

**INDUSTRY BIOSECURITY PLAN
FOR THE PAPAYA INDUSTRY**

Threat Specific Contingency Plan

Bacterial Crown Rot

Erwinia papayae

Prepared by Lynton Vawdrey
and Plant Health Australia
July 2011



Disclaimer

The scientific and technical content of this document is current to the date published and all efforts were made to obtain relevant and published information on the pest. New information will be included as it becomes available, or when the document is reviewed. The material contained in this publication is produced for general information only. It is not intended as professional advice on any particular matter. No person should act or fail to act on the basis of any material contained in this publication without first obtaining specific, independent professional advice. Plant Health Australia and all persons acting for Plant Health Australia in preparing this publication, expressly disclaim all and any liability to any persons in respect of anything done by any such person in reliance, whether in whole or in part, on this publication. The views expressed in this publication are not necessarily those of Plant Health Australia.

Further information

For further information regarding this contingency plan, contact Plant Health Australia through the details below.



Address: Suite 1, 1 Phipps Close
DEAKIN ACT 2600

Phone: +61 2 6215 7700

Fax: +61 2 6260 4321

Email: biosecurity@phau.com.au

Website: www.planthealthaustralia.com.au

1	Purpose of this Contingency Plan	5
2	Pest information/status	5
2.1	Pest details	5
2.1.1	General information	5
2.1.2	Disease cycle	5
2.2	Affected hosts	7
2.2.1	Host range	7
2.2.2	Geographic distribution	8
2.2.3	Symptoms	8
2.3	Pest risk ratings and potential impacts	9
2.3.1	Entry potential	9
2.3.2	Establishment potential	9
2.3.3	Spread potential	10
2.3.4	Economic impact	10
2.3.5	Environmental impact	10
2.3.6	Overall risk	10
2.4	Diagnostic information	11
2.4.1	Characteristics of <i>Erwinia papayae</i>	11
2.4.2	Diagnostic protocol	11
2.5	Response checklist	12
2.6	Delimiting survey and epidemiology study	12
2.6.1	Sampling method	12
2.6.2	Epidemiological study	14
2.6.3	Models of spread potential	15
2.6.4	Pest Free Area guidelines	15
2.7	Availability of control methods	15
2.7.1	General procedures for control	15
2.7.2	Control if small areas are affected	15
2.7.3	Control if large areas are affected	15
2.7.4	Specific controls for <i>E. papayae</i>	16
3	Course of action – eradication methods	17
3.1	Destruction strategy	17
3.1.1	Destruction protocols	17
3.1.2	Decontamination protocols	18
3.1.3	Priorities	18

3.1.4	Plants, by-products and waste processing	18
3.1.5	Disposal issues	19
3.2	Quarantine and movement controls	19
3.2.1	Quarantine priorities	19
3.2.2	Movement control for people, plant material and machinery	19
3.3	Zoning	19
3.3.1	Destruction Zone	19
3.3.2	Quarantine Zone	20
3.3.3	Buffer Zone.....	20
3.3.4	Restricted Area.....	20
3.3.5	Control Area	20
3.4	Decontamination and farm clean up	20
3.4.1	Decontamination procedures	20
3.4.2	General safety precautions	21
3.5	Surveillance and tracing	21
3.5.1	Surveillance.....	21
3.5.2	Survey regions	21
3.5.3	Post-eradication surveillance	22
4	References	23
	Appendix 1. Standard diagnostic protocols	24
	Appendix 2. Experts, resources and facilities	24
	Appendix 3. Communications strategy.....	25

1 Purpose of this Contingency Plan

This contingency plan provides background information on the pest biology and available control measures to assist with preparedness for an incursion into Australia of Bacterial crown rot (*Erwinia papayae*). It provides guidelines for steps to be undertaken and considered when developing a Response Plan to this pest. Any Response Plan developed using information in whole or in part from this contingency plan must follow procedures as set out in PLANTPLAN and be endorsed by the National Management Group prior to implementation.

2 Pest information/status

2.1 Pest details

Common names:	Bacterial Crown Rot, Bacterial Decline, Bacterial Stem Canker
Scientific name:	<i>Erwinia papayae</i>
Taxonomic position:	Kingdom, Animalia; Phylum, Proteobacteria; Class: Gammaproteobacteria; Order: Enterobacteriales; Family: Enterobacteriaceae

2.1.1 General information

Bacterial crown rot (BCR) also known as Bacterial canker or Bacterial decline is considered one of the most important diseases affecting papaya (*Carica papaya*). First reported in Java in 1931, this disease, which is caused by the bacterium *Erwinia papayae* (Gardan *et al.* 2004), has spread to many of the major papaya growing countries of the world (Trujillo and Schroth 1982; Webb 1985).

In the late 1960's the disease appeared in the West Indies and decimated the papaya fields in the area where the cultivar 'Solo' was grown for its high yields and fruit quality (Ollitrault *et al.* 2005). In 2003, the disease was first reported in Malaysia by the Johor State Department of Agriculture and by the end of 2006 it had spread to five other states on the west coast of the Malaysian Peninsula (Maktar *et al.* 2008), affecting around 800 ha of papaya (2.5 times the size of the Australian industry). The Johor peninsula experiences wet equatorial climatic conditions with monsoon rain and an average annual rainfall of 1778 mm. The most recent outbreak of BCR occurred in the Kingdom of Tonga in 2009 (Fullerton *et al.* 2011).

2.1.2 Disease cycle

E. papayae has been recovered from seed of infected papaya fruit and was shown to be viable in seed after an extraction and air drying process for at least 30 days (Obrero 1980). The reported outbreak of the disease at a research facility on the isolated Kingdom of Tonga in 2009 (Fullerton *et al.* 2011) where imported cultivars were being evaluated for commercial release, suggests that seed-borne transmission is the most likely mechanism of initiating an infection. Described as a systemic infection, early symptoms occur as spreading, dark green, water-soaked lesions on juvenile stem tissue which develop into a foul-smelling wet rot that destroys large sections of the stem (Figure 1). Coalescing, brown, angular, marginal and intercostal lesions kill large areas of the lamina. Symptoms on stems typically move towards the crown with the growing point being killed or the whole crown

breaking off at a canker below (Fullerton *et al.* 2011). Small water-soaked lesions which develop on green fruit later develop into firm depressed lesions which enter the seed cavity (Figure 1). Disease transmission is favoured by rain-splash with the bacteria entering neighbouring host plants via natural openings and wounds (Obrero 1980).



Figure 1. Symptoms of Bacterial Crown of papaya (Photos L. Vawdrey and R. Fullerton)

Research has shown that *E. papayae* does not survive well in association with papaya roots, is short-lived in decaying diseased plant material and does not survive longer than 2 weeks in soil (Obrero 1980; Webb 1985). Experience in the Philippines also suggests there is no carry-over of the disease in following plantings of papaya. However, the bacterium has been shown to survive for indefinite periods in the cankers and leaf lesions of affected papaya and will survive for at least 14 days on the leaves of tomato and rockmelon (Webb 1985). Research conducted by Obrero (1980) found there was no evidence of insect or snail transmission; in contrast, studies by Trujillo and Schroth (1982) showed the African snail can act as a vector of the disease.

Tests to recover *E. papayae* from field soils artificially infested with the pathogen and from underneath severely infected trees or on dried infected tissues were not successful, suggesting that *E. papayae* is short-lived outside its host, a poor soil competitor or is sensitive to soil bacteriosis. It was, however, able to survive in sterile soil, in advancing margins of infected tissues and inside infected vascular tissues of the stem. *E. papayae* is believed to survive from season to season inside the infected vascular bundles of diseased plants (Obrero 1980; 1991).

2.2 Affected hosts

2.2.1 Host range

The host range is confined to *Carica papaya* although *E. papayae* is known to survive on the leaves of cowpea, tomato and rockmelon for at least 14 days (Webb 1985).

Research by Obrero (1980) showed that 12 common weed species and 11 cultivated crops (Table 1) grown near papaya fields in the Philippines and inoculated with *E. papayae* were not susceptible to the BCR pathogen.

Table 1. Common weeds and cultivated crops tested as possible alternate hosts of BCR.

Host	Tissue inoculated
Weeds:	
<i>Ageratum conyzoides</i> L.	Leaves
<i>Amaranthus spinosus</i> L.	Leaves
<i>Crotalaria mucronata</i> Desv.	Leaves
<i>Eleusine indica</i> (L) Gaertn	Leaves
<i>Euphorbia heterophylla</i> L.	Leaves
<i>E. hirta</i> L.	Leaves
<i>Ipomoea triloba</i> L.	Leaves
<i>Mimosa inivisa</i> Mart. ex Colla	Leaves
<i>Panicum maximum</i> Jacq	Leaves
<i>Portulaca oleracea</i> L.	Leaves
<i>Sida rhombifolia</i> L.	Leaves
<i>Solanum nigrum</i> L.	Leaves
Cultivated crops:	
<i>Ananas comosus</i> (L.) Merr	Fruit
<i>Brassica oleracea</i> L.	Leaves
<i>Cucumis sativus</i> L.	Fruit

Host	Tissue inoculated
<i>Daucus carota</i> L.	Root
<i>Ipomoea batatas</i> (L.) L	Tuber
<i>Lactuca sativa</i> L	Leaves
<i>Lycopersicon lycopersicum</i> (L.) Karsten	Fruit, leaves
<i>Passiflora edulis</i> Sims	Leaves, fruit
<i>Phaseolus vulgaris</i>	Pod
<i>Solanum melongena</i> L.	Fruit
<i>S. tuberosum</i> L.	Tuber

Similar research by Olabiyi (2010) showed that of 13 plant species tested, measurable populations of *Erwinia* bacteria could only be detected on the surface of leaves of *Chromolaena odorata* (a dicotyledonous weed in Nigeria) and tomato 7 days after inoculation. After 14 days, pathogen populations were too low to count. The non-host species tested included *Chromolaena odorata* (weed), *Zea mays* (maize), *Vigna sinensis* (cowpea), *Manihot esculentus* (cassava), *Lycopersicum esculentum* (tomato), *Mangifera indica* (mango), *Solanum tuberosum* (potato), *Panicum maximum* (guinea grass), *Citrus sinensis* (sweet orange), *Musa* sp. (banana), *Cajanus cajan* (pigeon pea), *Abelmoschus esculentus* (okra), and *Psidium guajava* (guava).

2.2.2 Geographic distribution

E. papayae has been identified in the following countries:

- South-east Asia: Indonesia, Malaysia, the Philippines
- The Pacific: Mariana Islands; Tonga; Fiji
- The Caribbean and Americas: Anguilla, Antigua, Barbuda, Barbados, Dominica, Grenada, Guadeloupe, Grenadines, Martinique, Montserrat, Sainte Croix, Saint Kitts and Nevis, Saint Lucia, Saint Vincent, Trinidad and Tobago, the US Virgin Islands and Venezuela (AQIS 2010).

2.2.3 Symptoms

Early symptoms of BCR include angular water-soaked lesions on leaves which spread along the veins and eventually the petiole causing leaves at the top of the canopy to wilt and die. Firm water-soaked cankers develop on the stem causing the stem to collapse. Often these stem symptoms move towards the crown with the growing point being killed or the entire stem breaking off at a canker below. Small water-soaked lesions which develop on green fruit later develop into firm depressed lesions (Trujillo and Schroth 1982; Webb 1985; Fullerton *et al.* 2011). Infected plants may recover and produce productive branches during dry conditions (Figure 1). When the disease infection is followed by dry weather, water-soaked leaf lesions become dried brown patches which tear giving the leaf a tattered appearance.

2.3 Pest risk ratings and potential impacts

When the Industry Biosecurity Plan for the Papaya Industry was prepared in 2011, Bacterial crown rot was given an overall risk rating of Medium-High and as a consequence, this contingency plan was commissioned. During the preparation of the contingency plan, literature searches undertaken by the author have shown the ratings for entry potential to be medium, whereas the economic and spread potential remain high. A summary of these ratings are shown in Table 2.

Table 2. Pest risk ratings for Bacterial crown rot of papaya

Potential or impact	Rating
Entry potential	Medium
Establishment potential	High
Spread potential	High
Economic impact	High
Environmental impact	Negligible
Overall risk	High

2.3.1 Entry potential

Rating: Medium

Erwinia papayae is readily seed-borne on papaya. Imported fruit tends to be of high quality and from well managed farms creating a low risk situation. However, the entry potential is **high** if papaya seed were introduced from areas where the disease is known to occur. Such seed could enter as:

- Direct imports of papaya fruit for consumption or papaya seed for planting and/or breeding purposes
- Inadvertent entry (intentional or unintentional with travellers’ goods)

There is a high frequency of travel between areas in South-East Asia and the Pacific where the pathogen exists and Australian papaya growing areas.

The Australian Quarantine and Inspection Service (AQIS) now restrict the importation of *Carica papaya* seed from countries where BCR is known to occur.

2.3.2 Establishment potential

Rating: High

The incidence of seed transmission in fruit is considered low in BCR-affected countries; however, infested seed grown during climatic conditions suited to the development of BCR would have a high potential for establishing the pathogen. High rainfall is important for disease development and as 50% of Australia’s papaya is grown in the ‘wet tropics region’ of far north Queensland (average annual rainfall of 3750 mm per annum) the risk of establishment is considered **High**.

2.3.3 Spread potential

Rating: High

Research conducted by Obrero (1980) showed rainfall was the most important weather factor influencing BCR as it provided conditions necessary for the penetration and distribution of the pathogen. In 2003, the disease was first reported in Malaysia by the Johor State Department of Agriculture and by the end of 2006 it had spread to five other states on the west coast of the Malaysian peninsula (Maktar *et al.* 2008), affecting around 800 ha of papaya (twice the size of the Australian industry). The Johor peninsula experiences wet equatorial climatic conditions with monsoon rain and an average annual rainfall of 1778 mm. Fifty percent of Australia's papayas are grown on the wet tropical coast of far northern Queensland which has an average annual rainfall of 3750 mm. Consequently, the spread potential of BCR is **High**.

2.3.4 Economic impact

Rating: High

Production: The value of the current Australian papaya industry is estimated at \$25 million. It is known that BCR causes major yield losses in affected crops where climatic conditions are suitable for the development of this disease. Consequently, the impact to at least 50% of the industry (that which is grown on the wet tropical coast of far northern Queensland) would be devastating. Based on the experience in Malaysia, it would not be unrealistic to predict the total destruction of the industry on the wet tropical coast. The remainder of the industry is mostly grown to the west of the wet tropics region in the drier Mareeba-Dimbulah area (average annual rainfall of 900 mm) so the incidence and economic impact of the disease is likely to be much reduced.

The impact on trade is currently considered to be low as, at the present time, Australia does not export papaya fruit. The introduction of new commercially acceptable cultivars may see increased interest and opportunity in the export of fruit and if this occurred, the potential impact of this disease would be considered **High**.

2.3.5 Environmental impact

Rating: Negligible

There is no potential to degrade the environment or otherwise alter the ecosystems through the introduction of BCR.

2.3.6 Overall risk

Rating: High

With a medium risk of introduction, high risk of establishment and spread, and high economic loss predicted, the overall risk is considered **High**.

2.4 Diagnostic information

2.4.1 Characteristics of *Erwinia papayae*

E. papayae is described as a slow-growing Gram-negative bacterium giving colonies of 2-3 mm diameter after 3-4 days incubation at 25°C. On King's medium B, colonies are mucoid and white to creamy white in colour with a non-diffusible blue pigment (Gardan *et al.* 2004). Cells of *E. papayae* are single straight rods, 0.5-1.0 x 1.0-3.0 µm and motile by peritrichous flagella (Trujillo and Schroth 1982).

2.4.2 Diagnostic protocol

Streaking for single colonies of bacteria. Isolations, using fresh material with young lesions (Figure 2) need to be completed. The sample must be thoroughly surface-sterilised at least twice prior to isolation by rubbing with 70% ethanol and allowing to dry. Half the sample should be examined for ooze, while the other half should be placed in a drop of water for bacterial elution, prior to streaking. If there is no ooze, then discard the sample. Isolations should be attempted if possible on a number of samples (A. Young, pers. comm.).

Identification of the pathogen. The correct isolates will appear very fluidal and grey/white in colour on nutrient agar (A. Young, pers. comm.). If King's medium B is used, slow growing raised white mucoid colonies are formed that produce a conspicuous, non-diffusible blue pigment in the medium (Gardan *et al.* 2004, Fullerton *et al.* 2011). Colony growth occurs at 28°C but ceases above 36°C, and sucrose reducing compounds are produced. A range of other biochemical tests used to identify the pathogen are mentioned in Gardan *et al.* (2004).

Colonies of *E. papayae* are gram negative, facultative anaerobes, oxidase negative, non-fluorescent on King's medium B, induce a hypersensitive reaction on tobacco leaves, but do not cause soft rot on potato slices. These characteristics combined with the blue pigment production (Figure 2) are consistent with the bacterium *E. papayae* (Fullerton *et al.* 2011).

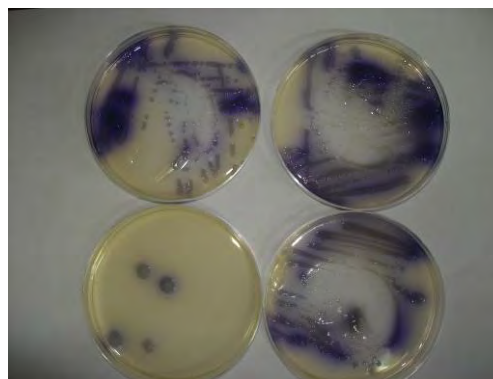
Phylogenetic analysis.

An isolate recovered from symptomatic plants by Maktar *et al.* (2008) and analysed by 16S rRNA gene sequencing was identified as *E. papayae* based on BLAST analyses of sequences in the NCBI data base, with the highest similarity to *E. papayae* (GenBank acc no: AY131237.1) from the Caribbean (Gardan *et al.* 2004).

In recent research by Fullerton *et al.* (2011) the partial sequence of the 16S rDNA gene of ~ 804 bp was amplified from four Tongan isolates suspected of being *E. papayae*. Sequences of these strains were 100% identical to each other and 97% identical to the 1616 SrDNA sequence of *E. papayae* (GenBank acc no: AY131237.1).



Figure 2. Fresh, young BCR lesions



Characteristic blue pigmentation

2.5 Response checklist

Guidelines for Response Checklists are still to be endorsed. The following checklist provides a summary of generic requirements to be identified and implemented within a Response Plan:

- Destruction methods for plant material, and disposable items
- Disposal procedures
- Quarantine restrictions and movement controls
- Decontamination and farm cleanup procedures
- Diagnostic protocols and laboratories
- Trace back and trace forward procedures
- Protocols for delimiting, intensive and ongoing surveillance
- Zoning
- Reporting and communication strategy (refer to Appendix 3)

Additional information is provided by Merriman and McKirdy (2005) in the Technical Guidelines for Development of Pest Specific Response Plans.

2.6 Delimiting survey and epidemiology study

Delimiting surveys should comprise local surveys around the area of initial detection. The normal procedure is to collect samples from symptomatic plants and to test them to confirm the presence of *E. papayae*. An estimate should be made of the disease incidence. All crops in the growing area of the outbreak would need to be surveyed. Seed trace-back will indicate the possibility of other growing areas being affected.

2.6.1 Sampling method

Once initial samples have been received and preliminary diagnosis made, follow up samples to confirm identification of the pathogen will be necessary. This will involve sampling directly from the infected crop, and sampling crops over a larger area to determine the extent of the disease

distribution. A system of sample identification should be determined early in the procedure to allow for rapid sample processing and accurate recording of results. Follow up samples will be forwarded to the nominated diagnostic laboratories for processing.

Samples should be initially collected over a representative area of the infected crop to determine the disease distribution. Depending on the stage of infection the symptoms may appear as (see Section 2.2.3 full details):

- Plants with leaf and petiole lesions and signs of premature defoliation
- Plants with stem and crown lesions
- Plants with stem and crown lesions with leaf collapsing about the stem and water soaked fruit lesions

Samples could also be collected from tomato, rockmelon and cowpea in close proximity to papaya plants as *E. papaya* can be found on leaves of these plants for up to 14 days.

All personnel involved in crop sampling and inspections must take precautions to minimise the risk of disease spread between crops by decontaminating between paddocks.

Any personnel collecting leaf samples for assessment should notify the diagnostic laboratory prior to submitting samples to ensure expertise is available to undertake the diagnosis. General protocols for collecting and dispatching samples are available within PLANTPLAN, Appendix 3 (Plant Health Australia 2010a).

2.6.1.1 NUMBER OF SPECIMENS TO BE COLLECTED

The initial outbreak will appear as water-soaked leaf, petiole and stem lesions on plants in groups within the planting. These will be associated with spread from the initial seed-borne infection. If only a small area is affected, four-to-five plants with symptoms should be collected. If there are several foci of infection, collect two plants with a range of symptoms from up to five locations within the affected plantings.

2.6.1.2 HOW TO COLLECT

Leaves, petioles, stems and fruit are the main organs infected with *E. papayae*. Samples should be collected that represent a range of symptoms on leaves, stems and fruit observed in the infected crop. Samples consisting of fresh and young leaf lesions are required for a positive laboratory diagnosis. Preferably enough material should be collected to allow for immediate processing.

Samples should be treated in a manner that allows them to arrive at the laboratory in a fresh, well-preserved state. Samples should be placed in a labelled paper bag which in turn should be placed in a clear zip lock plastic bag with the label visible from the outside.

Samples should be stored in a cool, air-conditioned, secure area and despatched to an appropriate diagnostic laboratory in a Styrofoam or hard plastic esky.

It is important to record the precise location of all samples collected, preferably using GPS, or if this is not available, map references including longitude and latitude and road names should be recorded. Property and owners names should also be included where possible.

It is important that all diagnoses of suspected exotic and emergency pathogens are undertaken according to the following parameters:

- The laboratory diagnostician has expertise in this form of diagnosis

- The test is undertaken as described in Section 2.4.2
- The results are confirmed by diagnosis in another recognised laboratory or by another diagnostician
- Where possible, diagnosis is confirmed by a second method

2.6.1.3 HOW TO PRESERVE PLANT SAMPLES

Samples should be stored in a cool, air-conditioned, secure area. See above for details.

2.6.1.4 HOW TO TRANSPORT PLANT SAMPLES

Suspect samples should be marked “Plant Sample for Urgent Diagnosis” and sent to the nearest diagnostic laboratory (see Appendix 2 of this document for addresses and Appendices 3-5 of PLANTPLAN for collection and transport of samples (Plant Health Australia, 2010a).

Samples of leaves or stem should be placed in a labelled paper bag which in turn should be placed in a clear zip lock plastic bag with the label visible from the outside.

Double bag the samples and wipe the outside of the bag with alcohol and allow to dry before dispatching the sample to the laboratory.

Additional information including the detail of the sample date, location and site must be recorded on an accompanying sheet, together with all relevant paperwork. This information should be placed in a plastic bag, on which is also written the summary details of the sample and the address, and included with the samples that are dispatched.

All samples should be dispatched using an overnight courier service, Express Post or hand delivered.

Important: Prior to dispatch, the Manager of the laboratory to which the sample is being consigned should be advised by telephone (not e-mail – a more direct method of communication than e-mail is required) of the expected arrival date. Special arrangements may need to be made for weekends. If the receiving laboratory is in another state, then a permit may be required for the movement of plant material into that State. Check with the State or Local Pest and Disease Control Headquarters that approval has been granted.

See PLANTPLAN for further details of sampling and transport (Plant Health Australia 2010a).

2.6.2 Epidemiological study

The number of infected plants within a crop will depend on the amount of inoculum available and whether climatic conditions have been favourable for the disease to spread from initial foci.

Sampling of crops within a district and beyond will be based upon the origins of the initial suspect sample(s). Factors to consider will be:

- The source of seed used and how long it has been since the seed was sown
- If any other crops have been sown from the same seed source
- The proximity of other susceptible crops to the initial infected crop, both in the current growing season and previous season. This will include the grower’s own crops and those on neighbouring properties
- What machinery or vehicles have been into the infected crop
- A possible link to recent overseas travel and countries known to have BCR

2.6.3 Models of spread potential

Some general comments about possible mechanisms of spread are:

- Movement of infected seed. The pathogen has the potential to be transmitted as infected seed.
- Small fragments of infected plant debris and bacterial spores spread from infested plants via wind-blown rain into surrounding paddocks during tropical storms. This allows the pathogen to move considerable distances away from the infected crop. The spread from initial infections will occur in the direction of the prevailing winds and show a gradient with highest incidence along the side of the planting closest to the source of inoculum.

2.6.4 Pest Free Area guidelines

Points to consider are:

- Design of a statistical delimiting field survey for symptoms on host plants (see section 2.6.1 for points to consider in the design)
- Plant sampling should be based on samples from at least four plants taken at random from each crop

Additional information is provided by the IPPC (1995) in Requirements for the Establishment of Pest Free Areas. This standard describes the requirements for the establishment and use of Pest Free Areas (PFA) as a risk management option for phytosanitary certification of plants and plant products. Establishment and maintenance of a PFA can vary according to the biology of the pest, pest survival potential, means of dispersal, availability of host plants, restrictions on movement of produce, as well as PFA characteristics (size, degree of isolation and ecological conditions).

2.7 Availability of control methods

2.7.1 General procedures for control

- Plant tolerant cultivars (if available) in affected areas
- Prompt removal and destruction of infected plants or potential host plants (burning or burial).

2.7.2 Control if small areas are affected

Collect all plants in the area into bags and destroy by burning or burial. As the pathogen is believed not to survive well in soil, surveillance and destruction of infected material is likely to be effective.

2.7.3 Control if large areas are affected

A large area may become affected if a large quantity of infected seed has been widely distributed or if the disease has gone unnoticed for a number of years.

Given the medium-high overall risk posed by this pathogen, if confirmed across large areas, eradication could be considered, however it would be dependent on benefit: cost.

Implementation of large area controls will depend on the ability to determine the original source and track/trace the spread. If the disease is found early and shown to be confined to a single seed lot, it may be possible to eradicate the disease by destroying all crops from that seed lot in the region.

If eradication was attempted, there would need to be ongoing monitoring of infected paddocks to ensure there was no opportunity for the pathogen to re-establish itself.

2.7.4 Specific controls for *E. papayae*

2.7.4.1 CULTURAL CONTROL

Pathogen levels in seeds can be reduced through hot water treatment (AQIS 2010). Hot water treatment (50°C for 20 minutes) is recommended by AQIS for the decontamination of seed grown in countries known to have BCR.

E. papayae is known to only survive in soil for 2 weeks (Obrero 1980; Webb 1985) so the thorough incorporation of infected papaya material into the soil to allow breakdown to occur can significantly reduce the risk of further disease spread. In the Philippines there is also anecdotal evidence that healthy papaya can be grown in fields where infected papaya had been grown.

Disease management may include phytosanitation to reduce disease inoculum.

2.7.4.2 HOST PLANT RESISTANCE

Research conducted in the Philippines by Obrero (1980) in which 31 canning cultivars and 'Solo' papaya selections were field evaluated for resistance to *E. papayae*, showed that two Philpack 'Solo' selections (individual plant selections from survivors in a BCR infected field) and six Philpack canning cultivars (commercial lines developed by inter-crosses between Iligan and Cavite cultivars) had good resistance to BCR.

Research conducted by Trujillo and Schroth (1982) in the Mariana islands showed that of 17 papaya cultivars spray inoculated with *E. papayae*, Saipan Red, Dwarf Solo No. 7355 and Waimanolo Solo were the most resistant. The wild papaya indigenous to the Mariana Islands was highly resistant to the disease. Their results suggested the best possibility for economic control would come from the development of resistant cultivars.

Twenty-nine commercial papaya cultivars from Hawaii, Puerto Rico, Java, Canary Islands, Costa Rica, Virgin Islands, Jamaica, Trinidad and Barbados were evaluated for resistance to BCR under glasshouse conditions (Webb 1985). The least susceptible cultivars were Barbados Dwarf 2X, Trinidad pink, STT 683-1 and P. R. 10-65.

In breeding program commenced by CIRAD in Guadeloupe where BCR had decimated all 'Solo' papaya plantings in the region, forty-six papaya breeding accessions were evaluated in the greenhouse (Ollitrault et al. 2005). Local Guadeloupe accessions showed a high level of disease tolerance (96-100%) and F1 crosses between 'Solo' and local accessions an intermediate level of disease tolerance (64-86%). The authors felt that disease tolerance was transmitted in a co-dominant way in F1 hybrids between the cultivar 'Solo' and tolerant accessions. This provides opportunity for a breeding program to develop improved disease tolerant papaya cultivars in regions where BCR is a production issue.

2.7.4.3 CHEMICAL CONTROL

Attempts in the Caribbean to control BCR with bactericides, antibiotics and the chemicals copper hydroxides and mancozeb were not effective (Webb 1985). Prophylactic applications of copper hydroxide are made in the Philippines.

2.7.4.4 MECHANICAL CONTROL

There are no mechanical controls for BCR.

2.7.4.5 BIOLOGICAL CONTROL

There are no known biological controls for BCR.

2.7.4.6 INTEGRATED CONTROL

For long term management of an established population of BCR, disease control will depend largely on the use of disease free seed, the growing of tolerant cultivars and prophylactic sprays with copper hydroxide.

3 Course of action – eradication methods

Additional information is provided by the IPPC (1998) in Guidelines for Pest Eradication Programmes. This standard describes the components of a pest eradication programme which can lead to the establishment or re-establishment of pest absence in an area. A pest eradication programme may be developed as an emergency measure to prevent establishment and/or spread of a pest following its recent entry (re-establish a PFA) or a measure to eliminate an established pest (establish a PFA). The eradication process involves three main activities: surveillance, containment, and treatment and/or control measures.

3.1 Destruction strategy

3.1.1 Destruction protocols

- Infected crops should be destroyed by ploughing as the disease has been shown to not survive in field soil. This will also assist to prevent the dispersal of the pathogen via wind-blown rain
- Infested fields should not be replanted to papaya until all previous papaya crop residues are broken down
- Disposable equipment and infected plant material should be disposed of by autoclaving, high temperature incineration or deep burial
- Any equipment removed from the site for disposal should be double-bagged

3.1.2 Decontamination protocols

If containment, eradication and/or best practice hygiene measures are implemented, machinery, equipment, vehicles in contact with infected plant material present within the Quarantine Area should be washed to remove plant material using high pressure water or scrubbing with products such as a farm degreaser or a 1% bleach (available chlorine) solution in a designated wash down. General guidelines for wash down areas are as follows:

- Located away from crops or sensitive vegetation
- Readily accessible with clear signage
- Access to fresh water and power
- Gently sloped to drain effluent away
- Effluent must not enter water courses or water bodies
- Allow adequate space to move larger vehicles
- Away from hazards such as power lines
- Waste water, soil or plant residues should be contained (see PLANTPLAN Appendix 18, Plant Health Australia 2010b)
- Disposable overalls and rubber boots should be worn when handling infected plant material in the field. Boots, hats, clothes and shoes in contact with infected plant material should be disinfected at the site or double-bagged to remove for cleaning
- Skin and hair in contact with infested plant material should be washed

3.1.3 Priorities

Specific priorities for eradication:

- Confirm the presence of the pathogen
- Prevent movement of vehicles and equipment through affected areas
- Priority of eradication/decontamination of infected host material
- Determine the extent of infection through survey and seed trace back
- Stop the movement of any seed that may be infected with the pathogen

3.1.4 Plants, by-products and waste processing

- Seeds harvested from infected plants and infected plant material removed from the infected site should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial (in a non-cropping area)
- Infested paddocks should remain free of susceptible host plants until all infested plant residues are no longer evident

3.1.5 Disposal issues

- Particular care must be taken to minimise the transfer of infected plant material from the area

3.2 Quarantine and movement controls

3.2.1 Quarantine priorities

- Plant material at the site of infestation to be subject to movement restrictions
- Machinery, equipment, vehicles and disposable equipment in contact with infested plant material to be subject to movement restrictions

3.2.2 Movement control for people, plant material and machinery

Movement of people, vehicle and machinery, from and to affected farms, must be controlled to ensure that infected plant debris is not moved off-farm. This can be achieved through:

- Signage to indicate quarantine area and/or restricted movement in these zones
- Fenced, barricaded or locked entry to quarantine areas
- Movement of equipment, machinery and plant material by permit only
- Clothing and footwear worn at the infected site should either be double-bagged prior to removal for decontamination or should not leave the farm until thoroughly disinfected, washed and cleaned
- Fruit and plant seedlings must not be removed from the site
- All machinery and equipment should be thoroughly cleaned down with a pressure cleaner prior to leaving the affected farm. The clean down procedure should be carried out on a hard surface, preferably a designated wash-down area (see Section 3.1.2)
- Seed from the affected site should not be used for planting new crops

3.3 Zoning

The size of each quarantine area will be determined by a number of factors, including the location of the incursion, biology of the pest, climatic conditions and the proximity of the infected property to other infected properties.

3.3.1 Destruction Zone

The size of the destruction zone (i.e. zone in which the pest and all host material is destroyed) will depend on the ability of the pest to spread, distribution of the pest (as determined by delimiting surveys), time of season (and part of the pest life cycle being targeted) and factors which may contribute to the pest spreading.

The entire crop should be destroyed after the level of infestation has been established. The delimiting survey will determine whether or not neighbouring host crops are infested and need to be destroyed.

The Destruction Zone may be defined as contiguous areas associated with the same management practices as the infested area (i.e. the entire trial, paddock or farm if spread could have occurred prior to the infestation being identified).

Particular care needs to be taken to ensure that plant material is not moved into surrounding areas not showing symptoms of disease.

3.3.2 Quarantine Zone

The Quarantine Zone is defined as the area where voluntary or compulsory restraints are in place for the affected property(ies). These restraints may include restrictions or movement control for removal of plants, people or contaminated equipment from an infected property.

3.3.3 Buffer Zone

A Buffer Zone may or may not be required depending on the incident. It is defined as the area in which the pest does not occur but where movement controls or restrictions for removal of plants, people, or equipment from this area are still deemed necessary. The Buffer Zone may enclose an infested area (and is therefore part of the Control Area) or may be adjacent to an infested area.

3.3.4 Restricted Area

The Restricted Area is defined as the zone immediately around the infected premises and suspected infected premises. The Restricted Area is established following initial surveys that confirm the presence of the pest. The Restricted Area will be subject to intense surveillance and movement control with movement out of the Restricted Area to be prohibited and movement into the Restricted Area to occur by permit only. Multiple Restricted Areas may be required within a Control Area.

3.3.5 Control Area

The Control Area is defined as all areas affected within the incursion. The Control Area comprises the Restricted Area, all infected premises and all suspected infected premises and will be defined as the minimum area necessary to prevent spread of the pest from the Quarantine Zone. The Control Area will also be used to regulate movement of all susceptible plant species to allow trace back, trace forward and epidemiological studies to be completed.

3.4 Decontamination and farm clean up

Decontamination practices are aimed at eliminating the pest thus preventing its spread to other areas.

3.4.1 Decontamination procedures

General guidelines for decontamination and clean up:

- Refer to PLANTPLAN (Plant Health Australia 2010b) for further information

- Keep traffic out of affected area and minimise it in adjacent areas
- Adopt best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms
- Machinery, equipment and vehicles in contact with infected plant material within the Quarantine Area, should be washed to remove plant material using high pressure water or scrubbing with products such as a detergent, a farm degreaser or a 1% bleach solution in a designated wash down area as described in 3.1.2
- Only recommended materials are to be used when conducting decontamination procedures, and should be applied according to the product label

3.4.2 General safety precautions

For any chemicals used in the decontamination, follow all safety procedures listed within each MSDS.

3.5 Surveillance and tracing

3.5.1 Surveillance

Detection and delimiting surveys are required to delimit the extent of the incursion, ensuring areas free of the pest retain market access and appropriate quarantine zones are established.

Initial surveillance priorities include the following:

- Surveying all papaya growing properties in the pest quarantine area
- Surveying all properties identified in trace-forward or trace-back analysis as being at risk
- Surveying all papaya growing properties that are reliant on trade with interstate or international markets which may be sensitive to presence of *E. papayae*
- Surveying commercial nurseries selling at risk papaya plants (if applicable)
- Surveying other papaya growing properties and backyards

3.5.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (see Section 3.3), and prioritised based on their potential likelihood to currently have or receive an incursion of this pest. Surveillance activities within these regions will either allow for the area to be declared pest free and maintain market access requirements or establish the impact and spread of the incursion to allow for effective control and containment measures to be carried out.

Steps outlined in Table 2 form a basis for a survey plan. Although categorised in stages, some stages may be undertaken concurrently based on available skill sets, resources and priorities.

Table 3. Phases to be covered in a survey plan

Phase 1	<ul style="list-style-type: none"> Identify properties that fall within the buffer zone around the infested premise Complete preliminary surveillance to determine ownership, property details, production dynamics and tracings information (this may be an ongoing action)
Phase 2	<ul style="list-style-type: none"> Preliminary survey of papaya crops in properties in buffer zone establishing points of pest detection
Phase 3	<ul style="list-style-type: none"> Surveillance of an intensive nature, to support control and containment activities around points of pest detection
Phase 4	<ul style="list-style-type: none"> Surveillance of contact premises. A contact premise is a property containing papaya plants, which are known to have been in direct or indirect contact with an infested premises or infected plants. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the disease. Pathways to be considered are: <ul style="list-style-type: none"> Items of equipment and machinery which have been shared between properties including bins, containers, irrigation lines, vehicles and equipment The producer and retailer of infected material if this is suspected to be the source of the outbreak Labour and other personnel that have moved from infected, contact and suspect premises to unaffected properties (other growers, tradesmen, visitors, salesmen, crop scouts, harvesters and possibly beekeepers) Movement of plant material from controlled and restricted areas Storm and rain events and the direction of prevailing winds that result in air-borne dispersal of the pathogen during these weather events
Phase 5	<ul style="list-style-type: none"> Surveillance of nurseries, gardens and public land where papaya are being grown
Phase 6	<ul style="list-style-type: none"> Agreed area freedom maintenance, pest control and containment

3.5.3 Post-eradication surveillance

The period of pest freedom sufficient to indicate that eradication of the pest has been achieved will be determined by a number of factors, including cropping conditions, the previous level of infection and the control measures applied. As a guide, the following activities should be carried out following the eradication of the pathogen:

- Establishment of sentinel plants at the site of infection
- Maintain good sanitation and hygiene practices throughout the year
- Sentinel plants should remain in place and inspected on a fortnightly basis for a further 12 weeks and then on a monthly basis. Sentinel plants showing signs of the disease should be tested for confirmation then immediately removed and destroyed
- Surveys comprising of plant samples for testing for *E. papayae* are to be undertaken for a minimum of 12 months after eradication has been achieved

4 References

- AQIS (2010) Condition C18638: Seed for sowing conditions for *Carica papaya*. AQIS ICON Database (www.aqis.gov.au/icon32/)
- Fullerton RA, Taufan L, Vanneste JL, Yu J, Cornish DA, Park D (2011) First record of bacterial crown rot of papaya (*Carica papaya*) caused by an *Erwinia papayae*-like bacterium in the Kingdom of Tonga. *Plant Disease* **95**, 70.
- Gardan L, Christen R, Achouak W, Prior P (2004) *Erwinia papayae* sp. nov., a pathogen of papaya (*Carica papayae*). *International Journal of Systematic and Evolutionary Microbiology* **54**, 107-113.
- IPPC (1995) Requirements for the Establishment of Pest Free Areas. International Standards for Phytosanitary Measures (ISPM) No. 4.
- IPPC (1998) Guidelines for Pest Eradication Programmes. International Standards for Phytosanitary Measures (ISPM) No. 9.
- Maktar NH, Kamis S, Mohd Yusof FZ, Hussain NH (2008) *Erwinia papayae* causing papaya dieback in Malaysia. *New Disease Reports*.
- Merriman P, McKirdy S (2005) Technical guidelines for the development of pest specific response plans. Plant Health Australia, Canberra, ACT, Australia.
- Obrero FP (1980) Bacterial crown rot of papaya in the Philippines: Etiology, epidemiology and screening for disease resistance. *PhD Thesis*. University of the Philippines at Los Banos. pp 145.
- Obrero FP (1991) Bacterial crown rot of papaya in the Philippines. In: *Proceedings of First National Symposium/Workshop on Ring Spot and other diseases of papaya in the Philippines*, The Philippine Phyt. Soc. Bureau of Plant Industry, San Andres, Malate, Manila, pp 20-23.
- Olabiya (2010) First report of *Erwinia* Stem Canker of papaya (*Carica papaya* L.) in Nigeria. *European Journal of Scientific Research* **46**, 422-430.
- Ollitrualt P, Bruyere J, Ocampo L, Gallard A, Argoud L, Duval MF, Coppens d'Eeckenbrugge G, Le Bellec F (2005) Papaya breeding for tolerance to bacterial decline (*Erwinia* sp.) in the Caribbean region. *Acta Hort.* (ISHS) **740**, 79-91.
- Plant Health Australia (2010a) PLANTPLAN Australian Emergency Plant Pest Response Plan. Version 1. Appendix 3: Sampling procedures and protocols for transport, diagnosis and confirmation of EPPs. Plant Health Australia, Canberra, ACT, Australia. (www.planthealthaustralia/plantplan)
- Plant Health Australia (2010b) PLANTPLAN Australian Emergency Plant Pest Response Plan. Version 1. Appendix 18: Disinfection and decontamination. Plant Health Australia, Canberra, ACT. (www.planthealthaustralia/plantplan)
- Trujillo EE and Schroth MN (1982) Two bacterial diseases of papaya trees caused by *Erwinia* species in the northern Mariana Islands. *Plant Disease* **66**, 116-120.
- Webb RR (1985) Epidemiology and control of bacterial canker of papaya caused by an *Erwinia* sp. on St. Croix, U.S. Virgin Islands. *Plant Disease* **69**, 305-309.

Appendix 1. Standard diagnostic protocols

For a range of specifically designed procedures for the emergency response to a pest incursion refer to Plant Health Australia's PLANTPLAN (www.planthealthaustralia.com.au/plantplan).

Appendix 2. Experts, resources and facilities

The following tables provide lists of experts (Table 3) and diagnostic facilities (Table 4) for use in professional diagnosis and advisory services in the case of an incursion.

Table 4. Experts who can be contacted for professional diagnostic and advisory services

Expert	State	Details
Dr Nandita Pathania, Bacteriologist, DEEDI, Mareeba	Qld	Dr. Pathania is familiar with the papaya industry and has experience in the recovery of bacterial plant pathogens.

Table 5. Diagnostic service facilities in Australia

Facility	State	Details
DPI Victoria Knoxfield Centre	Vic	621 Burwood Highway Knoxfield VIC 3684 Ph: (03) 9210 9222; Fax: (03) 9800 3521
DPI Victoria Horsham Centre	Vic	Natimuk Rd Horsham VIC 3400 Ph: (03) 5362 2111; Fax: (03) 5362 2187
DPI New South Wales, Elizabeth Macarthur Agricultural Institute	NSW	Woodbridge Road Menangle NSW 2568 PMB 8 Camden NSW 2570 Ph: (02) 4640 6327; Fax: (02) 4640 6428
DPI New South Wales, Tamworth Agricultural Institute	NSW	4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100; Fax: (02) 6763 1222
DPI New South Wales, Wagga Wagga Agricultural Institute	NSW	PMB Wagga Wagga NSW 2650 Ph: (02) 6938 1999; Fax: (02) 6938 1809
SARDI Plant Research Centre - Waite Main Building, Waite Research Precinct	SA	Hartley Grove Urrbrae SA 5064 Ph: (08) 8303 9400; Fax: (08) 8303 9403
Grow Help Australia	QLD	Entomology Building 80 Meiers Road Indooroopilly QLD 4068 Ph: (07) 3896 9668; Fax: (07) 3896 9446

Facility	State	Details
Department of Agriculture and Food, Western Australia (AGWEST) Plant Laboratories	WA	3 Baron-Hay Court South Perth WA 6151 Ph: (08) 9368 3721; Fax: (08) 9474 2658

Appendix 3. Communications strategy

A general Communications Strategy is provided in Appendix 6 of PLANTPLAN (2010, Version 1).