needed to grow a crop of mango.

The ASLP Best Mango Orchard Practice recommends use of registered effective agricultural chemicals, replacing many of the older less effective chemicals traditionally being used. Removal of ineffective older chemistry will benefit the environment by a reduction in soil residues of toxic poisonous chemicals.

8.4 Communication and dissemination activities

Communicating project findings has been a priority to maximise the benefits that are flowing from both ASLP 1 and 2 mango production projects. Communicating the project activities has used many approaches and has targeted many sectors of the Pakistan mango industry and research and development sectors. The type and number of communication and dissemination activities are outlined below.

Farmer training

Farmer training was undertaken using the model of Farmer Field Schools where a participatory learning approach was used. Most farmer training was done on the project's many demonstration blocks, where ASLP best management practices were demonstrated affording a hands-on experience for farmer clusters in many mango growing districts. Farmer training sessions were conducted on each demonstration block at each stage of the annual growth cycle when management intervention was recommended. This approach allowed farmers to see and be trained by one of the project officers with expert knowledge of the particular management practices being taught. An emphasis was placed on participation encouraging farmers to have a go themselves. Often the training was given by an ASLP project researcher who have developed the management practice.

Extension materials

Pamphlets and brochures were developed throughout the project to communicate some of the technical and management practices to the farmer and nursery communities. The brochures were often translated in to several native languages to make them more accessible to small farmers. Extension materials targeting the small landholders were developed using lots of photos and diagrams so illiterate readers could still understand the messages. A list of extension pamphlets is presented in Appendix 3.

News letters and newspapers and magazine articles

ASLP activities on the demonstration plots on cluster farms attracted a lot of community interest and with it its fair share of newspaper and magazine reports and articles. Sometimes these were written by the project scientists and other times by journalists. The Projects Sindh Project officer Mr Gul Bahar Poussio regularly put timely articles in to local agricultural magazines on mango management and ASLP activities. A list of articles is presented in Appendix 3.

Farm Demonstration plots

A key tool used in the dissemination of mango orchard and nursery practices was demonstration plot. Demonstration plots were developed in mango orchards primarily on grower's properties in small cluster villages but also on research stations and universities. These sites were often referred to as integrated research sites as they were used for training, further orchard management research and to supply fruit for quality studies by this project and our sister ASLP project on the postharvest management and export of mangoes in Pakistan; HORT 2010/001.

Radio and Television

Radio and television were also used as a media to extend the findings and recommendations of the project. Dr Nazim Labar Hussain, Professor of Horticulture, Bahauddin Zakariya University, Multan, has a regular weekly program on a Punjab Agricultural television station. He also is a regular broadcaster on local radio. Dr Nazim regularly featured the activities of the ASLP mango project on his broadcasts.

Field days and expositions

The project booked a booth at several agricultural field days/expositions to highlight the work of the project to the farming community and to the public.

Conferences and symposia

The project was science based project researching and extending best practices in the mango production and nursery sectors. Such scientific conferences and symposia were an important component of the communication strategy of the project to a two-way scientific interaction for the projects scientists. Pakistan project scientists attended many local, national and international conferences and symposia where they presented the work they had undertaken during the project. A list of the conferences attended is presented in Appendix 4.

Scientific publications

Several of the Pakistan scientists working on this project published their work in the scientific literature. A list of scientific publications is presented in appendix 3.

Political, agricultural department and university communications

As this project was one of several projects making up the ASLP program it was necessary to continually communicate with the Pakistan federal and state politicians and senior departmental representatives to inform them of the progress of the project and the good work being done. This approach kept the project and program's profile high among Pakistan agricultural decision makers. The popularity of the project among Pakistan's politicians was shown by the acceptance of the federal Minister for Food Security Mr Bosan to launch the ASLP joint mango and citrus nursery manual.

Video

Video production of extension messages was planned to be more prominent in the project however due changes in the Australian extension specialists associated with the project only one extension video was produced in Australia for the Australian mango industry.

Students

Communication and training of students was a significant part of the project with students being trained at several levels, including several PhD students trained in Australian universities. PhD, Masters and Bachelor degrees were also associated with the project in Pakistan universities. Undergraduate agricultural students often attended ASLP training sessions for farmers and extension workers and undertook small projects related to the studies of the researchers associated with the project. A list of the students associated with the project is presented in Appendix 1.

Project coordination

Much of the success of the project was due to the coordination of the project in Pakistan. The project coordinating institution was the Pakistan federal government agricultural research agency, Pakistan Agricultural Research Council (PARC) led by the Chairman Dr Iftikhar Ahmad and Director Dr Azeem Khan. The project coordinator who managed the day to day coordination of the project program was Mr Faisal Sohail Fateh, Senior Scientific Officer. Having PARC as a coordinator was essential in providing an ongoing management point for all the various state government and university research groups to report to and solve problems as they arose. Travel by Australian project staff was not always possible at the time originally planned and there were some years where the Australian project leader was unable to visit Pakistan. The PARC coordination bridged the gaps where Australians were absent. In periods where the project leader was not in Pakistan, coordination of the project was maintained by Skype and email communication between the Project Leader in Australia and the Project coordinator in Pakistan.

Communication across and between projects within the ASLP program.

Communication across the projects within the ASLP Program was undertaken in Australia and Pakistan by project team members both at formal annual meetings in Canberra and Islamabad as well as during day-to-day operations where activities had dual project relevance.

A major collaboration between the mango and the citrus production projects occurred with activities of nursery improvement leading to a joint Pakistan citrus and mango nursery manual being developed by the Australian team in consultation with many researchers and nursery operators in Pakistan (Figure 10). Communication and collaboration in the nursery sector also extended to joint training of nursery operators in Australia and the outputs of Pakistani potting media research being used in citrus and mango nurseries and mango researchers being used in the training of citrus nursery operators.

Communication between the two mango projects was constant throughout the project concentrating on overlapping areas of interest such as the effects of mango orchard management on the postharvest performance and quality of fruit. Joint areas of work included the identification of mango postharvest pathogens from various markets, districts and management systems in Pakistan.

Communication with the ASLP project occurred formally at annual review meetings in Australia and Pakistan where feedback and was given on activities of the mango production and social projects. Joint social and mango production activities were centred on the Dolat Leghari village in Sindh where the ASLP social project developed a community centre and the mango production project provided tools and orchard chemicals and trained villagers in all aspects of mango orchard management.

9 Conclusions and recommendations

9.1 Conclusions

Key Learnings

One of the key learnings from the project is the need to look at all sectors of an industry if the improvements are to be sustainable.

- Nursery sector is critical to the future of the mango industry in Pakistan and without improvements in the quality of nursery trees the Pakistan mango industry will not be able to manage several critical yield limiting diseases such as mango malformation and mango sudden death.
- Productivity and fruit quality of Pakistan mangoes can be improved through better management of trees in orchards. Both productivity and fruit quality will add value to the crop for growers and others in the value chain. This is especially true for small growers who traditionally have poor horticultural knowledge. Extension and adoption of best mango tree management practices in Pakistan is the best way to realise the potential productivity and quality gains.
- The level of understanding of academics in universities and Government departments on technical and scientific components of growing mangoes is limited and needs continual upgrading as these people are the ones training the next generation.
- One of the key learnings of the Pakistan project participants is in the way collaborative science works and how linkages between researchers, extension officers and growers can give better insight to industry issues and a channel for adoptions of findings of research.

Future needs

- There is an ongoing need to continue the communication and training work started in ASLP if the benefits are to be realised by the majority of Pakistan mango growers. This is especially important for the nursery sector that requires a lot more education of farmers to inform them of the physical and economic benefits of high health nursery trees.
- There is a need for training of university and government researchers in project development skills including writing grant proposals and managing large multi-disciplinary teams. The ASLP project has successfully introduced the collaborative research model where multi-disciplinary research projects address industry issues. However, if Pakistan research institutions are to successfully attract project grants from Pakistan federal and state governments they need to write better research proposals.

9.2 Recommendations

Recommendations for further actions to Increase the likelihood of potential impacts

- Scale up of extension to smaller land holders as outlined above.
- There is a need for a larger skilled agricultural workforce to correctly manage and harvest mango orchards. In regions dominated by small farmers, the gaining of the required skills and the equipment needed to manage trees is often difficult for individual farmers. However, there is an opportunity to employ many of the landless villagers as agricultural contractors who have the skills and equipment to offer services locally such as pruning, spraying and harvesting. The affordability of pruning operations can be offset by selling pruned wood as fire wood.
- One of the research projects undertaken by a PhD student (Mr Rasool Bux Khaskely) of Sindh Agricultural University was to look for saline resistant rootstocks. The local varieties Meho & Sheedi were found to be tolerant to low & medium salinity; whereas the other three varieties (Totapuri, Khatmithroand Sawro) were found to be sensitive to medium salinity levels. This work needs to be continued to go from the discovery phase to using the rootstocks in mango orchards that are on saline soils or are using poor quality water.
- Continue to evaluate rootstock cultivars “Bullocks Heart” and “Carabao” for their tolerance to mango sudden death (MSD).

Follow up project recommendations

- Nationally coordinated mango extension and training project to include provincial extension officers and train them in mango best management practices.
- A nationally coordinated nursery development program with a research component to develop best practices in potting media and seedling production. Nursery hygiene needs to be reinforced as many nurseries that currently claim to be following the ASLP nursery best practices, have potting media infected with *Ceratosystis frimbriata*. A nursery extension component to train nurseries in best nursery practice and a training and awareness campaign to inform growers of the economic benefits of high quality nursery trees including a demonstration field establishment plots.
- Refine tree mango nutrition standards.
- Further evaluation of genetically tolerant cultivars to diseases and abiotic stresses.

10 References

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Ramos, L.J. et al. 1997. The resistance of mango (*Mangifera indica*) cultivars to dieback disease in Florida. *Plant Disease* (1997), 81 (5): 509- 514.

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11 Appendixes

Appendix 1: Student thesis associated with the ASLP project

Table 6. Summary of student involvement with the project.

Degree	Number of student
Ph.D.	8
M.Pil.	6
M.Sc.	21
B.Sc.Hon	20
B.Sc.	27

The details of student involvement with the project are listed below under formal education awards.

PhD studies

Ms Arslan Quershi, 2014, The Epidemiology of Dendritic spot and Stem-end-rot of mango, School of Agriculture and Food Science, University of Queensland, Brisbane, Australia.

Mr Asad Habat Ullah, started 2012, Improving the efficiency of mango breeding, School of Marine and Tropical Biology, James Cook University, Cairns Australia.

Ms Ghazal Naeem, 2012, Efficacy of Different Fungicides on Post Harvest Fungal Disease (Stem-End Rot) Pathogen of Mango, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi

Ms Asma Rasheed, started 2014, PhD, Pathogenic and genetic characterization of strains of *Ceratocystics* affecting mangoes in Pakistan, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.

Ms Madiha Tahir, started 2015, PhD, Detection, Quantification and Molecular Characterization of *Fusarium spp.* associated with malformation in mango orchards of Punjab and Sindh, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.

Ms Amna Malik, started 2015, PhD, Current status of mango pre-harvest diseases with respect to environmental factors, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.

Ms Hajra Faiz, started 2015, PhD, Management of mango diseases anthracnose and blossom blight by ecofriendly methods, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.

Ms Farah Feroze, Started 2014, PhD, Raising productive seedling rootstocks and grafts of mango, Department of Soil Science, Sindh Agricultural University.

Masters studies

Mr. Yaseen Solangi, 201?, M.Sc. Hons. Internship, Survey and identification of different fungi associated with decline plants in Sindh, Plant Pathology, Sindh Agricultural University, Tandojam.

Mr. Sajjad Ahmed Mari, 201?, M.Sc. Hons. Internship, Behaviour of *Fusarium nivale* at different temperature, nutrient media in vitro and their control, Plant Pathology, Sindh Agricultural University, Tandojam.

- Mr. Ghulam Yaseen Dahar, 201?, MS.Sc honours thesis, Physiological studies of *Ceratocystics frimbriata* causal agent of MSD and its in-vitro control, Plant pathology, Sindh Agricultural University, Tandojam.
- Mr Farhan Majeed, (2015), M.Sc.(Hons.), Management of Mango midges through irrigation schedule. Department of Entomology, Bahauddin Zakariya University, Multan.
- Mr Hasham Khaliq, (2014), M.Sc.(Hons.), Survey for damage assessment of Cecid flies on mango in Southern Punjab. Department of Plant and Environment Protection.PARC Institute of Advanced Studies in Agriculture. National Agriculture Centre Islamabad, The University of Agriculture, Peshawar.
- Mr Amin, M. A, (2013), M.Sc.(Hons.), Effectiveness of different traps as a monitoring tools for mango blossom and leaf gall midges. Department of Entomology, Bahauddin Zakariya University, Multan.
- Mr Rizwan M., (2013), M.Sc.(Hons.), Assessment of economic losses incurred by mango gall midges. Department of Entomology, Bahauddin Zakariya University, Multan.
- Mr Muhammad W., (2011), M.Sc.(Hons.), Monitoring and management of mango gall midges through sticky coloured traps. Department of Entomology, Bahauddin Zakariya University, Multan.
- Ms Munaza Rana, 2011-12, M.Sc., Studies on die back disease of mango, Bahauddin Zakariya University, Multan.
- Mr. Talha, 2011-12, M.Sc., Studies on mango malformation disease in Multan, Bahauddin Zakariya University, Multan.
- Mr. Zubair, 2011-12, M.Sc., Monitoring of inoculum load of *Fusarium mangiferae* in improved and traditional mango orchard, Bahauddin Zakariya University, Multan.
- Mr Amir Hussain Goraya, 2013, M. Sc., NPK nutrition of mango at pre & post harvest stages, Department of Soil Science, Sindh Agricultural University.
- Mr Mohammad B. Dalwani, 2014, M. Sc., Sulphur in soil and plant tissue of mango orchards in Sindh, Department of Soil Science, Sindh Agricultural University.
- Mr Saleem H. Babbar, 2014, M. Sc., Macronutrient evaluation in mango orchards of Kotri, Sindh, Department of Soil Science, Sindh Agricultural University.
- Mr Mahander Kumar, 2014, M. Sc.,Macronutrients in mango orchards of lower Sindh, Department of Soil Science, Sindh Agricultural University.
- Mr Mansoor Ali Ansari, 2014, M. Sc., Primary macronutrients in mango orchards of lower Sindh, Department of Soil Science, Sindh Agricultural University.
- Rashid Hussain Arain, 201?, M. Sc., Evaluation of fertilizer practices on NPK nutrition of mango, Department of Soil Science, Sindh Agricultural University.
- Mr Imran Ali Rajpar, 2014, M. Sc., Evaluation of boron in mango orchards of lower Sindh, Department of Soil Science, Sindh Agricultural University.
- Mr Shoaub Ali Jatoi, 201?, M. Sc., Macronutrients in mango orchards of Khairpur Mir's Sindh, Department of Soil Science, Sindh Agricultural University.
- Mr Mohammad Bux, 2004, M.Sc., Sulphur status in soil and plant tissue of mango orchards in some districts of Sindh. Sindh Agricultural University.
- Mr Naseem Kakar, 2014, M.Sc., Boron status in soil and plant tissue of mango orchards in Sindh. Sindh Agricultural University.

Masters of Philosophy studies

- Ms Hamd Meer, 2012, M. Phil., Post harvest fungal spoilage in local Markets of Punjab., Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.
- Ms Qanita Rashid, 2013, M. Phil., Pathological and Molecular Characterization of Post-Harvest Fungal Pathogens of Mango, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.
- Ms Sumera Abrar, 2014, M. Phil. 2014, Genetic variability among post-harvest fungal pathogens of *Mangifera indica* L. by molecular marker, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.
- Ms Sadia Fida, 2014, M. Phil., Isozymes and biocontrol analysis of *Collectotrichum* isolates from diseased mangoes, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.
- Ms Sehar Gullai, 2014, M. Phil., Analysis of Protein and Biocontrol Agent of Stem End Rot Fungi of *Mangifera indica* L., Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.
- Ms Ruqiyya Kausar, 2014, M. Phil., Genetic diversity among isolates of *Colletotrichum* species of *Mangifera indica* L. by molecular marker, Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.

Bachelor's studies

- Ms Hina Imtiaz, 2012, B. Sc. Hons., Genetic variability of *Lasiodiplodia theobromae* isolates from *Mangifera indica* L., Department of Environmental Sciences, Fatima Jinnah Women University, Rawalpindi.
- Mr Aamer Ali, 201?, B Sc., NPK nutrition status of mango at pre and post harvest growth stages, Sindh Agricultural University, Tandojam.
- Mr Rashid, 201?, B. Sc., Comparative evaluation of two fertilizer practices on N, P and K nutrition of mango, Sindh Agricultural University, Tandojam.
- Mr Naseem Kakar, 201?, B Sc., Boron status in soil and plant tissue of mango orchards in Sindh, Sindh Agricultural University, Tandojam.
- Mr Mohammad Bux, 201?, B Sc., Sulphur status in soil and plant tissue of mango orchards in some districts of Sindh, Sindh Agricultural University, Tandojam.
- Mr Imran Khan Rajpar, 201?, B Sc., Comparative evaluation of boron in some mango (*Mangifera indica* L.) orchards of lower Sindh, Sindh Agricultural University, Tandojam.
- Mr Mahender Kumar, 201?, B Sc., Evaluation of secondary macronutrients (Ca, Mg and S) in mango orchards of lower Sindh, Sindh Agricultural University, Tandojam.
- Mr Mansoor Iqbal Ansari, 201?, B Sc., Assessment of primary macronutrients in mango orchards of lower Sindh, Sindh Agricultural University, Tandojam.
- Mr Abdul Saleem Babar, 201?, B Sc., Macronutrient evaluation in mango orchards of Kotri, Sindh, Sindh Agricultural University, Tandojam.

Bachelor's studies, Honours

- Mr. Sajjad Mari, 201?, B.Sc.Hons., Lab protocol, media preparation for fungi associated with MSD, Plant Pathology, Sindh Agricultural University, Tandojam.
- Mr. Sajjad Mari, 201?, B.Sc. Hons. , Lab protocol, media preparation for fungi associated with MSD, Plant Pathology S.A.U Tandojam.
- Mr. Raiz Ali Nahiyoon, 201?, B.Sc. Hons. Internship, Lab protocol, media preparation for fungi associated with MSD, Plant Pathology, Sindh Agricultural University, Tandojam.
- Mr. Sooraj Kumar, 201?, B.Sc. Hons. Internship, Lab protocols, media preparation and isolation of fungi associated with mango through soil dilution method, Plant Pathology, Sindh Agricultural University, Tandojam.
- Mr. Ramesh Kumar, 201?, B.Sc. Hons. Internship, Different Isolation techniques for detection of fungi associated with mango, Plant Pathology, Sindh Agricultural University, Tandojam.
- Mr. Muhammad AyoubHingoro, 201?, B.Sc. Hons. Internship, Isolation and identification of fungi associated with mango nursery plants, Plant Pathology Sindh Agricultural University, Tandojam.
- Mr. Zubair Ali , 201?, B.Sc.Hons. Internship, Isolation and identification of fungi associated with mango sudden death, Plant Pathology, Sindh Agricultural University, Tandojam.
- Mr. Inam Ali Ujjan, 201?, B.Sc.Hons. Internship, Isolation and identification of nematodes associated with mango and banana plants, Plant Pathology, Sindh Agricultural University, Tandojam.
- Ms MarviHingoro, 201?, B.Sc.Hons. Internship, Efficacy of different botanical extract against *Fusarium spp.* Isolated form banana and mango, Plant Pathology, Sindh Agricultural University, Tandojam.
- Ms. LubnaNawab, 201?, B.Sc. Hons. Internship, Pathogenicity test of *Fusarium spp.* Associated with banana and mango, Plant Pathology, Sindh Agricultural University, Tandojam.
- Ms. MeenaKumari, 201?, B.Sc.Hons. Internship, Pathogenicity test of fungi associated with mango nursery plant, Plant Pathology ,Sindh Agricultural University, Tandojam.
- Miss. AnumNaz, 201?, B.Sc.Hons. Internship, Survey of declined plants in the premises of S.A.U Tandojam and their sample collection for lab studies, Plant Pathology ,Sindh Agricultural University, Tandojam.
- Mr Fraz Mushtaq, 2014, B. Sc. (Hons)
- Mr Farhan Majeed, 2014, B. Sc. (Hons)
- Mr Muhammas Ahsan, 2014, B. Sc.(Hons)
- Mr Shafiq ur Rehman, 2014, B. Sc. (Hons)
- Mr Raiz Ahmad, 2014, B. Sc. (Hons)
- Mr Muhammad Umair, 2014, B. Sc. (Hons)
- Mr Muhammad Kalem, 2014, B. Sc. (Hons)
- Mr Muhammad Jawad, 2014, B. Sc. (Hons)

Appendix 2: Training recipients

Table 7. Summary of training of project staff during the project 2011 to 2015

Title	Date	Number of participants	Comments
Diagnosis and management of mango postharvest diseases, NARC, Islamabad	26-28 Aug 2012	24	Specialised training for Plant Pathologists
Hands on Training for day to day management of mango nurseries at Birdwood nursery, Nambour, Australia	May 2013	Mr Inam ul Haq	One week training imbedded in an Australian commercial mango nursery (Birdwood Nursery, Nambour, QLD)
9th Australian Mango Industry association conference, Cairns and Mareeba, Australia	May 2013	Mr Inam ul Haq	Attended 2 day conference and one day field tour. Report Nursery training in Australia May2013 of Inam ul Haq.pdf
Nursery Management Training, Maejo University, Chiang Mai, Thailand	Nov 2014	Mr Inam ul Haq	Sponsored by the ASLP citrus project
e-Connect Communications workshop	2013	27	Specialised extension training.
ICPP Conference, China	2013	Mr Gulbahar	Poster presentation
ACIAR Australia Awards, short training in Australia	Sep 2014	Mr Muhammad Asif Arif	Irrigation training, University of Queensland.
4 th ASIAN Conference on Plant Pathology, and 18 th Biennial Australian Plant Pathology Conference, Darwin	April 2011	22 Pakistani personnel in attendance	Specialised training for Plant Pathologists
Mango breeding and Canopy management training	Sep 2014	Mr Muhammad Asif Arif	One week at DAF Mareeba with mango research team.
29 International Horticultural Congress, Brisbane	August 2014	6 Pakistani personnel in attendance	This symposium was also attended by other Pakistani scientists from other ASLP projects.
XI International mango Symposium, Darwin, Australia	28 Sep - 2 Oct 2015	12 Pakistani personnel	
International Horticultural Conference at UAF Faisalabad	18-20 Feb 2016		

Table 8. Seminars/workshops/training given by the project team during the project.

Date	Seminar or workshop name	Who presented	where	comments
2010 to 2015	Mango diseases and their management in Sindh with special reference to MSD	Mr Leemon Kumar	National Mango Festival	
2011	Mango disease management in rain effected area	Mr Leemon Kumar	Sukrand, Sindh	
2011	Mango disease management in rain effected area	Mr Leemon Kumar	Tando Allahyar	
2011	Mango disease management in rain effected area	Mr Leemon Kumar	Mirpurkhas	
2012-2013	MSD disease and their control along with field demonstration	Mr Leemon Kumar	Agricultural Training Institute, Sakrand, Sindh	pecially arranged for agriculture officers
3 February 2012	Seminar on mango nutrition	Dr Ian Bally	International Agricultural Training Institute, Rahim Yaar Khan, Punjab	
July 2012	Training on mango pruning	Mr Gulbahar, Yusif Chenna, Dr Kazi Sulamon Memon	Demonstration plot at SAU, Tandojam	75 Growers in attendance
26-8 August 2012	ASLP workshop on diagnosis and control of mango postharvest diseases	Mr Faisal Fetah	National Agricultural Research Centre, Islamabad, Pakistan	
27 August 2012	Half day pathology workshop	Dr Chrys Akem and Mr Tony Cooke	University of Faisalabad	
29 August 2012	Seminar on mango tree Nutrition	Dr Ian Bally	Bahauddin Zakariya University	
5 September 2012	Half day pathology workshop	Dr Chrys Akem and Mr Tony Cooke	Sindh Agricultural University	
5 September 2012	Seminar on mango tree Nutrition	Dr Ian Bally	Sindh Agricultural University	
5 September 2012	Seminar on Extension methods	Mr Mat Weinart	Sindh Agricultural University	Pakistan extension research officers
February 2013	Lectures given on improved orchard management,	ASLP Team	Held at ASLP demonstration sites	150 growers in Punjab and 100 in Sindh
2013	ASLP training workshop on mango canopy management	Mr Leemon Kumar	Sindh Agricultural University, Tandojam, Sindh	

7 March 2013	Mango Phenology at the International Seminar on Mango Current Issues and Strategies to Boost Export and Industry	Dr Ian Bally	Mango Research Institute, Multan, Punjab	Attended by 150 growers, students and academics, of which 15 were female.
2013	MSD early symptoms and their control with field practices	Mr Leemon Kumar	Nawazabad farm and Umer Bughio farm, Mirpurkhas, Sindh	USAID Growers
7 March 2013	Modern Technology Adoption by mango growers to boost quality and production at the International Seminar on Mango Current Issues and Strategies to Boost Export and Industry	Mr Mathew Weinert	Mango Research Institute, Multan, Punjab	Attended by 150 growers, students and academics, of which 15 were female.
7 March 2013	Salient achievements of the ASLP Project at the International Seminar on Mango Current Issues and Strategies to Boost Export and Industry	Dr Munawar Raza Kazami and Mr Faisal Fateh	Mango Research Institute, Multan, Punjab	Attended by 150 growers, students and academics, of which 15 were female
8 March 2013	Mango nursery training day and on production of clean mango	Mr Inam ul Haq, Mr Mohammad Tariq Malik	Bahauddin Zakariya University, Multan Punjab	10 growers, 50 students
13 March 2013	Nursery seminar	Dr Noor un Nisa Memon, Dr Kazi Sulamon Memon,	Mirpurkhas, Sindh	
31 March 2013	one day seminar on production of clean mango nurseries	Mr Inam ul Haq	Mango Research Station, Shujabad, Punjab	
April 2013	Presentation on MSD management at one day seminar on mango diseases	Mr Leemon Kumar	Agricultural Extension Naushero Feroze	
April 2013	Mango diseases	Mr Leemon Kumar	Agricultural Research Institute, Tandojam, Sindh	U.A.E and Nigerian expert delegation
May 2013	Mango Sudden death in mango and it's management	Mr Leemon Kumar	Agricultural training institute, Sakrand, Sindh	Extension department Sakrand, Sindh
May 2013	Seminar for Nursery growers	Researchers from SAU	Sindh horticultural research institute, Mirpurkhas, Sindh	25 nurserymen attended
May 2013	isolation and identification of mango fungal pathogens	Mr Leemon kumar and Mr Gul Bahar	ARI, Tandojam	30 students
15- 16 June	2 day workshop on developing farmer field school curriculum for extension workers. Students, and ASLP demonstration growers Multan, Punjab.	Faisal Fateh and ASLP team	Multan, Punjab	

4 July 2013	Mango Canopy workshop	All the Sindh ASLP team	Sindh Agricultural University, Tandojam	Banners for Back Drop in the Hall and for the Field.jpg Invitation Card2.jpg
30 November 2013.	One day seminar on Nursery hygiene and transplantation of new nursery plants	Inam ul Haq	Bahauddin Zakariya University, Multan Punjab	
30 November 2013.	Orchard floor management training	MRS team	Bahauddin Zakariya University, Multan Punjab	
1 December 2013	ASLP experience sharing workshop with ASLP mango value chain	Project staff from ASLP production and value chain projects	SAU, Tandojam	
17 to 18 January 2014	Consultative workshop on the development of a vision a training curriculum for Pakistan mango industry – ng		organised by PHDEC at Agricultural Extension, Shahabz building, Hyderabad	Attended by ASLP project team and others from government and university sector
2014	Nursery diseases and their control	Mr Leemon Kumar	Sindh Horticultural Research Institute, Mirpurkhas, Sindh	
8 March 2014	One day seminar on Nursery hygiene and transplantation of new nursery	Inam Ul Haq	Bahauddin Zakariya University, Multan Punjab	
10 April 2014	Seminar potting media at a one day training workshop on high health citrus and mango nursery promotion through modern techniques at	Inam up Haq, Dr Nazim Labar	Bahauddin Zakariya University, Multan Punjab	
4 July 2014	ASLP Training Workshop on Mango Canopy Management	Dr Kazi Sulamon Memon, Mr Faisal Fateh, Mr Gul Bahar, Mr Leemon Kumar, Mr Ishail Kumbhar, Mr Hadi Bux Leghari	Sindh Agricultural University, Tandojam, Sindh	
Mach 25 2014.	Salinity tolerance of mango rootstock, training workshop for farmers	Mr Rasool Bux Kashkheli and Dr Rajupt	Senate Hall, SAU, Tandojam,	
	Training of injection techniques against MSD at cluster demonstration plot			40 Growers
	Demonstration of Mango Malformation management on integrated research sites			20 Growers
29 April 2015	Extension theory and methods	Dr Geoff Dickinson	BXU, Multan	

Table 9. Landholder training events given by the project team.

Training description	Number of events	Participant Number
Training workshops on mango Sudden death	18	900
Training workshops on mango malformation disease	22	1100
Management of nursery diseases	3	150
Plant protection Issues in mango	25	2000
Lectures to under graduate Plant pathology at Universities	7	550
Total people trained in nursery technologies in Punjab	20	1500
Farmers and researchers exchange visits between Punjab and Sindh institutions	3	20
ASLP Farm Demonstration sites	28 Punjab, 13 Sindh	41
Demonstration of injection methods	5	33
Nursery disease management and their remedy	5	33
Screening of different fungicides at farmers field	5	33
Suggestion and control measures of mango diseases.	5	33
MSD Disease survey and sample collection.	5	33

Appendix 3: Publications and reports produced by project

Journal Publications

Abro, M. A., Marri, S. A., Kumar, L., Pussio, G. B. 2014, Behaviour of *Fusarium nivale* causal agent of mango malformation against different culture media and range of different temperatures and *in-vitro* control, European Academic Research Journal, Vol. 2 (8), 10089-10113.

Khaskheli, M. I., Jiskani, M. M., Soomro, M. H., Talpur, M. A., & Poussio, G. B. (2011). Prevalence of Mango Sudden Decline/Death Syndrome (MSDS) on Various Varieties at the Orchards of Different Age in the Vicinity of Tando Qaiser, Hyderabad, Sindh. *Pak. J. Agri., Agril. Engg., Vet. Sci*, 27(2), 160-167.

Kumar, Leemon. Et al., (2015) Effects of integrated practices on the yield of mango in ASLO demonstration block, submitted.

Kumar, Leemon et al., Screening different fungicides against MSD through injection methods, Submitted,

Asif, I., Faisal, F.S. Munawar, K.R. Chrys, A.N., Poussio, G. B., Nazim, L.H., 2011, Trend of mango sudden death syndrome (MSDS) in relation to fungal microflora and nematodes fauna in Punjab, Pakistan, Pakistan journal of nematology, Vol. 29 (1), 45-51.

Gul Bhar Poussio, Munawar Raza Kazmi, Chrys Akem, Faisal Sohail Fateh. First record of *Ceratocystis fimbriata* associated with shisham (*Dalbergia sissoo*) decline in Pakistan,

Australasian Plant Disease Notes, 2010, 63-65, DOI: 10.1071/DN10023.

Poussio, G. B., et. al , 2015, Influence of different fungicides and Plant extracts against *Ceratocystis fimbriata* associated with mango sudden decline (MSD) , Accepted in Indian Journal.

Poussio, G. B., et. al, 2015, Effect of irrigated management practices on the mango yield at ASLP-mango demonstration block, Acta Horticulturae Accepted

Iram.S. and Abrar. S. 2015. Pathological and molecular characterization of post harvest fungal pathogens of mango. International Journal of Agronomy and Plant Production. **Impact factor 0.467.**

Iram, S., Rasool, A. and Ahmad. I. 2014. Comparison of incidence, prevalence and severity of post-harvest fungal diseases in Pakistan improved integrated management orchards and conventional practices blocks. International Journal of Scientific & Engineering Research. 5(10) 1274-1284. **Impact Factor:3.2**

Iram.S. and Abrar. S. 2014. Isolation and Molecular Characterization of *Lasiodiplodia theobromae* by SSR Markers. International Journal of Agronomy and Plant Production. 5 (1) 31-36. **Impact factor 0.467.**

Rashid, A., Iram, S. And Ahmad. I. 2014. Molecular characterization of *Ceratocystis manginecans* sp. from mango in Pakistan. Pakistan Journal of Agricultural Sciences. 51(4), 901-905. **Impact factor 1.054**

Rashid,A., **Iram,S.,** Ahmad,I. Study on Incidence, Molecular Characterization and Pathogenesis of Different Fungi Associated with Sudden Death of Mango. International journal of Agronomy and Plant Protection. Vol. 51(4), 901-905. **Impact factor 0.467.**

Iram, S., Meer, H. and Ahmad, I. 2013. Major post-harvest diseases of mango and their management. International Journal of Agronomy and Plant Production. 4 (12): 3470-3484. **Impact Factor 0.467.**

Meer, H., **Iram, S.,** Ahmad, I., Fateh, F.S. and Kazmi. M. R. 2013. Identification and characterization of post harvest fungal pathogens of mango from domestic markets of Punjab. International Journal of Agronomy and Plant Production. 4(4) 650-658. **Impact factor 0.467.**

Syed Atif Hasan Naqvi, Rashida Perveen, M. Tariq Malik, Owais Malik, Ummad ud Din Umer, M. Sajid Wazeer, Ateeq ur Rehman, Taha Majid, Zaighum Abbas, Characterization of symptoms severity on various mango cultivars to quick decline of mango in district Multan, International Journal of Biosciences (Online) Vol. 4, No. 11, p. 157-163, 2014.

Masood, A., Saeed, S. H. A. F. Q. A. T., Iqbal, N. A. E. E. M., Malik, M. T., & Kazmi, M. R. (2010). Methodology for the evaluation of symptoms severity of mango sudden death syndrome in Pakistan. *Pakistan Journal of Botany*, 42(2), 1289-1299.

Masood, A., Saeed, S. hafqat Saeed., Silveira, S. F. D., Akem, C. N., Hussain, N. A. Z. I. M., & Farooq, M. (2011). Quick decline of mango in Pakistan: survey and pathogenicity of fungi isolated from mango tree and bark beetle. *Pak. J. Bot*, 43(3), 1793-1798.

Masood, A., Saeed, S., Mahmood, A., Malik, S. A., & Hussain, N. (2012). Role of Nutrients in Management of Mango Sudden Death Disease in Punjab, Pakistan. *Pak J. Zool*, 44(3), 675-683.

Saeed, S., Khan, M. I., & Masood, A. (2011). Symptom development after artificial inoculation of *Botryodiplodia theobromae*, a possible causal organism to quick decline in mango trees. *Pak. J. Agri. Sci*, 48(4), 289-294.

Saeed, S., Masood, A., & Khan, S. M. (2012). Diseased Plants as a Source of Dissemination of Mango Sudden Death Disease in Healthy Mango Plants. *Pak. J. Phytopathol*, 24(1), 21-25.

Iqbal, N., & Saeed, S. (2012). Isolation of Mango Quick Decline Fungi from Mango Bark Beetle, *Hypocryphalus Mangiferae* S. (Coleoptera: Scolytidae). *J. Ani. & Plant Sci*, 22(3), 644-648.

Conference proceedings

Ul Haq, Inam., Ghaffar, Abdul., Umar, Humara., 2015, Standardization of potting media for the rapid growth of mango nursery plants, proceedings of the XI International Mango Symposium, *Acta Horticultuae*, accepted, pp7.

Fateh, F. S., Ahmed, I., Malik, T. Bally, I. S. E., Mehmood, A., Kazmi, M.R., 2014, Factors affecting the Adoption of good mango orchard management practices in Pakistan, Proceedings of IHC, Brisbane, XX –XX August 2014

Ibell, P., Bally, I., Wright, C. and Maddox, C. 2015, When is the best time to apply post-harvest Nitrogen fertiliser? proceedings of the XI International Mango Symposium, *Acta Horticultuae*, accepted.

Ibell, P., Bally, I., Wright, C. and Maddox, C. 2015, Does soil applications of fulvic acid applied with potassium sulphate influence mango fruit quality?, proceedings of the XI International Mango Symposium, *Acta Horticultuae*, accepted.

Quershie, A., Galea, V., Akem, C., Atkin, E., Bally, I., 2013, The effect of postharvest hot fungicide dip and exogenous ethylene gas application on the incidence of dendritic spot and stem end rot in Kensington Pride (KP) mangoes. The 19th Australian Plant Pathology Conference, 25- 28 November 2013, Auckland, New Zealand.

Quershie, A., Galea, V., Akem, C., Atkin, E., Bally, I., 2013, The effect of bagging on the incidence of dendritic spot and stem end rot in Kensington Pride (KP) mangoes. The 19th Australian Plant Pathology Conference, 25- 28 November 2013, Auckland, New Zealand.

Conference posters

Quershie, A., Galea, V., Akem, C., Atkin, E., Bally, I., 2013, The effect of bagging on the incidence of dendritic spot and stem end rot in Kensington Pride (KP) mangoes. The 19th Australian Plant Pathology Conference, 25- 28 November 2013, Auckland, New Zealand.

Arif, Asif., Malik, M. T., Hussain, H., Ahmad, I., Bally, I., 2014, Management of tree decline using thiophanate methyl and plant activators through a macro infusion system, International Horticultural Congress, Brisbane, XX – XX August 2014,

Poussio, G. B., et. al, 2015, Effect of irrigated management practices on the mango yield at ASLP-mango demonstration block, XI International Mango Symposium, Darwin Australia, September 28 to October 02 2015.

Ul Haq, Inam., Ghaffar, Abdul., Umar, Humara., 2015, Standardization of potting media for the rapid growth of mango nursery plants, proceedings of the XI International Mango

Symposium, Darwin Australia, September 28 to October 02 2015.

Local language journals

Gulbhar Poussio, ASLP Project Officer, Sindh, November 2012: Intercropping and uses of irrigation in mango orchard, Monthly Sindh Zraiat, November ed., pp (24)

Gulbhar Poussio, ASLP Project Officer, Sindh, December 2012: December activities in mango orchards, Monthly Sindh Zraiat, December ed., pp (24)

Gulbhar Poussio, ASLP Project Officer, Sindh, January 2012: January and February activities in mango orchards, Monthly Sindh Zraiat, January ed., pp (32)

Gulbhar Poussio, ASLP Project Officer, Sindh, The role of irrigation and intercropping in mango orchards, Sindh Zarait Magazine, January 2013

Gulbhar Poussio, ASLP Project Officer, Sindh, December activities in mango orchards, Sindh Zarait Magazine, December 2013

Gulbhar Poussio, ASLP Project Officer, Sindh, February activities in mango orchards, Sindh Zarait Magazine, January 2014

Kumar, Leemon., 2012, Mango Sudden death and their management after rain flood in Sindh, National Mango Souvenir, 2012

Radio and Media presentations

Lemon Kumar gave 3 TV and one Radio interview

Dr Nazim Labar of Bahauudin Zakaraya University, Multan gave regular radio and TV commentary on the ASLP Project.

Published abstracts

Poussio, G. B. et al, 2013, Culture sensitivity test of *Ceratocystis fimbriata* associated with Mango Sudden Death/Decline (abstract published in ICCP 2013 August 25-30 Beijing, China)

Poussio, G. B. et al, 2013, Pathogenic and genetic characterization of strains of *Ceratocystis sp.* Affecting mangoes in Pakistan (abstract published in ICCP 2013 August 25-30 Beijing, China)

Poussio, G. B. et al, (????), Efficacy of different fungicides and application methods against MSD (Mango Sudden Decline) *in-vivo*.

Poussio, G. B. et al, 2013, Pre-harvest management strategies for post-harvest diseases control in mango (abstract published in ICCP 2013 August 25-30 Beijing, China)

Iftikhar, Shazia., Fateh, Faisal., Bally, I., Ahmed, Iftikhar., 2014, Mango Postharvest Pathological studies in Pakistan (abstract published in IHC, Brisbane, August 2014, congress handbook)

Hussain, N., Arif, A. M., Saeed, S., Ahmad, I., Bally, I. S. E., 2014, Comparative study of high health and conventional mango nurseries in Pakistan (abstract published in IHC, Brisbane, August 2014, congress handbook)

Saeed, S., Amin, M. A., Saeed, Q., Rizwan, M., Hussain, N., Bally, I., Newton, I., Kazmi, M. R., Ahmed, I., 2014, Studies on monitoring damage assessment and management of mango gall midge in Pakistan, (abstract published in IHC, Brisbane, August 2014, congress handbook)

Kumar, L., ????, Culture sensitivity test of *Ceratocystis frimbariata* associated with mango sudden death.

Behaviour of *Fusarium nivelea* at different ranges of temperature nutrient media and *in-vitro* control

Associated publications and Reports

Anon (2014). Codes of Practice of Mango Farm Management, Manual for the Training of Master Trainers. Faisalabad, Pakistan, UNIDO - TRTA II.

Bally, I., Donovan, N., Kurshid, T., and Falvine, S., 2013, Training of Pakistani Nurserymen in Australia, report to Agriculture Sector Linkage program, Agricultural Capability fund, pp43.

Ul Haq, Inam., Ghaffar, Abdul., Umar, Humara., 2012, Standardization of potting media for the rapid growth of mango nursery plants, report to Project leader on research activity, pp7.

Johnson, G.I. Akem, C., Weinert, M., Munawar R Kazmi, Faisal Sohail Fateh, Abdul Rehman, Shazia Iftikhar, and Cooke, A.W. (Eds) 2012. Handbook for a Workshop on Diagnosis & Control of Mango Postharvest Diseases –26-28 August, 2012, National Agricultural Research Center, Islamabad, Pakistan ACIAR pp 58.

Saeed, S., Saeed, Q., Amin, M.A., Rizwan, M. 2012, Identification, monitoring and damage assessment of cecid flies of mango, Department of Entomology, Faculty of Agricultural Science and Technology, Bahauddin Zakariya University, pp 79.

Ul Haq, Inam, 2013, Nursery training in Australia, final training report (Nursery training in Australia May2013 of Inam ul Haq.pdf)

Rajpur, I. and Khaskhely, 2015, Evaluating salinity tolerance of mango rootstocks, Project Brief, Centre for Biosaline Agriculture, Department of Soil Science, Faculty of Crop Production, Sindh Agricultural University, pp 5.

Khan, M. A. and Chan, K., 2014, Codes of practice for mango farming & processing., Trade Related Technical Assistance programme (TRTA II) United Nations Industrial Development Organisation, pp27. (UNIDO Mango Codes of Practice. pdf).

Annual Project Reports

2011 annual report HORT2010/006

2013 annual report HORT2010/006

2014 annual report HORT2010/006

2015 annual report HORT2010/006

Extension pamphlets

Nursery pamphlets

- Basic requirements of clean mango nursery
- Basic requirements of grafting
- Potting mixes for mango nurseries - guidelines.pdf Care of hygiene during grafting.pdf
- A training guide how to raise mango nursery a training guide
- A comparison between clean and traditional nursery.pdf
- Shujabad, Mango Nursery Manual.pdf
- Pre-Feasibility of Clean Container Mango Nursery.pdf
- Nursery management guidelines.pdf

Disease pamphlets

- Development of ICM Practices in mango - in Urdu.pdf
- Mango sudden death management - in Urdu - mango sudden death management.pdf
- Pictorial symptoms of mango sudden death.pdf Mango sudden death – in Urdu – mango sudden death.pdf
- MSD early detection.pdf
- Survey report for the assessment of mango insects & diseases during flowering season, 2012 – Pest and Disease Survey, March 2012.
- A Review on the epidemiology of mango malformation - A Review on the epidemiology of mango malformation.docx
- Different forms of mango tree decline in Pakistan.pdf,
- ASLP mango leaf diseases.pdf, one page pamphlet.

Orchard management pamphlets

- Mango Orchard Management for Punjab - english.pdf
- ASLP Integrated crop management.pdf, in Urdu
- Existing and modern mango orchard management.pdf, pamphlet for illiterate growers.
- ASLP activities.pdf one page flyer in Urdu.
- Urdu version of mango orchard management guide – ASLP Urdu.pdf
- Development of ICM Practices in mango - in Urdu.pdf, ASLP ICM booklet.pdf
- Mango Management in Sindh along with mango growers' directory, (in English, Urdu and Sindhi).
- Mango Management Calendar Sindh.
- Use of Paclobutrazol (PBZ) in mango orchards

Future planned publications

- Genetic variability among post-harvest fungal pathogens of *Mangifera indica* L. by molecular marker
- Isozymes and biocontrol analysis of *Colletotrichum* isolates from diseased mangoes.
- Analysis of Protein and Biocontrol Agent of Stem End Rot Fungi of *Mangifera indica* L
- Genetic diversity among isolates of *Colletotrichum* species of *Mangifera indica* L. by molecular marker
- Management of mango diseases anthracnose and blossom blight by ecofriendly methods
- Current status of mango pre-harvest diseases with respect to environmental factors

Appendix 4: Conferences and symposia attended

Table 10. Conferences and symposia attended and presentation types given by Pakistani project officers during the Project HORT2010/006

Conference name	Project delegates	presentations
10 th International Congress of Plant Pathology	Mr GulBahar Poussio Mr Faisal Fateh Dr Shazia Iftikhar	Poster Poster Oral
4 th ASIAN Conference on Plant Pathology, and 18 th Biennial Australian Plant Pathology Conference, Darwin, April 2011	Mr Faisal Fateh Mr Mohammad Tariq Malik 4 others	
29 th International Horticultural Congress, Brisbane, August 2014	Mr Faisal Fateh Mr Mohammad Tariq Malik Mr Mohammad Ikhlāq Mr Yusof Chenna Dr Shazia Iftikhar Mr Muhammad Asif Arif	Oral Oral None None Oral Poster
11 th International Mango Symposium, Darwin, Australia, 28 September to 2 October, 2015	Mr Faisal Fateh Dr Nazil Labar Hussain Dr Shazia Iftikhar Mr Inam ul Haq Dr Iftikhar Ahmad Dr Noor un Nissa Memon Dr Mehurum Nisa Memon Mr Gulbahar Poussio Dr Shafqat Saeed Mr Asad Habaat Mr Ismail Kumbhar	Oral None Oral Oral None Oral Oral Poster Oral Poster Oral
9 th Australian Mango Industry Association Conference, Cairns, Australia May 2014	Mr Inam ul Haq	none

Appendix 5: Personnel associated with the project

Table 11. personnel associated with each Pakistan collaborating institution

Queensland Department of primary Industries			
Name	Association	ASLP Project area	Associated people
Dr Ian Bally	Project Leader	Leader and Horticulture research	
Dr Chrys Akem	Past Project Leader	Project initiation	
Dr Ian Newton	Senior Entomologist	Project Scientist (Entomology)	
Mr Tony Cooke	Senior Experimentalist	Project Scientist (Pathology)	
Dr Geoff Dickinson	Senior Horticulturist	Project Scientist (extension)	
Mr Mather Weinert	Senior Horticulturist	Project Scientist (extension)	
Dr Paula Ibell	Horticulturist	Project Scientist (Australia, plant physiology research)	
Ms Michelle Sinn	Project administration	Principal Coordinator External Funding	
Australian Centre for International Agricultural Research (ACIAR)			
Name	Association	ASLP Project area	Associated people
Dr Les Baxter	Previous Research Program Manager Horticulture	ASLP Coordination	
Dr Richard Markham	Current Research Program Manager Horticulture	ASLP Coordination	Mrs Chunyan Jia
Dr Kazmi Munawar	ASLP Operations Manager (Pakistan)	ALSP Program Operations	Ms Ayesha Arif Ms Rashida Ismail

Pakistan Agricultural Research Council, Islamabad			
Name	Association	ASLP Project area	Associated people
Dr Iftikhar Ahmad	Chairman PARC	Project Leader ASLP Mango Pakistan	All team of ASLP
Dr Azeem Khan	DG NARC	Focal Person ASLP Projects NARC	All team of ASLP
Faisal Sohail Fateh	Senior Scientific Officer	Project Coordinator	All target group of ASLP Kamran Ahmad Khan Zahir Naqvi Muhammad Fayyaz
Fatima Jinnah Women University (FJWU), Rawalpindi, Punjab			
Dr Shazia Iftikhar	Associate Professor Focal Person ASLP FJWU	Project Researcher	All students involved
Sindh Agricultural University Tandojam, Sindh			
Dr Kazi Suleman Memon	Projets and program Co-ordinator	Focal Person ASLP SAU	All field staff
Mr Ismail Kumbhar, Assistant Professor	Agricultural Extension	Focal Person ASLP SAU	Naseer Abbasi Jamshed Lal Bux Habib Sanallah
Dr. Inayatullah Rajpar	Chairman Department of Soil Science	Salinity Reseach	All students involved
Associate Professor Dr Mehrun Nisa Memon	Department of Soil Science	Mango orchard Nutrition	<u>Labour</u> Saeen Bux, Hakim Ali, Shevram, Kheemon Shaarif, Maqbool Hussain, Mola Bux Bhatti
Mr Rasool Bux Khaskheli, PhD	Department of Soil	PhD Student	All field staff

scholar		Salinity resistance in mango	
Dr Noor un Nisa Memon, Associate Professor	Department of Horticulture	Researcher	Mr. Habib, nursery Staff and students involved
Agriculture Research Institute Tandojam			
Lemon Kumar	Department of Plant Pathology	Researcher	All laboratory and field staff
Gul Bhar Poussio	Department of Plant Pathology	Project/Field Officer ASLP Mango Sindh	All research team
Sindh Horticulture Research Institute Mirpur Khas			
Noor Muhammad Baloch	Director Horticulturist	Researcher	All field staff
Ashraf Soomro	Director Plant Pathologist	Researcher	All field Staff
Agriculture Trainig Institute Sakrand			
Yousaf Channa	Focal Person ASLP Extension activity Sindh	Extensionist	All field staff
Asim Agriculture Farm (AAF)Tando Allahyar			
Imdad Nizamani	Progressive Grower	ASLP partner grower and facilitator	Labour of AAF
Mr Hadi Bux Leghari, Farm Consultant	Asim Farms, private consultant	Researcher, Facilitator and Resource Person	All field staff
Mango Research Station Shujabad, Punjab			
Mr Abdul Ghaffar	Horticulturist Incharge	Researcher	All field staff
Muhammad Ikhlq	Assistant Horticulturist	Researcher	All field staff
Inam ul Haq	Assistant Research Officer	Researcher	All nursery staff
Mrs. Humara	Assistant Research Officer	Researcher	All nursery staff
Mango Research Station Shujabad, Punjab			

Mr Muhammad Tariq Malik	Assistant Plant Pathologist	Researcher	All laboratory and field staff
Muhammad Ammar	Assistant Research Officer	Researcher	All laboratory staff
Bahauddin Zakariya University Multan			
Dr Nazim Hussain Labar	Professor Agronomy	Researcher and extensionist	All field staff
Dr Shafqat Saeed	Professor Entomology	Researcher	All field staff and students involved
Asif Mahmood Arif	Project/Field Officer ASLP Mango Punjab	Researcher and facilitator	All field labour involved