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Final report

project

Development of integrated crop management practices to increase sustainable yield and quality of mangoes in Pakistan and Australia

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1 Acknowledgments

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2 Executive summary

The four focus areas of the ASLP mango production project were: 1. Establishment of clean nurseries, 2. Improvements in orchard husbandry, 3. Detection and management of mango sudden death and 4. Improvements in training and extension services.

Significant achievements were recorded with the different activities associated with each of these focus areas during the operation of the project.

For the establishment of clean nurseries, two clean mango research nurseries were established at Research Institutes; one at the Mango Research Station (MRS) Shujabad in Punjab and the other at the Sindh Horticultural Research Institute (SHRI)at Mirpurkhas in Sindh. At both stations, some structures were re–furbished to establish good functional research nurseries which are now used as main centers for capacity building for private nursery operators. Experiments were conducted at these centers on a range of about 200 different media combinations from various local materials and two of the combinations showed good results and are being fine-tuned so that they can be used for various nursery research activities. Activities already in place in the research nursery include the evaluation of 30 mother plants made up of 6 different commercial varieties, so that clean bud wood can become available to commercial nursery operators for propagation. Local germplasm has been evaluated for root stock selections for use to improve adverse abiotic conditions and so far little break throughs have been realised, mainly because many of them are of mono-embryonic nature. Seedling plants of a known poly-embryonic salt tolerant variety (13-1) were imported from Australia and shared with the different research institutions for evaluation and use in future plant improvement programs.

The other activity associated with clean nurseries was to encourage and technically assist private commercial nursery operators to establish model commercial nurseries in each of the two main mango production regions of Punjab and Sindh, from which other operators could learn and duplicate in their establishments. One private commercial nursery operator from Multan (Faiz-a-Aam) was trained through a Crawford fund fellowship in a leading commercial nursery in Australia. Using this training and technical guidance from the Project Team, he was able to transform his nursery into a modern commercial clean establishment and is now selling clean plants to the public at premium prices. This has generated a lot of interest among other commercial nursery operators from Punjab & Sindh who are now trying to duplicate what he is doing.

The development and distribution of a nursery manual was another activity associated with the clean nursery focus. This became a joint initiative in collaboration with other research institutions that had a similar objective in their operational programs. This activity is yet to be finalised but a locally produced draft by the Fruit & Vegetable Development Project of Punjab is currently being evaluated and will form the basis for the final outcome of the activity.

The second focus area of the project was the improvement of plant husbandry. For this, nutrient and canopy management trials were conducted at Research Stations to which growers were invited at Field Days held at the different phenological stages of the crop development. The results of the pruning trials were very successful, indicating that current orchards could be improved through appropriate nutrient applications and a carefully planned pruning schedule to reduce tree height, without severely affecting the yields of quality fruits. This activity is being extended and demonstrated on model blocks at different sites on growers' properties across the different mango production districts of Punjab and Sindh provinces.

Experiments to assess the accuracy and useability of the Konica Minolta SPAD-502 chlorophyll meter to measure nitrogen concentrations in mango leaves and fluctuations in leaf N over time showed a significant linear relationship between the leaf chlorophyll index obtained with the meter and total leaf N in the mango cultivars Kensington Pride, R2E2 and Honey Gold, when analysed using simple linear regression. Thus the SPAD-502 meter can be used to monitor chlorophyll which can be correlated to the uptake and fluctuations in Nitrogen in mango trees over time.

At the start of the project, one of the biggest constraints reported by stakeholders and identified during a pre-project scooping study was the threat of the Mango Sudden Death Syndrome (MSDS). By popular demand from growers and other stakeholders, this became an important focus of the project activities. Through close linkages with an on-going national project on the aetiology and management of the disease, the main causal agent of the disease (*Ceratocystis fimbriata*) was established. This was a significant achievement, given the controversy surrounding the cause of the disease because of diverse published views and claims by different researchers. Studies through a graduate student thesis supported by the project, also established that the ambrosia beetle is a vector for the disease causing organism. Evaluations were also made on options for the management of the disease. Among these were different fungicides evaluated as tree sprays, trunk drenches and stem injections; cultural options such as orchard cultivation and flood irrigation systems. These did not produce any conclusive results and were recommended for further evaluations as part of integrated management systems for the disease.

Based on the findings from the MSDS management to date, a grower guide showing various stages of symptoms development was produced to help growers decide what interventions were needed at different stages of the disease development and when to decide that it was too late to safe the tree and it should be replaced. Different demonstration sites were also set up to guide the growers with different integrated disease management options that are currently available to stop or slow down the establishment and spread of the disease.

Some investigations were also undertaken to improve the timing of field fungicides application for the management of mango postharvest diseases. Based on different combinations and timings, it was established that a single systemic fungicide application at the very early stages of fruit development was more effective than one applied towards the end of the season, in controlling postharvest diseases of mango fruits.

Project findings were disseminated throughout the duration of the project through grower seminars, printed brochures and handouts and during field days. To share project outcomes with the different stakeholders, eleven issues of a Mango Newsletter were jointly produced with the Supply Chain project team and periodically distributed. Six brochures highlighting the project outcomes were also produced and distributed to growers and other stakeholders. A DVD highlighting mango nursery set up procedures was also produced and distributed to researchers and private nursery operators. The project developed close collaboration with the Punjab Fruit and Vegetable Development project through their established Farmer Field School (FFS) and through this more than 5000 farmers were trained in a year-long training in mango production practices, through 63 FFS dispersed throughout production districts of Punjab.

In other training activities, about 7000 growers, 385 extension workers, 550 students and 52 researchers were trained locally. There were also opportunities for overseas training in Australia. One John Dillon Fellowship for a short term visit and one John Alright Fellowship long term study fellowship were awarded project team members through a very competitive process.

3 Background

Poor horticultural practices and lack of disease quarantine measures during the establishment of new orchards are severely limiting the productivity and fruit quality of many orchards in Pakistan. The infection of nursery stock with diseases such as malformation (*Fusarium mangiferae*) and bacterial black spot (*Xanthomonas campestris* pv *mangiferae)* can greatly slow the establishment of orchards, producing uneven growth of trees. The production of nursery stock free of diseases such as mango malformation, sudden death and bacterial black spot is another important aspect of disease management. Planting material (nursery trees) is generally produced by the private sector, with little care for disease infection. Bacterial black spot has been shown to be easily disseminated through infected nursery stocks. The control of this disease through clean planting material is critical. Nursery stock transmission of malformation which was observed in high proportions in orchard nurseries during a scoping study is also a critical disease issue to be addressed through the establishment of clean nurseries. Improvement in commercial nursery practices is urgently needed. Poor canopy management, in particular, with little or no pruning, is another cause for low yields and poor fruit quality. The establishment of nurseries capable of producing clean planting stock for future plantings is a critical part of any long term disease management program.

There are several mango cultivars currently being grown across the different production districts of Pakistan. Most of these cultivars have been derived from mono-embryonic desi-type (local) rootstocks which are susceptible to a number of physiological stresses such as high soil pH and salinity, and to different pests and diseases. There is an urgent need to source and introduce poly-embryonic rootstocks that have resistance or tolerance to these stresses, and to develop appropriate management practices for their sustainable growth. Better tree management in conjunction with improved plant nutrition and irrigation regimes that are linked to tree phenology cycles are critical components of an improved orchard management system. In the focus of improving tree husbandry to increase yields of quality fruits, one of the important activities is the identification and introduction of rootstocks with tolerance to adverse abiotic conditions such as high pH and salinity.

Further impediments to increasing mango productivity and fruit quality reside in the fact that 90% of the mangoes are harvested by contractors, and not by the tree owners. Contractors provide cash flow to farmers by paying for the harvest rights well in advance of the harvest, but they have little interest in managing the trees except in some cases applying some minimal and inappropriate pesticides to protect their harvests. Conversely, because farmers are uncoupled from market signals, there is often little incentive for them to adopt whatever improved varieties and management techniques that may be available.

Key production issues that impact upon yield and fruit quality are inadequate orchard and irrigation/drainage management, as well as the incidence of major diseases and pests (Akhtar, 2006). Examples of such diseases are the sudden death of mango estimated at an incidence of more than 30% in most production areas, based on survey data from the recent scoping study under SRA Hort/2005/154, and malformation. Fruit flies are a widespread pest problem while mango midge appears to be an emerging new pest problem. The causal organism of malformation in Pakistan has been identified as *Fusarium mangiferae* in a recently completed project on the disease (Akhtar, 2006; Iqbal, *et al.,* 2006). The causes of the mango sudden death syndrome had not been fully confirmed and remained a source of conjecture among researchers in Pakistan. The researchers in Pakistan have linked *Lasiodiplodia theobromae* (Khanzada, et al., 2004) syn. *Botryodiplodia theobromae* (Akhtar, 2006) as playing a major role in mango sudden death. This is unlikely given the characters of these pathogens and the established symptoms of the diseases they cause. Recent research from outside Pakistan, especially in Oman, has shown that the fungus *Ceratocystis* sp. is involved in the syndrome (Van Wyk, *et al*. 2005; Al-Subhi, *et al*. 2006). From the recent scoping studies carried out in

Pakistan, the research team isolated *Ceratocystis* sp. from diseased samples from Punjab and Sindh orchards. It was therefore necessary to clearly establish that the fungus is playing a role in the phenomenon of mango sudden death syndrome and to develop integrated management strategies to address it.

The weak linkages between research and extension have also been highlighted as an issue in the uptake of research findings. This is an area that needs to be addressed if research is to make any meaningful contribution to the welfare of the mango growers. Capacity building within researchers could also be improved so that they are also able to improve on their investigative research capabilities deliver research outcomes to growers.

The above issues were identified as areas on which a new project could focus so that the sustainable yield of quality mango fruits could be enhanced providing better prices in the market place and uplifting the standards of living of the rural poor who produce and depend on mangoes for their livelihoods.

4 Objectives

The project had 4 objectives, each with related target activities. These were:

1. To facilitate the establishment of 'clean' mango nurseries in Pakistan

Under this objective the main target was to have two model research nurseries established at research stations by the end of the project. The benefits of these would be:

- Providing disease-free plants for experimentation and to growers
- Providing disease- free plants to commercial nurseries
- Act as training sites for commercial nursery operators
- Availability of a manual on modern nursery production practices for use by researchers and others in the nursery industry.
- The research sites would facilitate the Federal Seed Certification & Registration Department of Pakistan in developing a protocol for disease free nurseries in mango.

It was also the desire of this objective to have 2 commercial nurseries set up in the Multan and Hyderabad production districts of Punjab and Sindh, respectively. The benefits of these would be:

- Training of commercial nursery operators on modern techniques to establish clean nurseries.
- Availability of improved practices directly to the public at affordable prices.
- Duplication of the commercial nursery practices by other nursery operators through internal scaling up training.

2. To develop improved tree husbandry and management options to produce sustainable yields and quality mango fruit.

Most of the mango orchards in Pakistan are planted in adverse soil conditions (pH> 8, and high salinity). Thus a lot of pressure exists on trees right from the start. These stressed plants thus become easy targets for any diseases and or pests. It was decided that these issues be addressed on two ways:

- First, undertake an extensive testing of local gene pool for salt and high pH resistant rootstocks. Secondly, rootstocks from other countries (from or through Australia) be brought in to meet this challenge. It was planned that such activities will eventually become part of an indigenous mango development program of Pakistan.
- The second part of this objective was to improve the condition of the current mango trees in orchards. Their nutritional and irrigational requirements needed attention to improve yields of quality fruits. The tree sizes also needed to be reduced so that spray treatments could be more effective. Canopy management thus became and important activity.

3. To develop improved detection and management strategies for MSDS and other major diseases of mangoes.

The Mango Sudden Death Syndrome (MSDS) was identified as the most important problem during pre-project scoping studies. A National Project investigating the spread, cause and management of this important disease was already operational at the start of the project and needed to be linked to as same players were involved in both.

This objective was to link up and improve on the findings of the on-going project by:

- Developing uniform, standardized and consistent processes to isolate and identify the causal agent or agents of the disease;
- Undertake studies on the disease epidemiology; especially sources of inoculum, mechanisms of initiation and spread within and between orchards and methods or transmission
- Particular focus was to be placed on studying the possible role of the ambrosia bark beetle as the possible vector of the causal agent of MSDS. Considering the frequent association of the beetle with symptomatic trees.
- Research on other important mango diseases, especially those that impact on postharvest quality, was to be undertaken in Australia and the findings shared or transferred and used by the Pakistan industry.

4. ***To build capacity in the mango industry to undertake integrated crop management research.***

Under the capacity building objective, it was decided that

- Researchers and extension agents would be fully trained in general orchard management and disease and pest management strategies through a series of in-country training courses.
- A cross-section of extension agents, growers and contractors would get training in participatory research and extension approaches in mango production methods.
- Students will undertake short and long term training within and outside Pakistan to improve their skills in different aspects of mango production
- An online learning facility will also be developed and this was to be useful to both Pakistan and Australian growers

A direct link was to be made to an on-going Australia mango extension project titled, "***Delivering mango technologies***" so that findings could be transferred and shared with the Pakistan industry.

5 Methodology

Objective 1: To facilitate the establishment of clean mango nurseries so that high quality planting material is widely available to the Pakistan industry.

The project trained researchers at the mango research stations in Punjab (Mango Research Station Shujabad) and in Sindh (Sindh Horticulture Research Institute, Mir pur Khas), on how to produce nursery stock trees free of the main diseases of concern such as mango malformation, bacterial black spot and sudden death.

The researchers were then provided with resources to develop, in conjunction with commercial nursery partners in the Punjab and Sindh provinces, model nurseries to produce clean trees for new orchard plantings. The model nursery would serve to demonstrate the advantages of producing containerised grafted mango seedlings in sterile media. Establishment of the model nursery required a shaded nursery facility with soil sterilisation facilities and reticulated watering system. Two Model nurseries were established, at the Mango Research Station (MRS), Shujabad and at the Sindh Horticulture Research Institute (SHRI) Mirpur Khas. At both places some available structures were converted into model clean nursery structures. These structures were equipped with the necessary tools.

All technical support including training in Australia was extended to a commercial nursery operator in Punjab. The operator spent time undergoing hands on training in a commercial nursery in Australia and on return set up a new nursery based on the standards learnt during the training visit. That nursery is now producing plants commercially and selling to the public.

Experiments were conducted to select the right potting mix for the establishement of containerised nursery seedlings. Out of some 300 mix combinations, two most promising ones were identified for further refinement and use. Thirty plants from six different varieties were screened, shifted to big pots using the new potting mixes and placed in isolation chambers to act as mother plants for future grafting in the nursery structures at the research stations.

Seeds were collected from trees showing no symptoms of bacterial black spot, malformation or mango sudden death, while buds were obtained from isolated plants. These mother plants were regularly checked and screened for any diseases or insects.
There were plans to develop a manual for a model nursery, outlining procedures and practices for production of fast growing disease-free grafted mango trees.

Objective 2: To develop improved tree husbandry and management options to produce sustainable yields and quality fruit.

i. Introduction of poly-embryonic rootstock to Pakistan

A poly-embryonic rootstock cultivar (13-1) with tolerance to high soil pH was imported into Pakistan from Australia. Another poly-embryonic root stock (Carabao) known to have good resistance to mango sudden death was also to be imported from Australia to Pakistan, but it was discovered that this variety was already available in Pakistan, at the Sindh Horticultural Research Institute (SHRI), Mir Pur Khas. A number of seedlings were brought from SHRI to Punjab. Both the targeted cultivars are public domain cultivars so there are no legal restrictions on their movement. The cultivar 13-1 was sourced from the

Queensland Department of Primary Industries and Fisheries mango germplasm collections at Ayr and Mareeba. The material was inspected and tested for any restricted pathogens and treated according to Pakistani import requirements.

In addition to this cultivar, the Project facilitated the Federal Seed Certification and Registration Department for import of 43 other poly-embryonic cultivars from Australia. These cultivars were placed at the Mango Research Station Shujabad. Even as new importations were coming in, screening of local material was continuing.

ii. *Evaluation of resistance to adverse soil and water conditions*

Identification and evaluation of rootstock and scion cultivars with tolerance to adverse soil and water conditions was also carried out in field trials. Seedlings of imported rootstocks and locally selected cultivars between 6 months and one year old were grown in combinations of high soil pH and saline water to determine their growth habits under such adverse conditions.

iii. *Evaluation of resistance to sudden death and tree decline pathogens*

The disease resistance status of imported and locally selected rootstock and scion cultivars with reported resistance to sudden death and dieback was evaluated under local conditions. Seedlings were inoculated with local isolates of the pathogens and evaluated for their reactions based on known symptoms typical from infections by the different pathogens.

iv. *Evaluation of rootstock /scion compatibility*

Evaluation of rootstocks and scion has been initiated but it may take a further 4 to 10 years for this activity to be completed. This activity is being conducted in collaboration and cooperation with a commercial nursery and growers. Only those cultivars with proven compatibility in the first two studies were used here.

Nutrition and canopy Management:

Nutrition management and tree canopy management recommendations and techniques developed in Australia were first evaluated on Pakistani cultivars at Research Stations before demonstrating it to growers at selected properties. The impressive results were then extended and demonstrated to growers with their direct participation. These demos have been established both in Punjab and Sindh. Neighbour growers were invited at different growth stages to share and show them the tree responses to this activity.

Objective 3: To develop improved detection and management strategies for the mango sudden death syndrome and other major diseases of mangoes.

The causal organism of MSDS had been a controversial issue in Pakistan with many contradictory reports speculating on the cause of the problem (Al-Subhi, 2006; and Khanzada *et al*, 2004). Others had suggested that insects, especially the Ambrosia bark beetle may be playing a role (Akhtar, 2006). Others even believed that it was actually causing the problem. It was largely because of the apparent confusion on the causal agents of sudden death that field surveys were undertaken during the initial scoping study. This project helped the local scientists and improved their capacity to determine the pathogenicity of the disease. Main emphasis was given to standardizing the isolation and identification procedures associated with MSDS.

An MSc level student was recruited to undertake some of the investigations. The more frequently isolated pathogens were used to establish their pathogenicity so as to ascertain their role in the sudden death syndrome. This was undertaken singly and in combinations using young trees. Isolations were also made from soils around infected trees, to determine if associated pathogens were soil borne. The other important area focused by the project was the disease epidemiology. The following were the focus:

1. Establishing methods of initial detection of sudden death on trees across orchards. This was critically needed by growers so that early interventions could be put in place to reduce the disease establishment and spread within orchards.
2. A pictorial stage- wise disease identification and management key so that growers could use in making decisions.
3. Investigations into the role of the bark beetle as a potential vector of the disease, responsible for the transmission of the disease from one tree to another within an infected orchard.

Experiments were also set up to investigate the management of MSDS using chemicals. Available fungicides as well as new ones were evaluated. Other studies focused on what role different orchard management practices had on MSDS.

Objective 4: To build capacity in the mango industry to undertake integrated crop Management research.

Capacity building activities were an important focus of the project. This was focused on young students but was later extended to the project staff and other young scientists. A series of training workshops were delivered during project visits to Pakistan by Australian project team members.

The project also facilitated the graduate student training for research and extension officers in appropriate institutions to enhance the ability of project staff to carry out research, development and extension activities. For this purpose some training courses were even conducted in Australia.

Information and training: A series of training workshops were delivered covering various aspects of orchard management including disease and pest management, nutrition, irrigation and crop phenology.

In collaboration with the mango supply chain project, a quarterly newsletter was produced both in English & Urdu and distributed via email and by postal mail to different stakeholders. The aim of this newsletter was to keep all stakeholders informed of project activities.

6 Achievements against activities and outputs/milestones

Objective 1: To Facilitate the establishment of clean mango nurseries in Pakistan

no.	Activity	outputs/ milestones	completion date	Comments
1.1	Establish a clean and disease-free model nursery in the major mango production districts of Punjab and Sindh. In doing so, study how different nutrient and irrigation practices influence disease development in nurseries, young and established orchards (P&A).	A certified nursery program adopted by the grower associations based on the model in place	Yr1 m3 to yr3m3	Two structures in Public sector and one in the Private sector were completed and are producing clean plants. Experiments on potting mixes identified two media mixes that are currently in use. Models will be used to scale up clean nursery concept in phase 2, while Certified nursery program is a long process and yet to be accomplished.
1.2	Develop a mango nursery production manual, outlining in detail procedures and practices for the establishment of a clean nursery (P)	A nursery production manual made available to growers	Yr 2, m1 to yr3 m 10	A draft nursery production manual is available but still needs to be finalised with input from other projects and stakeholders for distribution in next program phase.

PC = partner country, A = Australia

Objective 2: To develop improved tree husbandry and management options to produce sustainable and quality fruits

no.	activity	outputs/ milestones	completion date	Comments
2.1	Acquire and introduce salt and high pH resistant rootstocks into the Pakistan mango industry program (P). - Acquire and introduce other poly-embryonic rootstocks (P) - Evaluate the introduced potential rootstocks in saline and high pH soils at multi-locations to identify superior ones that could be multiplied and used in nursery establishments.	A few suitable new rootstocks with desired characteristics identified and multiplied for use in establishing nurseries for all new plantings.	Yr 1, m 3 to Yr 3, m 10	A salt tolerant variety, 13-1, was acquired and introduced into Pakistan from Australia. Its adaptation was tested at research stations, but it did not seem to be adapting very well. Three poly-embryonic varieties (R2E2, Nam Doc Mai & Carabao) were also acquired and shared with national researchers who are using as genetic sources in ongoing and future breeding programmes
2.2	Develop and evaluate improved nitrogen, potassium and canopy management strategies for different mango production districts (P&A)	Guidelines for nutrient use and pruning procedures available to growers	Yr 1, m6 to yr3 m10	Nutrient and canopy management trials undertaken under the project had great success and were welcome by growers This is now being demonstrated across different production locations in growers' orchards in Punjab and Sindh.

PC = partner country, A = Australia

Objective 3: To develop improved detection and management strategies for MSDS and other major diseases of mango

no.	Activity	outputs/ milestones	completion date	Comments
3.1	Study the epidemiology of the MSDS (P) and of dendritic spots (A).	Good understanding on the epidemiology of the diseases	Yr 1, m 3 to Yr 2 m 6	The main causal agent of MSDS (*Ceratocystis* spp) was established and research methods standardized across institutions The bark beetle was established as the vector of MSDS pathogens Studies on dendritic spot were just initiated towards the end of the project because of delays in securing a JAF fellowship for the studies. They are now progressing well
3.2	Establish methods of detecting initial infection of MSDS (P)	Methods of initial disease detection made available to growers.		After establishing the main causal agent of the disease, a stage- wise disease development and identification and management guide was developed and distributed to growers.
3.3	Determine sources and methods of transmission or establishment and spread of the pathogens involved (P)	Methods of transmission and spread established	Yr 1, m3 to Yr 2 m 9	Bark beetle was shown to be the main carrier of the pathogens. Potential for soil transmission of the disease was also demonstrated by isolating the pathogen (*Ceratocystis* spp) from infected soil.
3.4	Develop and evaluate integrated field management practices with grower involvement (P&A)	Guidelines for sustainable management of MSDS available to growers	Yr 2, m 1 to Yr 3, m 12	A grower guide showing various stages of symptoms development of the disease has been developed and is guiding growers in management decisions

Objective 4: To build capacity in the industry to undertake integrated crop management research

no.	Activity	outputs/ milestones	completion date	Comments
4.1	Carry out some workshops targeting RD&E staff in the supply chain in a “Train the Trainer” way. Direct others at growers, contractors and field workers (P)	Project commencement workshop held (P&A) Selected Growers and contractors trained to a level to train others	Yr 1, m 2 to m 6	Project Commencement workshop was successfully carried out and annual planning and review workshops brought researchers together yearly as planned Many workshops were conducted to train both researchers and selected growers in effective production practices. This was very effective at start of the project but was disrupted later because of other issues. About 50 researchers and more than 385 extension workers benefited from training in different aspects of mango R, D&E.

4.2	Develop workshop modules covering various aspects of orchard management including disease and pest management, nutrition, irrigation, phenology (P&A).	Training modules covering different production aspects completed.	Yr 2, m 1to m 12	A number of training modules were developed and some trainings conducted using these modules. Plans for more training sessions were disrupted by later events beyond project control.
4.3	Develop internet learning programs for growers based on training modules (A).	Internet learning programs in place.	Yr 1 m 6 to Yr 3 m 3	This was accomplished with linkage to a national Australian Deliverance project
4.4	Be involved in the selection and facilitation of graduate student training for researchers and Extension officers in appropriate institutions so that they can continue with RD&E in mangoes (P&A).	End-of-project workshop bringing together those directly involved and trained through the project	Yr 1 m3 to Yr 3 m10	About 25 students from different universities completed research in the form of internship or degrees under the project and were adequately trained to conduct R&D on mango in the different institutions. End of project workshop could not hold because of unexpected changes in the security situation. Only a partial one held in Australia to brief the reviewer on project outcomes before visit to project sites.

7 Key results and discussion

Objective 1: To facilitate the establishment of clean mango nurseries in Pakistan

Key Achievements for this objective:

- Two Model research Nurseries, one in Punjab at the Mango Research Station Shujabad, and the other in Sindh at the Sindh Horticulture Research Institute were completed and equipped with all required research facilities. The first lot of 3000 disease- free plants were produced from these nurseries.

- A Private Commercial Nursery operator received training on modern nursery establishment in Australia, and now has a modern operational nursery (Faiz-e-Aam) in the Multan District. It is now producing seedlings on commercial scale and sold to the public at reasonable prices.

- After evaluating several potting mix combinations, a couple of them were found to be suitable with the use of local materials and has been developed and tested at MRS Shujabad and shown to be doing well in supporting the growth of seedlings. These mixes are currently being evaluated by Soil Chemists and Plant Physiologist to confirm their suitability for wide recommendations.

- About 1150 plants from three varieties were tested against high salt to select for tolerance to salinity. Forty two were found to be quite tolerant and further multiplication of these ones is in progress so that they can be distributed.

- A new high salt and pH tolerant rootstock, 13-1, along with 41 other poly embryonic root stocks were imported into Pakistan and are still undergoing evaluations for adaptability.

- Canopy management trials were very successful at research stations and have been replicated in more than 6500 acres in production districts across Punjab and Sindh. Many growers are already adopting this technology.

- At the Mango Research Station Shujabad, 30 mother plants of 10 different varieties have been placed in isolation after identification of the suitability for rootstocks and clean scions. These mother plants are being regularly screened for various insects and diseases. They will continue to the source for healthy bud woods for both researchers and nursery operators as needed.

Several mango pests and diseases such as bacterial black spot, mango malformation and mango sudden death can be spread from tree to tree within orchards by contamination of pruning implements, through flood irrigation water or by blowing wind. The practice of establishing mango nurseries in orchards under trees sometimes infected with diseases such as bacterial black spot, mango malformation, and associated symptoms of sudden death is a major contributor to infection of new orchards with these diseases. The message went across to growers and was a good motivator in their willingness to change and adopt the new nursery production practices.

During survey visits, slow and uneven growth of seedlings was evident from high soil pH, micro nutrient deficiencies, water logging and disease infections. This current practice of establishing nurseries between orchard trees also cause damage to roots while uprooting the plants for transplanting, thus time required for tree establishment in the field and death rate of new transplants was found to be quite high. This method also helps in disease

spread to newly established fields. The establishment of disease-free containerised nursery stocks as demonstrated and recommended through the findings of this project will ensure uniform rapid establishment of new orchards and prevent the transfer and spread of the major production diseases into newly established ones.

Objective 2: To develop improved tree husbandry and management options to produce sustainable and quality fruits

Key Achievements for this objective:

- Out of about 1150 plants from three varieties evaluated for high salt tolerance, 42 were found to be tolerant and are being multiplied for distribution. A new high salt and pH tolerant rootstock, 13-1, was imported from Australia and shared with growers, University of Agriculture Faisalabad and Mango Research Station Shujabad. The evaluation of the variety is still in progress but it does not seem to be adapting well to the Pakistan conditions. Since it is a poly embryonic rootstock it will be used for new plant development.

- The project did facilitate the process of the Federal Seed Certification and Registration Department in importing some 43 poly-embryonic varieties, mostly as root stocks. These varieties have been placed at the Mango Research Station Shujabad for further evaluations.

- Locally available poly-embryonic varieties of R2E2, Nam Doc Mai and Carabao, were assembled and evaluated for resistance to the MSDS pathogens. The evaluations are still ongoing but R2E2 and Carabao are showing some good signs of resistance to the MSDS pathogen, *Ceratocystis fimbriata*

- Canopy management trials showed that trees can be pruned just after harvesting without compromise on yield the following season. This experiment has boosted the confidence of growers in tree sizing and pruning which was always thought to affect yield adversely. This experiment has successfully been demonstrated across a number of locations in grower's fields in Punjab and Sindh.

- Analysis of variance and repeated measures analysis established that the SPAD-502 meter can be used to monitor chlorophyll which can be correlated to the uptake and fluctuations in Nitrogen in mango trees over time.

Mango production in Pakistan is based on a wide range of poly-embryonic varieties grafted on to Desi (local seedling varieties) rootstocks. Such plants have their own advantages and disadvantages. As rootstock they present a problem to quality production and disease resistance in several ways. Mono-embryonic rootstocks are genetically variable from tree to tree, and such can have a variable influence on the scion, fruit quality, production and disease resistance characteristics. The current Desi varieties dominant in most Pakistan orchards are highly susceptible to the MSDS pathogens as observed during recent farm surveys in the scoping study. The introduction and testing of mango rootstocks with tolerance to adverse soil conditions (pH> 8, salinity), and tolerance or resistance to the sudden death pathogens may provide a quick management option for Pakistan mango growers.

The project therefore decided on a two way approach; improving the quality by exploring the indigenous material and adding new poly-embryonic varieties in the gene pool from elsewhere

The project intended to introduce several mango rootstocks and scion varieties into Pakistan to test and evaluate for scion compatibility, high pH, salinity and disease resistance. One rootstock, 13-1, was introduced while others were found in the gene pool

of Sindh Horticulture Research Institute (SHRI). Thus the project only facilitated the exchange of the material between Sindh and Punjab. Rootstocks with potential beneficial characteristics for Pakistan productions were also sourced from Australia or other countries when not available in Australia. Adoption of poly-embryonic rootstocks for future crop improvement would provide a consistent rootstock effects on scions.

Objective 3: To develop improved detection and management strategies for MSDS and other major diseases of mango

Key Achievements for this objective:

- A standardize method for the isolation and characterisation of MSDS causal agent was developed and share among researchers so that a uniform process is used in undertaking research on MSDS

- A Pictorial guide showing the various stages of MSDS development and links to possible management practices was developed, printed and disseminated to growers. It is also being used a good diagnostic tool for the disease.

- Investigations on the possible vector-relationship of the bark beetle with the MSDS pathogen were completed at the Agriculture College of B.Z. University, Multan as part of a PhD graduate research study. This established the bark beetle (*Hypocryphalus mangiferae*) is one of the main sources for spreading of the MSD disease.

- An early single field application of a systemic fungicide was more effective than a late single application, in controlling anthracnose and stem end rots of mangoes.

The Mango Sudden Death Syndrome has been a very serious issue for Pakistan mango. There has been lot of efforts to understand the cause of the problem and management strategies to contain its spread. This resulted in controversy among scientists about its causal organisms. There were many published contradictory reports speculating on the cause of the disease (Al-Subhi, 2006; Banik and Kaiser, 1998 and Khanzada *et al*, 2004). Others suggested that insects, especially the Ambrosia bark beetle are causing the disease while others felt that it may only be playing a role in its transmission (Akhtar, 2006).

There was also very limited understanding on the general epidemiology of the disease as no one understood where it came from, how it spreads and when the damage starts. It was largely because of the apparent confusion on the causal agents of sudden death that field surveys were undertaken during the scoping study.

The project helped the local scientists to build their diagnostic capacity and to determine the pathogenicity of the associated causal agents. Main emphasis was given to the standardization of the pathogen isolation and identification procedures. New ideas and techniques were introduced to study the epidemiology of the disease. With the help of project a consensus was achieved about its causal organisms. A stage wise pictorial guidance for growers was developed and distributed. It clearly described various disease stages and associated management options to be considered at each stage.

Objective 4: To build capacity in the industry to undertake integrated crop management research

Key Achievements for this objective:

- In collaboration with the Fruit and Vegetable Development Project of Punjab, some 5200 farmers were visited in the 63 Farmer Field Schools (FFS) used for demonstration of Integrated Disease Management practices.

- In Sindh 2-Acre model blocks of mango orchards were established in collaboration with the provincial Agricultural Extension Department.

- Through 53 seminars/workshops in collaboration with the Punjab Fruit & Vegetable Development Project, about 252 extension workers/researchers and students were exposed to various aspects of mango production.

- More than 3600 growers were engaged and provided with information on mango production practices, through 19 seminars/workshops conducted in different production districts.

- Six project scientists and one commercial nursery operator visited Australia for different training activities.

- Eleven news letters were produced and distributed to growers and other stakeholders, summarising project findings. Distribution records show that more than 1200 stakeholders associated with the mango industry received the newsletters

- A total of 12 publications which includes brochures and Booklets,were published and distributed among some 2200 mango stakeholders. Some of these publications were translated into the local languages. A fungal identification key was also printed for researchers and students.

- A DVD/CD on nursery establishment procedures and management was produced and distributed to mango stakeholders.

The capacity building activities were one of the major thrust of the project. During the entire project operation, every visit of the Australian team member was marked with training in different areas of specialisation of the visiting scientist.. Similarly, scientists who went to Australia and received some training became trainers of others on return to Pakistan.

Good focus was given to students as concerns training. A number of students from different agriculture universities were engaged as internees under the project. These students were also encouraged to apply for different merit scholarships for PhD. All the training activities were targeted towards facilitating growers. Mega seminars and events were organized for small and medium mango growers. These activities were carried out in collaboration with Agriculture Extension Departments.

There were some individual specialised training in Australia, like on project management through the John Dillon fellowship and the John Alright Fellow ship for PhD research training. These were in addition to the group training seminars and workshops delivered by visiting Australian project scientists as well as national project counterparts on different areas of the project focus. These trainings were also largely focused on integrated disease management strategies, tree pruning, good orchard management, procedures for the establishment of clean and disease-free nurseries and modern orchard planting systems.

8 Impacts

It may still be a bit too early to detect measurable impacts of activities undertaken in the project, especially because we are dealing with a perennial crop like mango which may need more time for this to be noticed. There are, however, some areas where definite changes can be noticed even within the short pace of time that the activities were undertaken or introduced.

The most important readily impact was the interest of various other donors in mango value chain work in Pakistan. Based on the influence and spread of word about the ASLP work on the mango projects, the mango producing regions has become a hub for different donors and NGOs who are initiating activities along similar lines with the project or just picking on from on-going activities and continuing from there. The general adoption of good agricultural practices has increased, as evidenced by the establishment of more than 10 medium pack houses for mangoes. Growers, extensionists and researchers have been exposed to different training opportunities both locally and abroad. One of the international agencies, with the mandate of facilitating international trade from Pakistan, has been investing in setting up big demonstration blocks in collaboration with the ASLP project. Growers are now also aware of their important place and role in the industry. They also have a better understanding of the mango crop and can start to address some of the practical issues while working on this complex fruit tree. The growers are also realizing that the Pakistan Government is serious about mango and is directing lots of resources to it through the scientists that are placed at the disposal of the industry to improve productivity and grower incomes.

Continuous interactions between researchers and growers have helped in developing confidence of the growers on the research system and FFS approach has improved in the direct delivery of project findings and outcomes to growers. Scientists and Extension staff have also realized their role and the importance of involving growers in meetings to plan and discuss research outcomes.

The involvement of commercial nursery men in the project did widen the scope and impact of the project. The commercial nursery operator who received training through the project from Australia has been investing a good amount of resources to develop a state of the art structure for modern nursery production only with Project technical support.

Collaborative linkages developed with ongoing National Projects during the operation of the project were also an important outcome because it helped to bring researchers from different national institutions to start working together. Project team also developed international linkages with collaborators outside Pakistan. Even within Pakistan different research, extension and university personnel started working together in addressing common issues in a collaborative rather than a competitive mode of operation.

8.1 Scientific impacts – now and in 5 years

The most important scientific impact has been the change in thinking of researchers, extension workers and growers. Traditionally, mango orchard management was not a routine practice but with the exposure to the Australian mango industry and frequent visits of Australian experts, this has changed their perspective in mango orchard management. They have started to see the scientific side of mango orchard management. Pruning, for example, was always considered a practice that would lead to loss of yield, but with one experiment in just one year, the perspective of researchers changed and in just three years time growers have started adopting this practice.

Establishing the cause of Mango Sudden Death Syndrome and developing consensus of all scientists was yet another major scientific impact so far. There had been a lot of guess work and stories regarding the causal organisms and the epidemiology of this important

disease until the project helped in identifying the real cause and gave an opportunity to explore its epidemiology. The possible role of the insect vector in MSDS had only been speculative until the project provided opportunities to Pakistan scientists to investigate and establish the link to the disease as a vector.

The project also facilitated various Institutes and organizations to develop common packages for good orchard management of mango, which have been published and widely circulated through the project. Growers were exposed to the concept to modern disease-free nurseries. Soil less media for seedling growth was tested and experiments were conducted to develop this using indigenous material. The project team also managed to develop separate mango orchard management calendars for Punjab and Sindh Provinces. The calendar is being demonstrated at farmer level in blocks at 11 locations in Sindh. The growers are so impressed by this positive change in the demo orchards that they are now trying to adopt the practices in the whole orchards. The mystery of the Mango Sudden Death has been resolved and a coloured guide for identification of various stages of the diseases along with management options is now in place and should continue to impact on sustainable production of quality mangoes.

8.2 Capacity impacts – now and in 5 years

Capacity building was a very important component of the Project. The aim right at the start was to develop the capacity of local R, D &E personnel so that they could take on the activities initiated, once the project ends. This was largely achieved, thanks to the focus on hands-on training. The training needs were met both locally and internationally with outside visits such as was the case through a number of Crawford fellowship visits to Australia. The train-the-trainer approach used was quite effective as training has been continued even after the project has ended.

For growers, the Farmer Field School approach used in collaboration with the Fruit & Vegetable Development Project of Punjab Agriculture Extension, empowered them into decision making in their farms. It proved to be the best way of educating growers.

The individual farm visits by the Project Team (both local as well as Australian counterparts) provided a great opportunity for capacity building where few growers come in contact with scientists and things were discussed with practical approach. Thus the knowledge and skills of individual growers that were involved did present their increases many folds..

8.3 Community impacts – now and in 5 years

In order to develop a sense of ownership, the project initiated group discussions through emails, forum meetings and project newsletters. The quarterly newsletter initiated as a joint publication for both ASLP mango projects served as a good tool that brought growers together as a community with common goals and aspirations. This newsletter kept the growers regularly informed of various activities from scientists concerned. The individual direct interactions of the Project Team with growers also helped the growers to understand various issues and concern their farms and helped form a community that extended beyond growers to researchers.

The establishment of the demo blocks was a joint activity between researchers and growers and enabled both to share experiences and learned from each other through regular interactions and feedback. Grower involvement in Farmer Field Schools actually helped to knit farmers into a community where they sought solutions of common issues and problems together.

8.3.1 Economic impacts

The technology for mango tree canopy management was standardized and demonstrated at grower's fields. The activity created good awareness that tree size could be maintained or managed in mango through immediate pruning soon after harvest. It also demonstrated the influence of proper nutrition on fruit yields. Some limited extension activities were undertaken to spread awareness of the orchard management technologies. Many growers have adopted the technologies and are already enjoying the economic benefits of increased yields of quality fruits.

Scientific data collected from some of the Demonstration plots do reflect this direct benefits by growers following adoption of the technologies. By adopting improved Mango orchard management practices the average net income of those growers increased by up to 51 %. Improved fruit quality, uniform fruit size were the additional benefits for the growers which could not be directly quantified because none of the growers engaged was involved in self marketing of his fruits. All were selling their orchards to contractors before harvest. Only the yield difference in value could be measured at the time of harvesting.

The demo blocks also included the integrated management of MSDS. The different detection stages developed and distributed to growers the growers in their management decisions in a curative or preventive way. Some growers were able to reduce their annual tree mortality from 7-10% down to 1 or 2 % just be adopting some of the improved practices for MSDS. This reduction in plant mortality enhanced the income of the growers at similar proportions. The project activities had a great economic impact on the growers community not only in terms of high production with the improved practices but also money saved. Some growers reported that the average per acre increase in their income was almost equal to US$ 500 with the project recommended practices. Moreover, money was also saved on the ploughing cost, unnecessary sprays as reduced tree height enabled few sprays to be more effective.

8.3.2 Social impacts

Ultimately after acquiring the economic benefits due to the activities of the project, individual or community started paying attention towards education, health, religious, political, ethnic or demographic status. The demonstration orchards acted as hub for the growers around in the area. They were visiting orchards, linking up with the extension workers guiding in the demo block and consequently adopting the practices.

Some of these growers were encouraged by a similar USAID project which introduced them as Global Gap Certified growers after follow-up training. These grower communities as a whole had meetings with researchers and extension workers and reduced the communication gap, that prevailed in the past.

8.3.3 Environmental impacts

The project developed integrated approaches for orchard management, which helped in rationalizing the use of different farm chemicals, thus protecting the fragile environment. More advanced growers that were relying on routine chemical sprays to reduce pests and diseases were taught how to reduce this by pest monitoring and consideration of weather factors. These reductions were of immediate benefit to the environment.

The development and introduction of a management calendar definitely helped in getting the message about the need to protect the environment home. The promotion of a low till or reduced under-tree cultivation resulted in under-tree vegetative growth that helped to control the temperature and reduced unnecessary sprays thereby reducing air toxicity and also saved friendly and beneficial creatures in the orchards that acted as pest natural enemies.

8.4 Communication and dissemination activities

Throughout the duration of the project, there were different ongoing communication activities through which project findings were disseminated to end users. These include Field days, seminars and workshops and project visits to project sites and overseas to see and learn first-hand process that could impact on mango productivity.

Highlighted below are just some of these communication processes through which the project results were disseminated to different stakeholders.

- In collaboration with the Fruit and Vegetable Development Project (F&VDP) of Punjab, about 5200 farmers were visited by project teams through the 63 Farmer Field School (FFS) for demonstration of Integrated Crop Management practices.
- In Sindh 2 acre model blocks in selected mango orchards have been set up to demonstrate project outcomes, through the cooperation of the Agriculture Extension Department.
- Through 53 seminars and workshops delivered in collaboration with the F&VD Project, about 252 extension workers and researchers, as well as students have been trained and exposed to various aspects of mango production.
- About 3600 growers were engaged and provided with information on improved mango production practices, through 19 seminars and workshops conducted in the different production districts.
- Six project scientists and a commercial nursery operator visited Australia for training in different aspects of mango production as related to their disciplines.
- 11 news letters have been produced and distributed to approximately 1200 mango stakeholders.
- Total 12 publications (broachers & Booklets) have been published and distributed among 2200 mango stakeholders. A fungal identification key has been printed for researchers and students.
- A DVD/CD on nursery management has been produced and distributed among mango stakeholders.
- A pocket guide for management of MSDS has been produced and distributed to more than 8000 growers and still in demand.

9 Conclusions and recommendations

9.1 Conclusions

The professionalism, unity and rapport developed by the Australian and Pakistani project teams were are impressive, and have ensured a close and responsive professional relationship. In particular, the Pakistani team appreciated the blend of scientific professionalism and on-the-ground practicality demonstrated by the Australian team. Pakistani stakeholders expressed particular appreciation for the intensive trainings provided, and the care taken to ensure that project activities integrated with on-going Government programs.

As can be seen in the list of the project objectives, the focus of the project was on developing clean nurseries, encouraging and demonstrating good orchard husbandry, and taking on and finding solutions to the detection and management of the mango sudden death disease. It also had as a focus capacity building in research development and extension to bring all the findings together and disseminate them to the appropriate stakeholders.

The project was been rated as highly satisfactory by the reviewer, based on what was achieved. It also demonstrates many “best practice” features in the different areas of investigations. Progress was in full accordance with, and in most cases exceeded what was planned for in the design of the various activities. Reporting was very comprehensive, of high quality and project outputs by way of any publications strongly featured Pakistani authors.

The project generated outcomes of both scientific and commercial significance. Scientific outputs included the establishment of the exact cause of the mango sudden death which paved the way to the development of more appropriate management strategies. Commercial outputs included the change in nursery production practices from crude plantings inside orchards to establishments in properly designed modern sheds with associated expansion of the business for commercial gains.

9.2 Recommendations

The project activities started by engaging the scientific community to focus on some basic research to establish the cause and epidemiology of the mango sudden death disease. Because of this initial focus, full attention was not given to the applied part of research in developing practical strategies for the management of the research. It will be good to put together all the control strategies that were identified or initiated for validation and demonstration on grower properties so that these could be quickly adopted. This should be an area for any follow-up phase of the project.

The project initiated most of its activities with medium to large innovative growers who were able and keen to take up any findings from the research. This was the right way to get started. The real people that need help are the small scale growers who will need to be engaged by expanding the technologies developed into their farms so that they can quickly adopt and improve their livelihoods. This should be a focus area for a follow-up phase of the project.

Capacity building at the group level was excellent but not so much at the individual scientist level because of initial difficulty in securing funding for long term training of young researchers. This area should receive high priority in a follow-up phase by engaging young researchers to do their research work as part of the project and making sure some funding is dedicated to long term training of young scientists.

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11 Appendixes

11.1 Appendix 1: Pictorial View of Focus Areas

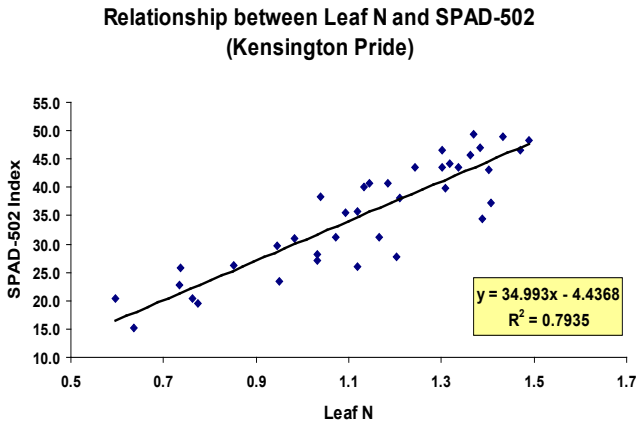
1 - Nursery Focus - Modern research nursery at Shujabad Punjab

1 - Nursery Focus - Modern research nursery at Mirpur Khas, Sindh

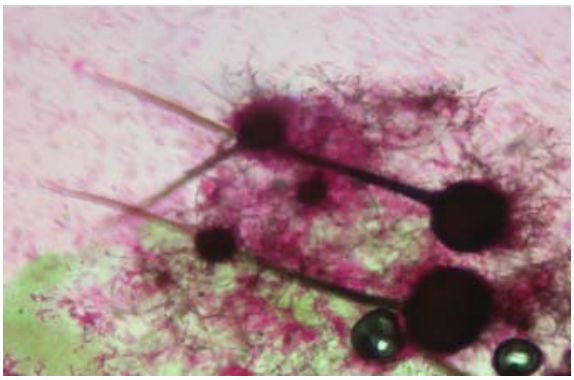
1 - Nursery Focus – Modern commercial nursery at Faiz I Aam

2 - Orchard husbandry focus - Comparison of control and demonstration plot.

2 - Nutrient focus – SPAD-502 meter



Relationship between leaf N and SPAD-502



3 - Mango Sudden Death focus – *Ceratocystis fimbriata;* main cause of mango sudden death

3 - Mango Sudden Death focus - Pictorial Guide on the development of MSD symptoms

4 - Extension & Capacity building focus – FFS Session