

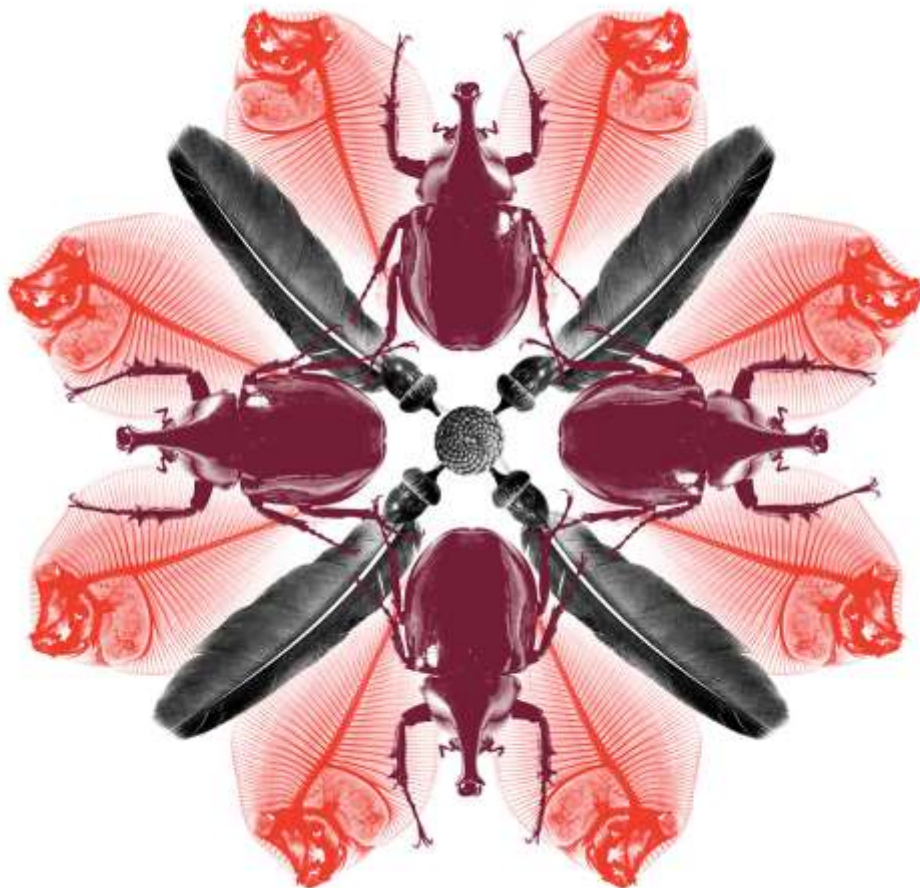


Australian Government  
Department of Agriculture  
and Water Resources

# Draft pest risk analysis for *Cucumber green mottle mosaic virus (CGMMV)*

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April 2016



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### **Stakeholder submissions on draft reports**

This draft report has been issued to give all interested parties an opportunity to comment on relevant technical biosecurity issues, with supporting rationale. A final report will then be produced taking into consideration any comments received.

Submissions should be sent to the Australian Government Department of Agriculture and Water Resources following the conditions specified within the related Biosecurity Advice, which is available at: [agriculture.gov.au/ba/memos](http://agriculture.gov.au/ba/memos).

# Contents

<b>Acronyms and abbreviations .....</b>	<b>vii</b>
<b>Summary .....</b>	<b>1</b>
<b>1. Introduction.....</b>	<b>3</b>
1.1 Australia's biosecurity policy framework .....	3
1.2 This Pest Risk Analysis.....	3
1.2.1 Background .....	3
1.2.2 Scope.....	4
1.2.3 Consultation.....	5
<b>2 Method for Pest Risk Analysis.....</b>	<b>7</b>
2.1 Stage 1: Initiation of the Pest Risk Analysis .....	7
2.2 Stage 2: Pest risk assessment .....	7
2.2.1 Pest categorisation .....	8
2.2.2 Assessment of the likelihood of entry, establishment and spread .....	8
2.2.3 Assessment of potential consequences .....	11
2.2.4 Estimation of the unrestricted risk .....	13
2.2.5 Australia's Appropriate Level of Protection .....	13
2.3 Stage 3: Pest risk management .....	14
2.3.1 Identification and selection of appropriate risk management options.....	14
<b>3 The pathogen.....</b>	<b>16</b>
3.1 Geographical distribution of CGMMV .....	16
3.2 Biology of CGMMV .....	17
3.2.1 Hosts of CGMMV .....	17
3.2.2 Spread of CGMMV .....	19
3.3 Symptoms of CGMMV .....	21
Symptoms caused by CGMMV on <i>Citrullus lanatus</i> .....	21
Symptoms caused by CGMMV on <i>Cucumis melo</i> .....	22
Symptoms caused by CGMMV on <i>Cucumis sativus</i> .....	22
Symptoms caused by CGMMV on other seed-borne hosts.....	23
<b>4 Pest risk assessment.....</b>	<b>25</b>
4.1 <i>Cucumber green mottle mosaic virus</i> (CGMMV) .....	25
4.1.1 Likelihood of entry .....	25
4.1.2 Likelihood of establishment.....	29

4.1.3	Likelihood of spread .....	31
4.1.4	Overall likelihood of entry, establishment and spread .....	33
4.1.5	Consequences .....	33
4.1.6	Unrestricted risk estimate .....	35
<b>5</b>	<b>Pest risk management .....</b>	<b>36</b>
5.1	Introduction of emergency measures .....	36
5.1.1	Emergency measures for host seeds for sowing .....	37
5.2	Evaluation of emergency measures.....	38
5.2.1	Seeds for sowing from all sources (commercial or small lots) .....	38
5.3	Proposed risk mitigation measures .....	38
5.3.1	Seeds for sowing from all countries .....	39
<b>6</b>	<b>Conclusion .....</b>	<b>40</b>
<b>Appendix A: Stakeholders comments on emergency measures .....</b>		<b>42</b>
	Issues raised by stakeholders in response to the emergency measures.....	42
	Questions in relation to <i>Cucumber green mottle mosaic virus</i> .....	42
	Questions in relation to emergency measures.....	45
<b>Appendix B: Additional quarantine pest data .....</b>		<b>49</b>
<b>Glossary.....</b>		<b>50</b>
<b>References .....</b>		<b>53</b>

## Tables

Table 1 Nomenclature of qualitative likelihoods .....	10
Table 2 Matrix of rules for combining qualitative likelihoods .....	11
Table 3 Decision rules for determining the consequence impact score based on the magnitude of consequences at four geographic scales .....	12
Table 4 Decision rules for determining the overall consequence rating for each pest.....	13
Table 5 Risk estimation matrix.....	13
Table 6 Natural hosts of CGMMV and its association with host seeds .....	17
Table 7 Unrestricted risk estimates of CGMMV for seed pathway .....	35
Table 8 Small seed lot weights for host cucurbit seeds under the emergency measures.....	38
Table 9 Effect of seed sample size on the confidence level in detecting infected seeds .....	46

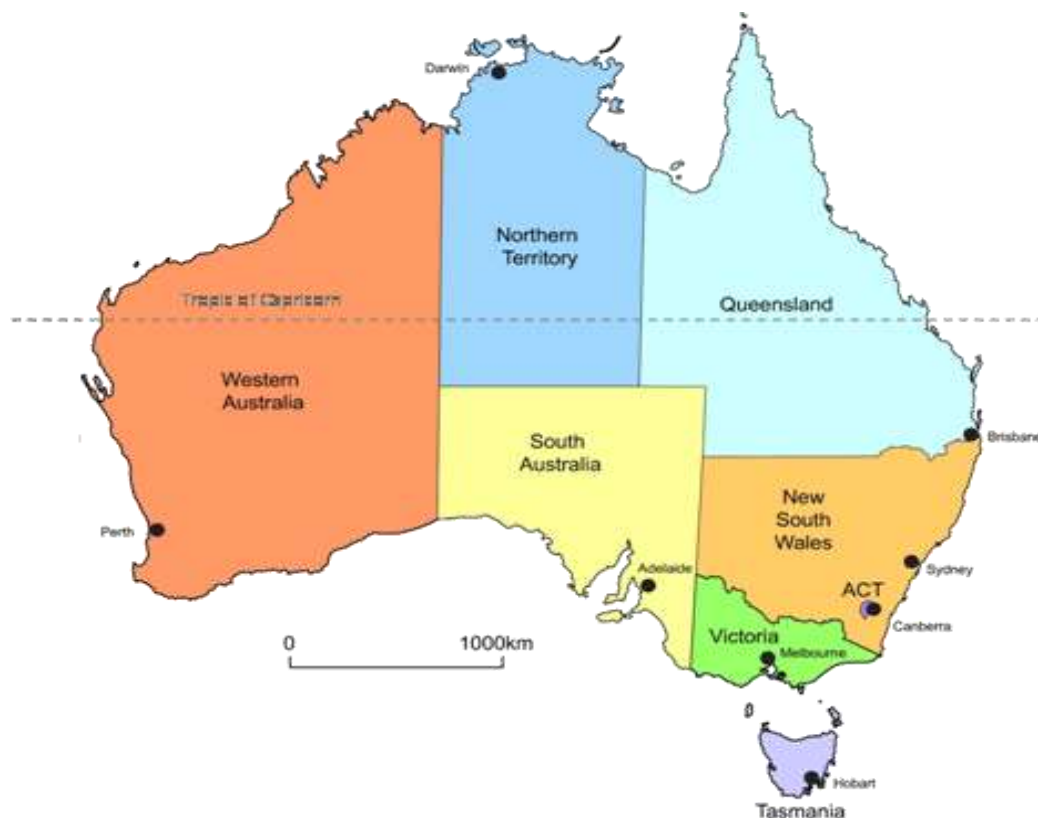
## Maps

Map 1 Map of Australia .....	vi
Map 2 A guide to Australia's bio-climatic zones.....	vi
Map 3 Global occurrence of CGMMV .....	16

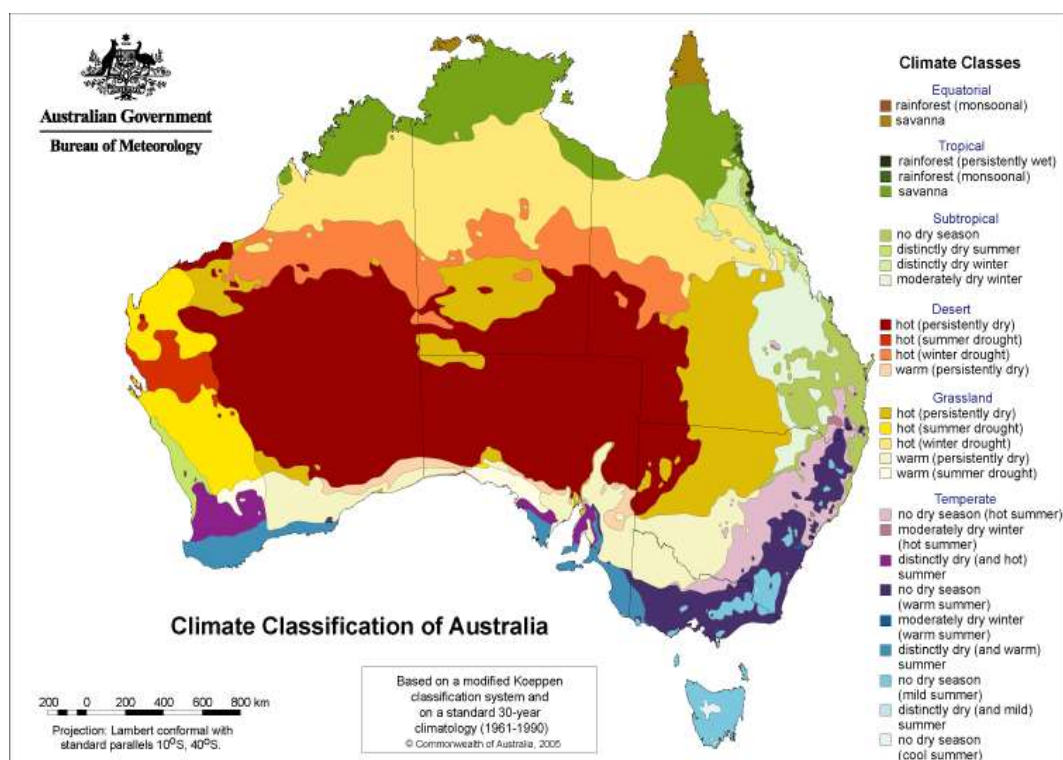
## Figures

Figure 1 CGMMV symptoms on watermelon: (A) leaf mottling and chlorotic mosaic symptoms; (B) peduncle necrosis; (C) whitish-yellow discoloration of the peripheral region of fruit; and (D) water-soaked inner pulp of fruit .....	22
Figure 2 CGMMV symptoms on melon leaves and fruits: (A) mild chlorosis and mosaic symptoms on leaves and (B) mottle on fruits .....	22
Figure 3 CGMMV symptoms on cucumber leaves and fruits: (A) leaf mottling and chlorosis; (B) fruit blistering and mottling; and (C) fruit distortion.....	23
Figure 4 CGMMV symptoms in zucchini: (A) mild mosaic leaf symptoms and (B) internal vein yellowing leaf symptoms.....	23
Figure 5 CGMMV mottle and mosaic symptoms on a bottle gourd leaf .....	24

Map 1 Map of Australia



Map 2 A guide to Australia's bio-climatic zones



## Acronyms and abbreviations

Term or abbreviation	Definition
ACT	Australian Capital Territory
ALOP	Appropriate level of protection
BICON	The Australian Government Department of Agriculture and Water Resources Biosecurity Import CONditions database
DEDJTR	Victorian Government Department of Economic Development, Jobs, Transport and Resources
DPIF	Northern Territory Government Department of Primary Industries and Fisheries
ELISA	Enzyme-Linked Immunosorbent Assay
FAO	Food and Agriculture Organization of the United Nations
IPC	International Phytosanitary Certificate
IPPC	International Plant Protection Convention
IRA	Import risk analysis
ISPM	International Standard For Phytosanitary Measures
ISTA	International Seed Testing Association
CGMMV	<i>Cucumber green mottle mosaic virus</i>
NSW	New South Wales
NPPO	National Plant Protection Organisation
NT	Northern Territory
PEQ	Post-entry quarantine
PCR	Polymerase Chain Reaction
PRA	Pest risk analysis
Qld	Queensland
SA	South Australia
SEM	Scanning Electron Microscopy
SPS	Sanitary and Phytosanitary
TAS	Tasmania
TEM	Transmission Electron Microscopy
VIC	Victoria
WA	Western Australia
WTO	World Trade Organization



## Summary

The Australian Government Department of Agriculture and Water Resources (the department) initiated this pathogen-based pest risk analysis (PRA) in response to the introduction of emergency measures against *Cucumber green mottle mosaic virus* (CGMMV). The virus was detected in September 2014 in the Northern Territory, Australia and declared a quarantine pathogen; and delimiting surveys were initiated for all cucurbit growing areas in the Northern Territory. Australia introduced emergency measures in October 2014 to mitigate the risk of further introduction of CGMMV into Australia. In April 2015, CGMMV was found on a single property near Charters Towers in Queensland and the infected property remains under quarantine. The emergency measures were amended in December 2015 to update the host list for CGMMV in response to the detection of this virus in the seeds of additional hosts. Although, the Northern Territory government formally revoked the CGMMV quarantine zone in February 2016, risk management measures have been implemented to contain the spread of this virus. Therefore, the virus is under official control. Consequently, CGMMV remains a quarantine pathogen for Australia.

The International Plant Protection Convention (IPPC) and the 'World Trade Organisation Agreement on the Application of Sanitary and Phytosanitary Measures' (SPS Agreement) requires that any phytosanitary measures against the introduction of new pests must be technically justified. The IPPC's International Standards for Phytosanitary Measures (ISPM) No. 1 states that 'countries may take appropriate emergency action on a pest posing a potential threat to its territories; however, it requires that the action be evaluated as soon as possible to justify the continuance of the action'. Therefore, this PRA meets Australia's international obligations to review the emergency phytosanitary measures on CGMMV associated with host cucurbit seeds (*Citrullus lanatus*, *Cucumis melo*, *Cucumis sativus*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Lagenaria siceraria*, *Trichosanthes cucumerina* and any hybrid of these species).

The scope of this PRA is limited to reviewing the emergency measures for CGMMV host seeds. The suspension of host nursery stock and tissue cultures is outside the scope of this PRA and will be reviewed at a later date.

The department considers that the emergency measures are adequate to mitigate the risk posed by CGMMV associated with host cucurbit seeds. The only proposed amendment is to provide the option for small seed lots to be tested off-shore.

The proposed import conditions for CGMMV host cucurbit seeds for sowing (*Citrullus lanatus*, *Cucumis melo*, *Cucumis sativus*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Lagenaria siceraria*, *Trichosanthes cucumerina* and any hybrid of these species) are summarised below.

### Commercial seed lots

- **Testing (off-shore or on-shore)**—mandatory testing by ELISA for CGMMV following the protocol of the International Seed Testing Association (ISTA) 7-026 using a sample size of 9,400 seeds;
- **Certification (off-shore testing only)**—consignments must be accompanied by an official government Phytosanitary Certificate endorsed with an additional declaration that '*The consignment of [botanical name (genus/species)] was tested by ELISA using a sample size of 9,400 seeds following the protocol of the ISTA 7-026 and found free from Cucumber green*



*mottle mosaic virus*’; and

- **On-arrival inspection**—to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material, animal material and any other extraneous contamination of quarantine concern.

#### **Small seed lots**

- **Testing (off-shore or on-shore)**—mandatory testing by ELISA for CGMMV following the protocol of ISTA 7-026 using a sample size of 20 percent of the seed lot weight or a 9,400 seed sample;
- **Certification (off-shore testing only)**—consignments must be accompanied by an official government Phytosanitary Certificate endorsed with one of the following additional declarations:
  - ‘The consignment of [botanical name (genus/species)] was tested by ELISA using 20 percent of the seed lot weight following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*’ **OR**
  - ‘The consignment of [botanical name (genus/species)] was tested by ELISA using a sample size of 9,400 seeds following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*, **and**
- **On-arrival inspection**—to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material, animal material and any other extraneous contamination of quarantine concern.

The department invites comments on the technical aspects of the proposed risk management measures within the consultation period. In particular, comments are sought on their appropriateness and any other measures stakeholders consider would provide equivalent risk management outcomes. The department will consider any comments received before finalising the PRA and import policy recommendations.

## 1. Introduction

### 1.1 Australia's biosecurity policy framework

Australia's biosecurity policies aim to protect Australia against the risks that may arise from exotic pests entering, establishing and spreading in Australia, thereby threatening Australia's unique flora and fauna, as well as those agricultural industries that are relatively free from serious pests.

The risk analysis process is an important part of Australia's biosecurity policies. It enables the Australian Government to formally consider the risks that could be associated with proposals to import new products into Australia. If the risks are found to exceed Australia's appropriate level of protection (ALOP), risk management measures are proposed to reduce the risks to an acceptable level. But, if it is not possible to reduce the risks to an acceptable level, then no trade will be allowed.

Successive Australian governments have maintained a stringent, but not a zero risk approach to the management of biosecurity risks. This approach is expressed in terms of Australia's ALOP, which reflects community expectations through government policy and is currently described as providing a high level of protection aimed at reducing risk to a very low level, but not to zero.

Australia's pest risk analyses (PRAs) are undertaken by the Department of Agriculture and Water Resources, hereafter referred to as the department, using teams of technical and scientific experts in relevant fields and involves consultation with stakeholders at various stages during the process.

Further information about Australia's biosecurity framework is provided in the *Import Risk Analysis Handbook 2011* located on the [Department of Agriculture and Water Resources](#) website.

### 1.2 This Pest Risk Analysis

The department undertook this PRA to meet Australia's obligations under the IPPC and ISPM No. 1 to review emergency phytosanitary measures introduced to manage the risk of introducing CGMMV into Australia. Australia introduced emergency measures for host propagative material and notified trading partners of the emergency measures in October 2014 through a World Trade Organization Sanitary and Phytosanitary (WTO SPS) notification (G/SPS/N/AUS/347). These emergency measures were amended in December 2015 to regulate the importation of additional seed-borne hosts of CGMMV (G/SPS/N/AUS/347/Add.3). The IPPC and the World Trade Organisation Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), require that any measure against the introduction and spread of new pests must be justified by a science-based assessment, such as a PRA.

#### 1.2.1 Background

The association of *Cucumber green mottle mosaic virus* (CGMMV) with crops in the Cucurbitaceae family (cucurbits) was first reported in the 1930s from the United Kingdom (Ainsworth 1935; Ugaki et al. 1991). Since then, the virus has spread among cucurbit crops worldwide, causing severe disease symptoms and yield loss (Shang et al. 2011; Reingold et al. 2013; Reingold et al. 2015). This virus systemically infects cucurbit hosts (Moreno et al. 2004) and is seed-borne and seed-transmitted in several cucurbit species (Yoon et al. 2008; Liu et al. 2014; Reingold et al.

2015). The association of CGMMV with seed in particular is likely to have contributed to its spread worldwide. For example, the introduction of CGMMV into Japan in 1966 was linked to *Lagenaria siceraria* seed imported from India (Tochihara & Komuro 1974; Kobayashi 1990).

Australia was free of CGMMV; however, in September 2014 this virus was confirmed to occur in commercial watermelon farms near Katherine and Darwin, in the Northern Territory. CGMMV was declared a quarantine pathogen and delimiting surveys were initiated for all cucurbit growing areas in the Northern Territory. The detection of CGMMV in the Northern Territory triggered the introduction of emergency measures in October 2014 to manage the risk of further introductions of CGMMV into Australia. In April 2015, CGMMV was found on a single property near Charters Towers in Queensland and the infected property remains under quarantine. The emergency measures were amended in December 2015 to update the host list for CGMMV in response to the detection of this virus in the seeds of additional hosts.

Prior to the introduction of emergency measures, the importation of cucurbit crop propagative material (tissue cultures, nursery stock and seeds) from all sources was permitted into Australia without any specific disease testing. The emergency measures require testing for seeds for sowing of seed-borne hosts of CGMMV. In addition, the importation of nursery stock and tissue cultures of natural hosts of CGMMV is suspended under the emergency measures.

Under ISPM No. 1: *Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade* (FAO 2011a), Australia is required to review emergency phytosanitary measures and conduct a science-based assessment, such as a PRA, to justify the continuance of the measures. Therefore, Australia initiated this pest risk analysis to justify the emergency measures put in place in October 2014 against CGMMV associated with cucurbit seeds.

In February 2016, the Northern Territory government announced that the CGMMV quarantine zone will be formally revoked. However, new regulations will prohibit the export of seeds, seedlings and bee hives from the Northern Territory without approval for the Chief Inspector of Plant Health, and requires growers to have an auditable farm biosecurity plan for the purpose of controlling CGMMV.

### 1.2.2 Scope

The scope of this PRA is limited to:

- assessing the risk of introducing CGMMV associated with cucurbit seeds for sowing from all sources;
- reviewing and evaluating the existing risk management measures (including emergency measures) for the identified risks; and
- proposing additional risk management measures where appropriate.

The current suspension of CGMMV host tissue cultures and nursery stock is outside the scope of this review. The suspension of host tissue cultures and nursery stock will be reviewed at a later date.

This PRA does not consider existing phytosanitary measures during the pest risk assessment. Existing phytosanitary measures are only considered during the development of risk management measures following the pest risk assessment.

This PRA is limited to recommending appropriate phytosanitary measures to address the risk of introducing CGMMV associated with cucurbit seeds for sowing into Australia. It is the importer's responsibility to ensure compliance with the requirements of all other regulatory and advisory bodies associated with importing commodities to Australia. These include the Department of Immigration and Border Protection, Department of Health, Therapeutic Goods Administration, Australian Pesticides and Veterinary Medicines Authority, Department of the Environment, and state and territory departments of agriculture.

### 1.2.3 Consultation

The department worked closely with industry stakeholders during the development of the emergency measures to minimise disruptions to trade and crop production. Prior to introducing emergency measures against CGMMV, the department consulted with the seed industry including AusVeg, the Australian Seed Federation, representatives of domestic and international seed companies and the Australian Melon Association.

- |                 |  |
|-----------------|--|
| 9 October 2014  | The department held a teleconference with industry to discuss the proposed emergency measures for the importation of host cucurbit seeds.  |
| 14 October 2014 | The department held a teleconference with industry to discuss the proposed testing requirements for the importation of host cucurbit seeds.  |
| 22 October 2014 | The department held a teleconference with industry to notify stakeholders of the immediate implementation of emergency measures for host cucurbit seeds and tissue cultures.   |
| 23 October 2014 | <p>Australia notified trading partners of the emergency measures on 23 October 2014 through a World Trade Organization Sanitary and Phytosanitary (WTO SPS) notification (G/SPS/N/AUS/347).</p> <p>The notification reported that the emergency measures for host cucurbit seeds (mandatory seed testing using ELISA) were to be implemented in three phases to minimise trade disruption.</p> <p><b>Phase 1:</b> Allowing entry of seeds in transit exported prior to 22 October 2014. However, the consignment had to be accompanied by a Phytosanitary Certificate or equivalent supporting document stating that the seed had been tested in accordance with the ISTA protocol 7-026 using a minimum sample size of 2,000 seeds.</p> <p><b>Phase 2:</b> Seeds must be ELISA tested for CGMMV using 9,400 seeds using ISTA 7-026.</p> <p><b>Phase 3:</b> Seeds must be subject to PCR testing using 9,400 seeds to replace ELISA testing.</p> |
| 5 November 2014 | Australia notified trading partners that Phase 1 has expired and was replaced with Phase 2 through a WTO SPS addendum notification (G/SPS/N/AUS/347/Add.1).  |
| 20 January 2015 | Australia notified trading partners that Phase 2 was to remain in place until further notice through a WTO SPS addendum notification (G/SPS/N/AUS/347/Add.2).  |

- 27 August 2015 The department notified industry stakeholders on the progress of the CGMMV PRA at the Australian Seed Federation Annual Conference held in Toowoomba, Australia.
- 11 December 2015 The department notified Australian industry stakeholders on the impending amendment of the emergency measures to include seeds for sowing of *Cucurbita maxima*, *Cucurbita moschata* and hybrids with host parentage.
- 18 December 2015 Australia notified international trading partners that the emergency measures against CGMMV would now apply to seeds for sowing of *Cucurbita maxima*, *Cucurbita moschata* and hybrids with host parentage. (G/SPS/N/AUS/347/Add.3).

## 2 Method for Pest Risk Analysis

The department has conducted this PRA in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM No. 2: *Framework for pest risk analysis* (FAO 2016a) and ISPM No. 11: *Pest risk analysis for quarantine pests* (FAO 2016b) that have been developed under the SPS Agreement (WTO 1995).

Phytosanitary terms used in this PRA are defined in ISPM No. 5: *Glossary of phytosanitary terms* (FAO 2016c). A glossary of the terms used is provided at the back of this report.

The PRA is conducted in the following three consecutive stages: initiation, pest risk assessment and pest risk management.

### 2.1 Stage 1: Initiation of the Pest Risk Analysis

According to ISPM No. 2 (FAO 2016a), a PRA process may be initiated as a result of:

- identification of a pathway that presents a potential pest risk (a means of pest introduction or spread);
- identification of a pest that may require phytosanitary measures (a pest may have been detected or intercepted, a request made to import it or it may have been reported elsewhere);
- review or revision of existing phytosanitary policies and priorities; or
- identification of an organism not previously known to be a pest.

Australia introduced emergency measures in October 2014 after the detection of *Cucumber green mottle mosaic virus* (CGMMV) in melon crops in the Northern Territory. In accordance with ISPM No. 2 (FAO 2016a), this PRA was initiated by the department as a basis for a review and possible revision of the emergency measures introduced by Australia for CGMMV host cucurbit seeds imported into Australia. In Australia, CGMMV has been regulated as a quarantine pest since October 2014.

In February 2016, the Northern Territory government announced that the CGMMV quarantine zone will be formally revoked. However, new regulations will prohibit the export of seeds, seedlings and bee hives from the Northern Territory without approval from the Chief Inspector of Plant Health, and requires growers to have an auditable farm biosecurity plan for the purpose of controlling CGMMV.

In the context of this PRA, the seeds of *Citrullus lanatus*, *Cucumis melo*, *Cucumis sativus*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Lagenaria siceraria*, *Trichosanthes cucumerina* and any hybrid of these species are a potential import 'pathway' by which CGMMV can enter Australia.

For this PRA, the 'PRA area' is defined as the whole of Australia for CGMMV associated with seeds of cucurbit crops.

### 2.2 Stage 2: Pest risk assessment

A pest risk assessment (for quarantine pests) is the 'evaluation of the probability of the introduction and spread of a pest and of the magnitude of the associated potential economic

consequences' (FAO 2016c). The pest risk assessment provides technical justification for identifying quarantine pests and for establishing phytosanitary import requirements.

The following three consecutive steps were used in the pest risk assessment:

- pest categorisation;
- assessment of the probability of entry, establishment and spread; and
- assessment of potential consequences.

### 2.2.1 Pest categorisation

Pest categorisation identifies which pests have the potential to be on the commodity, may become quarantine pests for Australia and require a pest risk assessment. A 'quarantine pest' is a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO 2016c).

The process of a pest categorisation is summarised by ISPM No. 11 (FAO 2016b) as a screening procedure based on the following criteria:

- identity of the pest;
- presence or absence in the PRA area;
- regulatory status;
- potential for establishment and spread in the PRA area; and
- potential for economic, environmental and social consequences in the PRA area.

### 2.2.2 Assessment of the likelihood of entry, establishment and spread

Details of how to assess the 'probability of entry', 'probability of establishment' and 'probability of spread' of a pest are given in ISPM No. 11 (FAO 2016b). The SPS Agreement (WTO 1995) uses the term likelihood rather than probability for these estimates. In qualitative PRAs, the department uses the term 'likelihood' for the descriptors it uses for its estimates of likelihood of entry, establishment and spread. The use of the term 'probability' is limited to the direct quotation of ISPM definitions. A summary of this process is given below, followed by a description of the qualitative methodology used in this PRA.

#### Likelihood of entry

The likelihood of entry describes the likelihood that a quarantine pest will enter Australia as a result of trade in a given commodity, be distributed in a viable state in the PRA area and subsequently be transferred to a host. Assessing the likelihood of entry requires an analysis of each of the pathways with which a pest may be associated, from its origin to distribution in the PRA area.

For the purpose of considering the likelihood of entry, the department divides this step into two components:

- **Likelihood of importation:** the likelihood that a pest will arrive in Australia when a given commodity is imported; and
- **Likelihood of distribution:** the likelihood that the pest will be distributed, as a result of the processing, sale or disposal of the commodity, in the PRA area and subsequently transfer to a susceptible part of a host.

Factors considered in the likelihood of importation include:



- distribution and incidence of the pest in the source area;
- occurrence of the pest in a life-stage that would be associated with the commodity;
- mode of trade (for example, bulk, packed);
- volume and frequency of movement of the commodity along each pathway;
- seasonal timing of imports;
- pest management, cultural and commercial procedures applied at the place of origin;
- speed of transport and conditions of storage compared with the duration of the lifecycle of the pest;
- vulnerability of the life-stages of the pest during transport or storage;
- incidence of the pest likely to be associated with a consignment; and
- commercial procedures (for example, refrigeration) applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors considered in the likelihood of distribution include:

- commercial procedures (for example, refrigeration) applied to consignments during distribution in Australia;
- dispersal mechanisms of the pest, including vectors, that allow movement from the pathway to a host;
- whether the imported commodity is to be sent to a few or many destination points in the PRA area;
- proximity of entry, transit and destination points to hosts;
- time of year at which importation takes place;
- intended use of the commodity (for planting, processing or consumption); and
- risks from by-products and waste.

### **Likelihood of establishment**

Establishment is defined as the ‘perpetuation for the foreseeable future, of a pest within an area after entry’ (FAO 2016c). In order to estimate the likelihood of establishment of a pest, reliable biological information (lifecycle, host range, epidemiology and survival) is obtained from the areas where the pest currently occurs. The situation in the PRA area can then be compared with that in the areas where it currently occurs and expert judgement used to assess the likelihood of establishment.

Factors considered in the likelihood of establishment in the PRA area include the:

- availability of hosts, alternative hosts and vectors;
- suitability of the environment;
- reproductive strategy and potential for adaptation;
- minimum population needed for establishment; and
- cultural practices and control measures.

### **Likelihood of spread**

Spread is defined as ‘the expansion of the geographical distribution of a pest within an area’ (FAO 2016c). The likelihood of spread considers the factors relevant to the movement of the pest, after establishment on a host plant or plants, to other susceptible host plants of the same or different species in other areas. In order to estimate the probability of spread of the pest, reliable biological information is obtained from areas where the pest currently occurs. The

situation in the PRA area is then carefully compared with that in the areas where the pest currently occurs and expert judgement used to assess the likelihood of spread.

Factors considered in the likelihood of spread include the:

- suitability of the natural and/or managed environment for natural spread of the pest;
- presence of natural barriers;
- potential for movement with commodities, conveyances or by vectors;
- intended use of the commodity; and
- potential vectors of the pest in the PRA area.

### ***Assigning likelihoods for entry, establishment and spread***

Likelihoods are assigned to each step of entry, establishment and spread. Six descriptors are used: high, moderate, low, very low, extremely low and negligible (Table 1). Definitions for these descriptors and their indicative probability ranges are given in Table 1. The indicative ranges are only provided to illustrate the boundaries of the descriptors and are not used beyond this purpose in qualitative PRAs. These indicative likelihood ranges provide guidance to the risk analyst and promotes consistency between different pest risk assessments.

**Table 1 Nomenclature of qualitative likelihoods**

<b>Likelihood</b>	<b>Descriptive definition</b>	<b>Indicative range</b>
High	The event would be very likely to occur	0.7 < to ≤ 1
Moderate	The event would occur with an even likelihood	0.3 < to ≤ 0.7
Low	The event would be unlikely to occur	0.05 < to ≤ 0.3
Very low	The event would be very unlikely to occur	0.001 < to ≤ 0.05
Extremely low	The event would be extremely unlikely to occur	0.000001 < to ≤ 0.001
Negligible	The event would almost certainly not occur	0 < to ≤ 0.000001

### ***Combining likelihoods***

The likelihood of entry is determined by combining the likelihood that the pest will be imported into the PRA area and the likelihood that the pest will be distributed within the PRA area, using a matrix of rules (Table 2). This matrix is then used to combine the likelihood of entry and the likelihood of establishment, and then the likelihood of entry and establishment is combined with the likelihood of spread to determine the overall likelihood of entry, establishment and spread.

For example, if the likelihood of importation is assigned a descriptor of 'low' and the likelihood of distribution is assigned a descriptor of 'moderate', then they are combined to give a likelihood of 'low' for entry. Then if the likelihood of establishment has been assigned a descriptor of 'high', this will be combined with the likelihood of entry (low), to give a likelihood for entry and establishment of 'low'. The assigned likelihood for spread (for example 'very low') would then be combined with the likelihood for entry and establishment (low), to give an overall likelihood for entry, establishment and spread of 'very low'. This can be summarised as:

importation x distribution = entry [E]

**low x moderate = low**

entry [E] x establishment = [EE]

**low x high = low**

[EE] x spread = [EES]

**low x very low = very low**

**Table 2 Matrix of rules for combining qualitative likelihoods**

	High	Moderate	Low	Very low	Extremely low	Negligible
High	High	Moderate	Low	Very low	Extremely low	Negligible
Moderate		Low	Low	Very low	Extremely low	Negligible
Low			Very low	Very low	Extremely low	Negligible
Very low				Extremely low	Extremely low	Negligible
Extremely low					Negligible	Negligible
Negligible						Negligible

**Time and volume of trade**

One factor affecting the likelihood of entry is the volume and duration of trade. If all other conditions remain the same, the overall likelihood of entry will increase as time passes and the overall volume of trade increases.

The department normally considers the likelihood of entry on the basis of the estimated volume of one year's trade. However, in case of a high risk commodity the volume of trade is restricted to certain numbers. Therefore, other factors listed in ISPM No. 11 (FAO 2016b) may not be relevant to propagative material of a high risk commodity.

**2.2.3 Assessment of potential consequences**

The objective of the consequence assessment is to provide a structured and transparent analysis of the potential consequences if the pest or disease agents were to enter, establish and spread in Australia. The assessment considers direct and indirect pest effects and their economic and environmental consequences. The requirements for assessing potential consequences are given in Article 5.3 of the SPS Agreement (WTO 1995), ISPM No. 5 (FAO 2016c) and ISPM No. 11 (FAO 2016b).

Direct pest effects are considered in the context of the effects on:

- plant life or health; and
- other aspects of the environment.

Indirect pest effects are considered in the context of the effects on:

- eradication or control;
- domestic trade;
- international trade; and
- the environment.

For each of these six criteria (direct and indirect pest effects), the consequences were estimated over four geographic levels, defined as:

**Local:** an aggregate of households or enterprises (a rural community, a town or a local government area).

**District:** a geographically or geopolitically associated collection of aggregates (generally a recognised section of a state or territory, such as 'Far North Queensland').

**Regional:** a geographically or geopolitically associated collection of districts in a geographic area (generally a state or territory, although there may be exceptions with larger states such as Western Australia).

**National:** Australia wide (Australian mainland states and territories and Tasmania).

For each criterion, the magnitude of the potential consequence at each of these levels was described using four categories, defined as:

**Indiscernible:** pest impact unlikely to be noticeable.

**Minor significance:** expected to lead to a minor increase in mortality/morbidity of hosts or a minor decrease in production but not expected to threaten the economic viability of production. Expected to decrease the value of non-commercial criteria but not threaten the criterion's intrinsic value. Effects would generally be reversible.

**Significant:** expected to threaten the economic viability of production through a moderate increase in mortality/morbidity of hosts, or a moderate decrease in production. Expected to significantly diminish or threaten the intrinsic value of non-commercial criteria. Effects may not be reversible.

**Major significance:** expected to threaten the economic viability through a large increase in mortality/morbidity of hosts, or a large decrease in production. Expected to severely or irreversibly damage the intrinsic 'value' of non-commercial criteria.

The estimates of the magnitude of the potential consequences over the four geographic levels were translated into a qualitative impact score (A–G) using Table 3. For example, a consequence with a magnitude of 'significant' at the 'district' level will have a consequence impact score of D.

**Table 3 Decision rules for determining the consequence impact score based on the magnitude of consequences at four geographic scales**

Magnitude	Geographic scale			
	Local	District	Region	Nation
Indiscernible	A	A	A	A
Minor significance	B	C	D	E
Significant	C	D	E	F
Major significance	D	E	F	G

Note: In earlier qualitative PRAs, the scale for the impact scores went from A to F and did not explicitly allow for the rating 'indiscernible' at all four levels. This combination might be applicable for some criteria. In this report, the impact scale of A to F has been changed to become B–G and a new lowest category A ('indiscernible' at all four levels) was added. The rules for combining impacts in Table 4 were adjusted accordingly.

The overall consequence for each pest is achieved by combining the qualitative impact scores (A–G) for each direct and indirect consequence using a series of decision rules (Table 4). These rules are mutually exclusive, and are assessed in numerical order until one applies.

**Table 4 Decision rules for determining the overall consequence rating for each pest**

Rule	The impact scores for consequences of direct and indirect criteria	Overall consequence rating
1	Any criterion has an impact of 'G'; or more than one criterion has an impact of 'F'; or a single criterion has an impact of 'F' and each remaining criterion an 'E'.	Extreme
2	A single criterion has an impact of 'F'; or all criteria have an impact of 'E'.	High
3	One or more criteria have an impact of 'E'; or all criteria have an impact of 'D'.	Moderate
4	One or more criteria have an impact of 'D'; or all criteria have an impact of 'C'.	Low
5	One or more criteria have an impact of 'C'; or all criteria have an impact of 'B'.	Very Low
6	One or more but not all criteria have an impact of 'B', and all remaining criteria have an impact of 'A'.	Negligible

### 2.2.4 Estimation of the unrestricted risk

Once the assessment of the likelihood of entry, establishment and spread for potential consequences are completed, the unrestricted risk can be determined for each pest or group of pests. This is determined by using a risk estimation matrix (Table 5) to combine the estimates of the likelihood of entry, establishment and spread and the overall consequences of pest establishment and spread. Therefore, risk is the product of likelihood and consequence.

When interpreting the risk estimation matrix, note the descriptors for each axis are similar (for example, low, moderate and high) but the vertical axis refers to likelihood and the horizontal axis refers to consequences. Accordingly, a 'low' likelihood combined with 'high' consequences, is not the same as a 'high' likelihood combined with 'low' consequences—the matrix is not symmetrical. For example, the former combination would give an unrestricted risk rating of 'moderate', whereas the latter would be rated as a 'low' unrestricted risk.

**Table 5 Risk estimation matrix**

Likelihood of pest entry, establishment and spread	Consequences of pest entry, establishment and spread					
	Negligible	Very low	Low	Moderate	High	Extreme
High	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Moderate	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Low	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk	High risk
Very low	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk
Extremely low	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk
Negligible	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

### 2.2.5 Australia's Appropriate Level of Protection

The SPS Agreement defines the concept of an 'appropriate level of sanitary or phytosanitary protection (ALOP)' as the level of protection deemed appropriate by a WTO Member

establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (WTO 1995).

Like many other countries, Australia expresses its ALOP in qualitative terms. Australia's ALOP, which reflects community expectations through government policy, is currently expressed as providing a high level of sanitary or phytosanitary protection aimed at reducing risk to a very low level, but not to zero. The band of cells in Table 5 marked 'very low risk' represents Australia's ALOP.

## 2.3 Stage 3: Pest risk management

Pest risk management evaluates and selects risk management options to reduce the risk of entry, establishment or spread of identified pests for the identified import pathways. To effectively prevent the introduction of pests associated with an identified pathway, a series of important safeguards, conditions or phytosanitary measures must be in place. Propagative material represents a direct pathway for pests identified by the pest categorisation. This pathway is direct since the end-use is the planting of a known host plant.

### 2.3.1 Identification and selection of appropriate risk management options

Phytosanitary measures to prevent the establishment and spread of quarantine pests may include any combination of measures, including pre- or post-harvest treatments, inspection at various points between production and final distribution, surveillance, official control, documentation or certification. A measure or combination of measures may be applied at any one or more points along the continuum between the point of origin and the final destination. Pest risk management explores options that can be implemented (i) in the exporting country, (ii) at the point of entry or (iii) within the importing country. The ultimate goal is to protect plants and prevent the introduction of identified quarantine pests.

Examples of phytosanitary measures which may be applied to propagative material consignments include:

- **Import from pest free areas only (ISPM No. 4)**—the establishment and use of a pest free area by a National Plant Protection Organisation (NPPO) provides for the export of plants from the exporting country to the importing country without the need for application of additional phytosanitary measures when certain requirements are met.
- **Inspections or testing for freedom from regulated pests**—this is a practical measure for visible pests or for pests which produce visible symptoms on plants.
- **Inspection and certification (ISPM No. 7, 12, 23)**—the exporting country may be asked to inspect the shipment and certify that the shipment is free from regulated pests before export.
- **Specified conditions for preparation of the consignment**—the importing country may specify steps that must be followed in order to prepare the consignment for shipment. These conditions can include the requirement for plants to be produced from appropriately tested parent material.
- **Pre-entry or post-entry quarantine**—the importing country may define certain control conditions, inspection and possible treatment of shipments upon their entry into the country. Post-entry quarantine (PEQ) of dormant cuttings, seed and even tissue cultures (*in vitro* plantlets) can help avoid the introduction of new viruses or allied pathogens into the importing countries.

- **Removal of the pest from the consignment by treatment or other methods**—the importing country may specify chemical or physical treatments that must be applied to the consignment before it may be imported.

Measures can range from total prohibition to permitting imports subject to visual inspection. In some cases, more than one phytosanitary measure may be required in order to reduce the pest risk to an acceptable level.



### 3 The pathogen

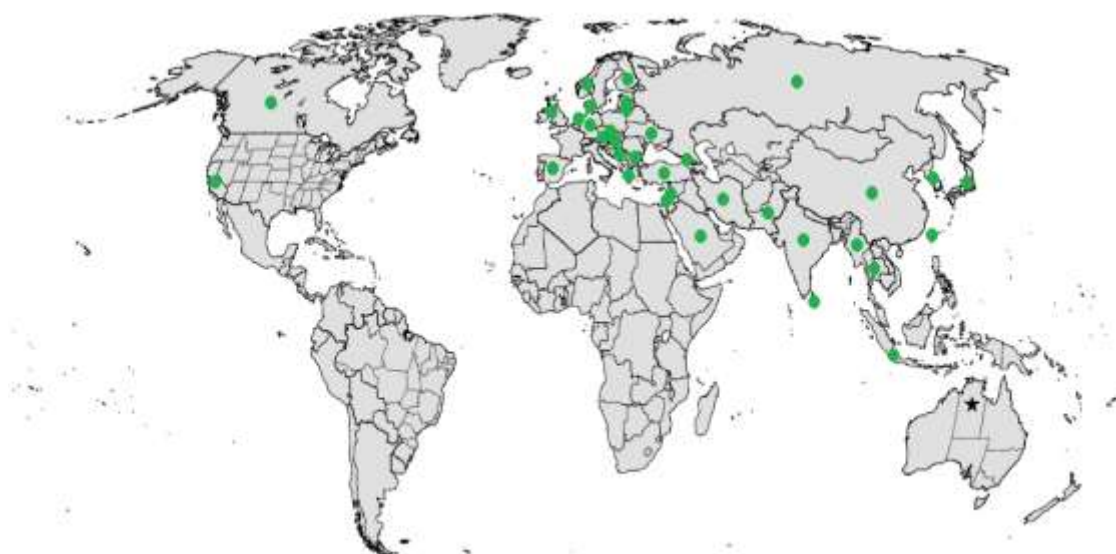
*Cucumber green mottle mosaic virus* (CGMMV) belongs to the genus *Tobamovirus* in the family *Virgaviridae* (Adams et al. 2009). The viruses in the genus *Tobamovirus* have a positive-sense RNA genome and rod-shaped virions (Gibbs 1986; Lewandowski 2000). CGMMV was first described in the 1930's in cucumber and was named *Cucumber virus 3* and *Cucumber virus 4* (Ainsworth 1935; Ugaki et al. 1991). CGMMV is rod-shaped (Lecoq & Desbiez 2012) and has single-stranded RNA (Hollings et al. 1975).

Many strains and isolates of CGMMV have been reported in the literature. Different authors have described CGMMV strains based on geographic distribution, host range, symptoms on natural host plants, serological methods, molecular methods or by differential responses on indicator plants such as *Chenopodium amaranticolor* and *Datura stramonium* (Hollings et al. 1975; Antignus et al. 2001; Boubourakis et al. 2015). Some isolates formerly classified as strains of CGMMV are now accepted to be a separate virus species; for instance, Yodo strain (CGMMV-Y) and Cucumber strain (CGMMV-C or CGMMV-Cu) were previously considered to be strains of CGMMV but are now considered to be strains of *Kyuri green mottle mosaic virus* (KGMMV) (Antignus et al. 2001; Varveri et al. 2002). Currently, all strains and isolates of CGMMV are either absent from Australia or have a limited distribution in Australia and are under official control. Therefore, this risk analysis considers CGMMV as a quarantine pest at the species level.

#### 3.1 Geographical distribution of CGMMV

CGMMV was first described in the United Kingdom in the 1930's (Ainsworth 1935; Ugaki et al. 1991). Since then, CGMMV has spread among cucurbit crops worldwide (Reingold et al. 2015). CGMMV is reported to occur in most continents and over 30 countries (Map 3). Choudhury and Lin (1982) also report the possible detection of CGMMV in melon in Brazil; however, this record has not been confirmed. Similarly, a CGMMV-like virus is reported to occur in mosses in Antarctica (Polischuk et al. 2007).

Map 3 Global occurrence of CGMMV



In September 2014, CGMMV was confirmed to occur in the Northern Territory, Australia on commercial watermelon farms (PIDS 2014; Queensland Government 2015). Later on, CGMMV was detected in a single cucurbit farm in Queensland and infected property remains under quarantine. In February 2016, the Northern Territory government announced that the CGMMV quarantine zone will be formally revoked. However, new regulations will prohibit the export of seeds, seedlings and bee hives from the Northern Territory without approval for the Chief Inspector of Plant Health, and requires growers to have an auditable farm biosecurity plan for the purpose of controlling CGMMV. Therefore, CGMMV is under official control in Australia and risk management measures have been implemented to contain the spread of this virus.

## 3.2 Biology of CGMMV

CGMMV infects host cucurbitaceous plants systemically (Inouye et al. 1967; Komuro et al. 1971) and causes structural changes in infected tissues (Hatta et al. 1971; Hatta & Ushiyama 1973). During colonisation of cucumber plants, CGMMV moves systemically through phloem (Simon-Buela & Garcia-Arenal 1999) and xylem (Moreno et al. 2004). CGMMV survives in seeds (Tian et al. 2014; Reingold et al. 2015), in infected plant debris (Choi 2001; Liu et al. 2014) and in soil contaminated with infected plant debris (Hollings et al. 1975; Rao & Varma 1984). CGMMV is also able to infect host plants through wounds caused by pruning or harvesting (Hollings et al. 1975; Lecoq & Desbiez 2012).

### 3.2.1 Hosts of CGMMV

The host range of CGMMV mainly includes species within the Cucurbitaceae family (Hollings et al. 1975). The Cucurbitaceae family has 122 genera and approximately 960 species (Mabberley 2008); however, not all of these genera or species are commonly cultivated (McCormack 2005; Freeman et al. 2015). According to the published evidence, the majority of genera and species within the family Cucurbitaceae are not known to be natural hosts of CGMMV. While this virus is reported to occur on multiple cucurbit species, it is only known to be associated with the seeds of *Citrullus lanatus*, *Cucumis melo*, *Cucumis sativus*, *Cucurbita maxima*, *Cucurbita maxima* x *Cucurbita moschata*, *Cucurbita moschata*, *Cucurbita pepo*, *Lagenaria siceraria* and *Trichosanthes cucumerina* (Table 6).

In recent years, CGMMV has also been detected in an increasing number of non-cucurbit host plants, particularly weeds. It has been reported to naturally occur in non-cucurbit species from the families: Amaranthaceae, Apiaceae, Boraginaceae, Chenopodiaceae, Portulacaceae and Solanaceae (Boubourakis et al. 2004; Cho et al. 2015). To date, CGMMV is not known to be associated with the seeds of non-cucurbit crops. The known natural cucurbit and non-cucurbit hosts of CGMMV are presented in Table 6.

**Table 6 Natural hosts of CGMMV and its association with host seeds**

Scientific name	Common name (s)	Natural host of CGMMV	Seed-borne
<b>CROPS</b>			
<i>Benincasa hispida</i> (Thunberg) Cogniaux [Cucurbitaceae]	Ash gourd, Wax gourd, White gourd	<b>Yes</b> (Noda et al. 1993)	No evidence of CGMMV being seed-borne in this species.

Scientific name	Common name (s)	Natural host of CGMMV	Seed-borne
<i>Citrullus lanatus</i> (Thunberg) Matsumura & Nakai [Cucurbitaceae]	Watermelon	<b>Yes</b> (Lee et al. 1990; Yoon et al. 2008; Reingold et al. 2015)	<b>Yes</b> (Lee et al. 1990; Yoon et al. 2008).
<i>Cucumis anguria</i> Linnaeus [Cucurbitaceae]	Bur cucumber, West Indian gherkin	<b>Yes</b> (Rashmi et al. 2005)	No evidence of CGMMV being seed-borne in this species.
<i>Cucumis melo</i> Linnaeus [Cucurbitaceae]	Cantaloupe, Melon	<b>Yes</b> (Sugiyama et al. 2006; Tian et al. 2014; Reingold et al. 2015)	<b>Yes</b> (Tian et al. 2014; Reingold et al. 2015).
<i>Cucumis sativus</i> Linnaeus [Cucurbitaceae]	Cucumber	<b>Yes</b> (Liu et al. 2014)	<b>Yes</b> (Faris-Mukhayyish & Makkouk 1983; Liu et al. 2014).
<i>Cucurbita maxima</i> Duchesne [Cucurbitaceae]	Buttercup squash, Kabotcha, Pumpkin	<b>Yes</b> (Stephen West [NT Department of Primary Industry and Fisheries (DPIF)] 2015, pers. comm., 9 September)	<b>Yes</b> (Fiona Constable [Department of Economic Development, Jobs, Transport and Resources, Victoria (DEDJTR)] 2015, pers. comm., 2 December).
<i>Cucurbita maxima</i> Duchesne x <i>Cucurbita moschata</i> Duchesne [Cucurbitaceae]	Kabotcha, Pumpkin	<b>Yes</b> (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December)	<b>Yes</b> (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December).
<i>Cucurbita moschata</i> Duchesne [Cucurbitaceae]	Butternut pumpkin, Butternut squash, Calabaza pumpkin, Pumpkin, Tropical pumpkin	<b>Yes</b> (Noda et al. 1993; Zhang et al. 2009)	<b>Yes</b> (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December).
<i>Cucurbita pepo</i> Linnaeus [Cucurbitaceae]	Acorn squash, Pumpkin, Summer squash, Zucchini	<b>Yes</b> (Qin et al. 2005; Al-Tamimi et al. 2009)	<b>Yes</b> (Al-Tamimi et al. 2009; Kwon et al. 2014).
<i>Lagenaria siceraria</i> (Molina) Standley [Cucurbitaceae]	Bottle gourd, Calabash, Korean native gourd, Long melon	<b>Yes</b> (Boubourakas et al. 2004; Zhang et al. 2009)	<b>Yes</b> (Choi 2001; Boubourakas et al. 2004).
<i>Luffa acutangula</i> (Linnaeus) Roxburgh [Cucurbitaceae]	Angled luffa, Chinese okra, Ridged gourd	<b>Yes</b> (Noda et al. 1993; Sharma et al. 2014)	No evidence of CGMMV being seed-borne in this species.
<i>Luffa cylindrica</i> (Linnaeus) Roemer [Cucurbitaceae]	Smooth loofah gourd	<b>Yes</b> (Noda et al. 1993)	No evidence of CGMMV being seed-borne in this species.
<i>Momordica charantia</i> Linnaeus [Cucurbitaceae]	Balsam apple, Balsam pear, Bitter gourd, Bitter melon	<b>Yes</b> (Pandey & Joshi 1989; Noda et al. 1993)	No evidence of CGMMV being seed-borne in this species.

Scientific name	Common name (s)	Natural host of CGMMV	Seed-borne
<b><i>Trichosanthes cucumerina</i></b> Linnaeus [Cucurbitaceae]	Serpent gourd, Snake gourd	<b>Yes</b> (Nagendran et al. 2015)	<b>Yes</b> (Ariyaratne et al. 2005).
<b>WEEDS</b>			
<i>Amaranthus blitoides</i> Watson [Amaranthaceae]	Mat amaranth, Prostrate amaranth	<b>Yes</b> (Boubourakas et al. 2004)	No evidence of CGMMV being seed-borne in these species.
<i>Amaranthus retroflexus</i> Linnaeus [Amaranthaceae]	Redroot amaranth, Redroot pigweed	<b>Yes</b> (Boubourakas et al. 2004)	
<i>Amaranthus viridis</i> Linnaeus [Amaranthaceae]	Green amaranthus	<b>Yes</b> (Stephen West [NT DPIF] 2015, pers. comm., 9 September)	
<i>Chenopodium album</i> Linnaeus [Chenopodiaceae]	Fat hen	<b>Yes</b> (Boubourakas et al. 2004)	No evidence of CGMMV being seed-borne in this species.
<i>Ecballium elaterium</i> (Linnaeus) Richard [Cucurbitaceae]	Squirting cucumber	<b>Yes</b> (Antignus et al. 1990)	No evidence of CGMMV being seed-borne in this species.
<i>Heliotropium europaeum</i> Linnaeus [Boraginaceae]	Common heliotrope	<b>Yes</b> (Boubourakas et al. 2004)	No evidence of CGMMV being seed-borne in this species.
<i>Heracleum moellendorffii</i> Hance [Apiaceae]	Duan mao du huo, Eosuri	<b>Yes</b> (Cho et al. 2015)	No evidence of CGMMV being seed-borne in this species.
<i>Portulaca oleracea</i> Linnaeus [Portulacaceae]	Parsley, Pigweed, Purslane	<b>Yes</b> (Boubourakas et al. 2004)	No evidence of CGMMV being seed-borne in this species.
<i>Solanum nigrum</i> Linnaeus [Solanaceae]	Blackberry nightshade, Black nightshade	<b>Yes</b> (Boubourakas et al. 2004)	No evidence of CGMMV being seed-borne in this species.

CGMMV is reported to be seed-borne in the host species in **bold**.

### 3.2.2 Spread of CGMMV

CGMMV is capable of natural spread in protected environments (such as greenhouses), in the field, and through human activities. Short-distance natural spread of CGMMV mainly occurs through physical contact between an infected plant and another host plant, mechanical transmission through contaminated hands, clothing or tools, contaminated water, contaminated soil and infected plant debris (Broadbent & Fletcher 1963; Choi 2001; Reingold et al. 2015). Human-mediated transport of infected seedlings, infected seed or contaminated soil is mainly responsible for the long-distance spread of CGMMV (Choi 2001).

#### Short-distance spread

The natural short-distance spread of CGMMV mainly occurs through physical contact, mechanical transmission, contaminated water, contaminated soil or infected plant debris (Broadbent & Fletcher 1963; Choi 2001; Reingold et al. 2015).

- CGMMV is very stable and can survive for long periods on equipment and on tools (ASTA 2014). The virus may be spread through standard cultivation practices and harvesting (Lecoq & Desbiez 2012), when plants are handled by farm personnel, or when infected equipment or machinery is used (Boubourakas et al. 2004; Reingold et al. 2015).
- Secondary spread of CGMMV can occur through leaf contact between healthy and infected plants (Lecoq & Desbiez 2012).
- CGMMV has been found in irrigation water, which can lead to plant infection. Spread of CGMMV through surface water and water for irrigation has been reported (Dorst 1988; Vani & Varma 1993). CGMMV can spread to new host plants through the recirculation of nutrient solutions (Buttner et al. 1995).
- CGMMV can survive for long periods on plant debris, which can assist in the spread. CGMMV may spread over short-distances through contact via roots in soil contaminated by infected plant debris (Hollings et al. 1975). For example, transmission due to root contact between infected and uninfected *Lagenaria siceraria* plants did not take place, but 18 percent transmission of CGMMV occurred among *L. siceraria* plants sown in soil mixed with infected plant debris (Rao & Varma 1984).

### Long-distance spread

Long-distance spread of CGMMV via human-mediated means is likely to be rapid, and the commercial movement of infected seeds or seedlings for planting is likely to be a significant pathway for the spread of this virus (Kobayashi 1990; Lecoq & Katis 2014; Liu et al. 2014). Other possible pathways for long-distance spread through human-mediated means include infested soil and debris contaminating seeds (Lecoq & Katis 2014).

- The seed trade is the main pathway for the worldwide introduction and spread of exotic pathogens, including CGMMV. The introduction of CGMMV into Japan in 1966 was linked to *Lagenaria siceraria* seed imported from India (Tochihara & Komuro 1974; Kobayashi 1990). Choi (2001) discovered that virus-contaminated bottle gourd seeds were the major cause of disease transmission to watermelon growing regions in Korea in 1998. The rapid spread of CGMMV throughout the cucurbit-growing areas of the world is likely to be associated with the trade of host cucurbit seeds.
- CGMMV is seed-borne in *Citrullus lanatus*, *Cucumis sativus*, *Cucumis melo*, *Cucurbita maxima*, *Cucurbita maxima* x *Cucurbita moschata*, *Cucurbita moschata*, *Cucurbita pepo*, *Lagenaria siceraria* and *Trichosanthes cucumerina* (Lee et al. 1990; Choi 2001; Liu et al. 2014; Fiona Constable [DEDJTR] 2015, pers. comm., 2 December). Seeds play a pivotal role in the spread and survival of CGMMV and infected seeds are probably the most important source of virus infection in commercial plantings.
- Seed to seedling transmission of CGMMV has been demonstrated in several host species. Seed transmission rates can be high; for instance, Liu et al. (2014) found that the rate of CGMMV transmission from cucumber seeds to seedlings was 76.7 percent.
- CGMMV transmission through seeds and soil, even at very low levels, may initiate the disease cycle (Choi 2001).

### Other potential means of spread

- **Pollen**—CGMMV has been detected in the pollen of bottle gourd (Rao & Varma 1984); however, natural spread by pollen has not been proven. Under experimental conditions, the artificial pollination of cucumber flowers with pollen infected with CGMMV resulted in the

infection of up to 51.2 percent of fruits. Seed samples from infected fruits also tested positive for the virus (Liu et al. 2014). Pollen infection could result in a systemic infection in mature plants and be passed on to the next generation via infected seeds. Therefore, pollen transmission could play a significant role in the epidemiology and management of CGMMV (Mink 1993; Liu et al. 2014). However, more information is required to establish that spread occurs naturally via pollen.

- **Insects**—No CGMMV transmission was observed in trials using aphids (*Aphis gossypii* and *Myzus persicae*) and cucumber leaf beetles (*Aulacophora femoralis*) as vectors (Hollings et al. 1975). However, Rao and Verma (1984) reported that cucumber leaf beetles are potential vectors of CGMMV. During transmission studies, cucumber leaf beetles transmitted CGMMV directly to 10 percent of tested plants (Rao & Verma 1984). Infective particles of CGMMV were also detected in the regurgitated fluid and excreta of cucumber leaf beetles (Rao & Verma 1984). Therefore, cucumber leaf beetles may be a potential vector for short-distance spread of CGMMV in some countries.
- **Parasitic plants**—There is a historic record that CGMMV can be transmitted by dodder species, including *Cuscuta subinclusa*, *C. lupuliformis* and *C. campestris*, under experimental conditions (Schmelzer 1956 cited in Hollings et al. 1975).

### 3.3 Symptoms of CGMMV

CGMMV can cause a range of symptoms in host plants and may also infect plants symptomlessly. In cucurbits, CGMMV symptoms typically include leaf mottling, mosaic symptoms and fruit mottling or distortion (Reingold et al. 2015). This virus may also symptomatically infect some non-cucurbit crops, for instance, *Heracleum moellendorfii* (Apiaceae) plants naturally infected with CGMMV have shown leaf mottling and mosaic symptoms (Cho et al. 2015). CGMMV symptoms may not be constant over time or between locations and may vary with isolate, strain, season, host and environmental conditions (ASTA 2014).

This review focuses on symptoms that CGMMV typically causes on the natural host species (*Citrullus lanatus*, *Cucumis melo*, *Cucumis sativus*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Lagenaria siceraria* and *Trichosanthes cucumerina*) that are known to carry this virus in seed.

#### Symptoms caused by CGMMV on *Citrullus lanatus*

Symptoms of CGMMV on watermelon (*Citrullus lanatus*) plants generally include vein clearing and crumpling of young leaves; mottling or mosaic patterns; a pale-yellow or bleached appearance on mature leaves (Figure 1A); and necrotic spots on the peduncle (Figure 1B) (Reingold et al. 2013). Fruit symptoms may include yellowing of the normally pink to red flesh, especially on its outer perimeter (Figure 1C), and the development of internal cavities and areas that prematurely soften and become mushy (Figures 1C–1D) (ASTA 2014; Northern Territory Government 2015).

Variability in CGMMV symptoms on watermelon plants has been reported. For example, Boubourakas et al. (2004) described three types of CGMMV symptoms on grafted watermelon crops in Greece. The first type consisted of asymptomatic leaves and the regular appearance of necrotic lesions on the fruit pedicel (Figure 1B). Fruits at maturity showed whitish-yellow discoloration of the peripheral region and water-soaked inner pulp (Fig. 1C–D). The second type of symptoms occurred more frequently and consisted of chlorotic leaf spots, which later



coalesced to form characteristic irregular chlorotic patterns on leaves. The third type of symptoms consisted of chlorotic leaf patterns followed by pedicel necrosis (Boubourakas et al. 2004).

**Figure 1 CGMMV symptoms on watermelon: (A) leaf mottling and chlorotic mosaic symptoms; (B) peduncle necrosis; (C) whitish-yellow discoloration of the peripheral region of fruit; and (D) water-soaked inner pulp of fruit**

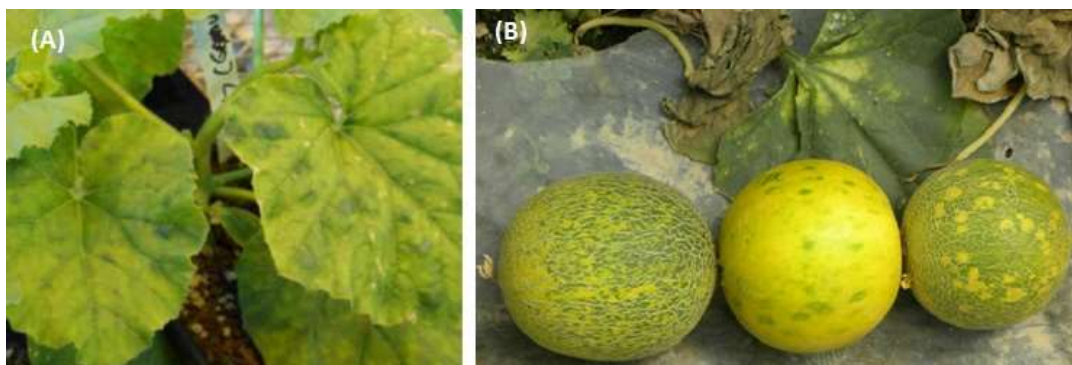


Source: AMA (2015).

### **Symptoms caused by CGMMV on *Cucumis melo***

*Cucumber green mottle mosaic virus* causes mosaic and wrinkling, green vein-banding and stunting of melon (*Cucumis melo*) crops in the field. In the greenhouse, symptoms can include mild chlorosis, mosaic, vein-banding, and deformed leaves with blisters in older leaves (Figure 2A; Raychaudhuri & Varma 1978; AMA 2015). Infected fruit may display mottled symptoms as shown in figure 2B (AMA 2015).

**Figure 2 CGMMV symptoms on melon leaves and fruits: (A) mild chlorosis and mosaic symptoms on leaves and (B) mottle on fruits**



Source: (A) Kurowski et al. (2015); (B) AMA (2015).

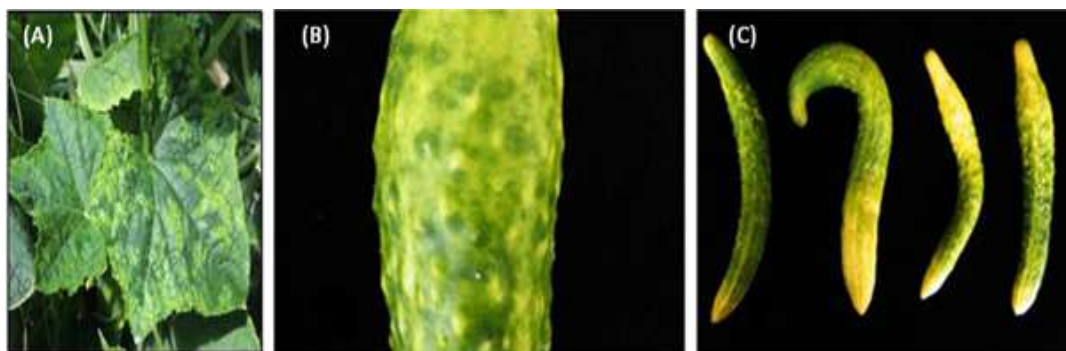
### **Symptoms caused by CGMMV on *Cucumis sativus***

CGMMV causes a range of symptoms in cucumber (*Cucumis sativus*), with symptoms varying between strains and isolates (Hollings et al. 1975). While the type strain does not typically cause



fruit symptoms in cucumber (Hollings et al. 1975), some strains can cause severe fruit mottling and distortion (Liu et al. 2014; Figure 3B–C). For example, leaf mottling, blistering and distortion (Figure 3A), and stunted growth have been observed on cucumbers infected with type strain CV3 (Hollings et al. 1975; Ling et al. 2014; AMA 2015). The Indian bottle gourd strain C can cause blister-mottle, stunting and crop losses (Hollings et al. 1975). Several Greek isolates showed symptoms of higher severity and have a wider host range, compared with other described CGMMV isolates (Boubourakas et al. 2004).

**Figure 3 CGMMV symptoms on cucumber leaves and fruits: (A) leaf mottling and chlorosis; (B) fruit blistering and mottling; and (C) fruit distortion**

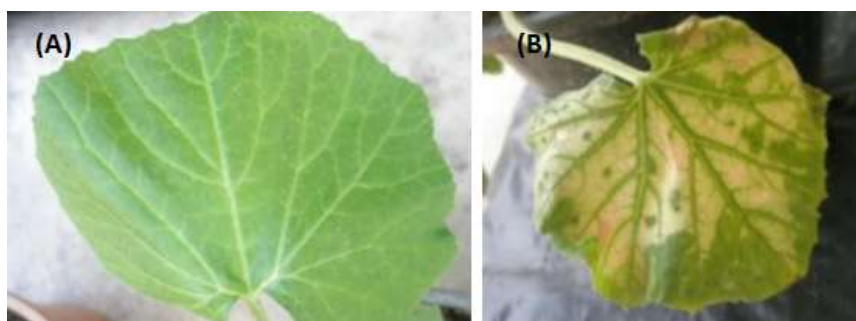


Source: AMA (2015); Liu et al. (2014).

### Symptoms caused by CGMMV on other seed-borne hosts

*Cucurbita maxima* has only recently been reported to be a natural host of CGMMV (Stephen West [DPIF] 2015, pers. comm., 9 September). This virus was reported to be associated with *C. maxima* seeds for sowing for the first time in December 2015 (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December). The symptoms of this virus in *C. maxima* are not reported. CGMMV is reported to cause systemic mosaic symptoms in *Cucurbita moschata* (Zhou et al. 2008). Under experimental conditions, symptomless CGMMV infection of *Cucurbita moschata* has also been reported (Moradi & Jafarpour 2010). In *Cucurbita pepo*, CGMMV is reported to cause systemic chlorotic spots, systemic mosaic symptoms, leaf mottle and leaf vein yellowing symptoms (Qin et al. 2005; Nontajak et al. 2014) (Figure 4A and 4B). This virus has been detected on the seeds of symptomless *Cucurbita pepo* fruit (Al-Tamimi et al. 2009).

**Figure 4 CGMMV symptoms in zucchini: (A) mild mosaic leaf symptoms and (B) internal vein yellowing leaf symptoms**



Source: Nontajak et al. (2014).

In bottle gourd (*Lagenaria siceraria*), CGMMV symptoms vary from leaf mosaic and mottle symptoms (Kim et al. 2010) (Figure 5) to systemic mosaic symptoms (Mandal et al. 2008; Zhang

et al. 2009). While in India, serpent gourd (*Trichosanthes cucumerina*) symptoms include leaf mosaic, leaf mottling, reduced leaf size and phylloid flowers (Nagendran et al. 2015).

**Figure 5 CGMMV mottle and mosaic symptoms on a bottle gourd leaf**



Source: Kurowski et al. (2015).

## 4 Pest risk assessment

This pathogen-based pathway risk assessment was initiated to fulfil Australia's obligations under the IPPC and ISPM No. 1 to review the emergency phytosanitary measures that Australia introduced on 20 October 2014 and amended in December 2015. CGMMV is identified as a quarantine pathogen for Australia because it:

- has a restricted distribution in Australia and is under official control;
- has the potential for introduction, establishment and spread in Australia. CGMMV has the potential to be introduced into Australia on the seed pathway (Choi 2001; Liu et al. 2014), has established in areas with a wide range of climatic conditions (Tian et al. 2014; CABI 2015) and can spread under natural conditions and by human activities (Tochihara & Komuro 1974; Kobayashi 1990); and
- is an economically important pathogen (Nilsson 1977; Reingold et al. 2015).

### 4.1 *Cucumber green mottle mosaic virus* (CGMMV)

CGMMV is associated with several species of cultivated cucurbit crops (Hollings et al. 1975; Lecoq & Desbiez 2012). However, it is only reported to be seed-borne in *Citrullus lanatus* (Lee et al. 1990; Yoon et al. 2008), *Cucumis melo* (Tian et al. 2014; Reingold et al. 2015), *Cucumis sativus* (Faris-Mukhayyish & Makkouk 1983; Liu et al. 2014), *Cucurbita maxima*, *Cucurbita maxima* x *Cucurbita moschata*, *Cucurbita moschata* (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December), *Cucurbita pepo* (Al-Tamimi et al. 2009; Kwon et al. 2014), *Lagenaria siceraria* (Choi 2001; Boubourakas et al. 2004) and *Trichosanthes cucumerina* (Ariyaratne et al. 2005). Therefore, the seeds of these species and their hybrids are a potential pathway for the introduction of CGMMV into Australia.

#### 4.1.1 Likelihood of entry

The likelihood of entry is divided for assessment purposes into the likelihood of importation (the likelihood that CGMMV will arrive when the host seed is imported) and the likelihood of distribution (the likelihood that CGMMV will be transferred to a suitable host).

##### Likelihood of importation

The likelihood that CGMMV will arrive in Australia with trade in host cucurbit seeds for sowing is **HIGH**.

##### Association of the pest with the pathway

- CGMMV is seed-borne in *Citrullus lanatus* (Lee et al. 1990; Yoon et al. 2008), *Cucumis melo* (Tian et al. 2014; Reingold et al. 2015), *Cucumis sativus* (Faris-Mukhayyish & Makkouk 1983; Liu et al. 2014), *Cucurbita maxima*, *Cucurbita moschata* (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December), *Cucurbita pepo* (Al-Tamimi et al. 2009; Kwon et al. 2014), *Lagenaria siceraria* (Choi 2001; Boubourakas et al. 2004) and *Trichosanthes cucumerina* (Ariyaratne et al. 2005). Therefore, CGMMV is associated with the seed pathway for these hosts. It also has been detected on the seeds of the hybrid *Cucurbita maxima* x *Cucurbita moschata* (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December), and therefore has the potential to be associated with the seeds of hybrids of other seed-borne hosts of CGMMV.

- The association of cucurbit seeds with CGMMV is mainly external (Lecoq & Desbiez 2012). The highly stable genome helps the virus remain infectious in dried seed coats and can subsequently infect plantlets during germination (Lecoq & Katis 2014). CGMMV is also found in the inner tissue (endopleura) of infected seeds (Reingold et al. 2015). Therefore, CGMMV is associated with the host seed pathway.
- Seed to seedling transmission has also been reported for CGMMV in multiple hosts (Lee et al. 1990; Choi 2001; Liu et al. 2014). Therefore, trade in seeds for sowing is a pathway for the introduction of CGMMV.
- CGMMV was first described in the 1930s in the UK (Ainsworth 1935; Ugaki et al. 1991) and has since been found to infect cucurbit crops worldwide (Reingold et al. 2015). Global trade in seeds and the associated movement of seeds across borders is likely to have played a significant role in the introduction of CGMMV into geographically distant areas.
  - CGMMV was presumed to have been introduced by infected bottle gourd (*Lagenaria siceraria*) seeds into Japan in 1966 (Tochihara & Komuro 1974; Kobayashi 1990).
  - An outbreak of CGMMV in the watermelon growing areas of Korea was considered to be caused by the introduction of contaminated bottle gourd seeds from China (Choi 2001).

#### ***Ability of the pest to survive transport and storage***

- CGMMV is highly likely to survive during transport and storage since the primary conditions for survival are fulfilled by the presence of viable seeds and associated environmental conditions. Host cucurbit seeds are packaged and shipped to areas conducive to their survival. The handling of the seed is highly unlikely to be detrimental to the survival of CGMMV.
- Most seed-borne pathogens use seeds as a vehicle for transport and survival (Elmer 2001). Seed associations can provide pathogens an opportunity for long-term survival. Survival of CGMMV is highly unlikely to be diminished during the transport or storage of host seeds.
- Transport and storage of seeds is done at low temperatures and these conditions are not expected to affect the viability of CGMMV. Hollings et al. (1975) reported that CGMMV is very stable and, when stored at 2 °C, can retain nearly all serological activity for at least six years. Therefore, CGMMV is highly likely to survive in or on seeds during transport and storage.

#### ***Ability of the pest to survive existing pest management procedures***

- Currently, there are few effective control strategies for the protection of cucurbit crops against natural infection of CGMMV. Cultural practices, including the use of CGMMV free seeds; removal and destruction of all infected host material; disinfection of equipment, tools and clothes; and strict control on the movement of potentially infected material from affected farms are critical factors in managing CGMMV.
- Currently, most commercial seed lots are subjected to dry heat or chemical disinfection treatments prior to marketing (Lecoq & Desbiez 2012). However, there is conflicting evidence on the effectiveness of heat and chemical treatments in eliminating CGMMV from host seeds. Therefore, CGMMV may be able to survive existing pest management procedures.
  - Some reports indicate that the virus can be completely eliminated using dry heat treatment. For example, Lecoq & Desbiez (2012) and Lecoq & Katis (2014) found that CGMMV could be eliminated from seed treated at 70 °C for 24 to 72 hours.
  - Other studies have found that heat and chemical treatments are inadequate in eliminating the virus from seeds. For instance, Reingold et al. (2015) found that heat treatment of seeds at 72 °C for 72 hours did not eliminate CGMMV from seeds, which had an infectivity

rate of 66.6 percent after treatment. Additionally, Reingold et al. (2015) found that all infected seeds treated with 10 percent trisodium phosphate (TSP) still contained the entire viral genome after treatment and had an infectivity rate of 83.3 percent after treatment. While the combination of treating seeds with 10 percent TSP then heat treatment was more effective in disinfecting seeds from CGMMV than either individual treatment, the infectivity rate was still 31.5 percent after both treatments (Reingold et al. 2015).

- Disinfection of pruning and harvesting tools with trisodium phosphate will reduce mechanical transmission of the virus, but will not prevent transmission through leaf contact (Lecoq & Desbiez 2012).

#### **Likelihood of distribution (transfer to a susceptible host)**

The likelihood that CGMMV will be distributed within Australia in a viable state with imported cucurbit host seeds for sowing and be transferred to a suitable host is **MODERATE**.

#### **Ability of the pest to move from the pathway to a suitable host**

- Cucurbit seeds infected with CGMMV arriving in Australia are already associated with a suitable host. These seeds can then be used for propagation (Liu et al. 2014; Reingold et al. 2015). Seed to seedling transmission has been reported for CGMMV (Lee et al. 1990; Choi 2001; Liu et al. 2014). Consequently, there is no need to move from the seed pathway to a new host, as CGMMV is already within a suitable host.
- Cucurbit seeds are imported specifically for the purpose of propagation and can be a significant investment for importers. Infected cucurbit seeds are therefore likely to be sown in suitable habitats at multiple locations throughout Australia. The distribution of infected cucurbit seeds commercially will facilitate the distribution of CGMMV.
- If an infected seed results in an infected seedling, CGMMV is likely to spread to other hosts by mechanical transmission. CGMMV is very stable and can survive for long periods on equipment and on tools (ASTA 2014). The virus may be spread through standard cultivation practices and harvesting (Lecoq & Desbiez 2012), when plants are handled by farm personnel and when infected equipment or machinery is used (Boubourakas et al. 2004; Reingold et al. 2015).
- CGMMV can spread through leaf contact between healthy and infected plants (Lecoq & Desbiez 2012). Cucurbit seeds for commercial production are likely to be propagated in large numbers in the field or glasshouse; therefore, multiple hosts are likely to be available in close proximity to the infected plant. Consequently, CGMMV is likely to spread through leaf contact between healthy and infected plants.
- CGMMV can survive for long periods on plant debris, which can assist in the spread. CGMMV may spread over short-distances through contact via roots in soil contaminated by infected plant debris (Hollings et al. 1975). For example, 18 percent transmission of CGMMV occurred among *Lagenaria siceraria* plants sown in soil mixed with infected plant debris (Rao & Varma 1984).
- CGMMV has been found in irrigation water, which can lead to plant infection. Spread of CGMMV through surface water and water for irrigation has been reported (Dorst 1988; Vani & Varma 1993). CGMMV is also reported to spread to new host plants through the recirculation of nutrient solutions (Buttner et al. 1995).
- Insect vectors may help transfer CGMMV from infected to healthy plants. Hollings et al. (1975) found the transmission of CGMMV by *Myzus persicae*, *Aphis gossypii* and *Aulacophora*

*femoralis* was not successful (Hollings et al. 1975). However, a later study has demonstrated CGMMV transmission through *A. femoralis* (Rao & Verma 1984). While *A. femoralis* is not present in Australia, it is unknown if related species that are present in Australia (for example, *A. abdominalis* and *A. hilaris*) would play a role in transferring CGMMV to healthy host plants.

- Suitable hosts for CGMMV are widely distributed across Australia. CGMMV mainly infects plants within the Cucurbitaceae family (Hollings et al. 1975), including fruit and vegetable crops such as cucumber, gourd, loofah, melon, pumpkin, squash, watermelon and zucchini (Qin et al. 2005; Liu et al. 2014; Reingold et al. 2015). These species are widely distributed throughout Australia, with many commercial farms, semi-rural properties and residential properties in the metropolitan areas growing these fruit and vegetables.
- A growing number of weeds have been reported as natural hosts of CGMMV, including species within the families Amaranthaceae, Apiaceae, Boraginaceae, Chenopodiaceae, Cucurbitaceae, Portulacaceae and Solanaceae (Antignus et al. 1990, Boubourakis et al. 2004; Cho et al. 2015). Many of these weeds are widely distributed throughout Australia.

#### ***Distribution of the imported commodity in the PRA area***

- Association with cucurbit seed hosts provides the opportunity for CGMMV to be distributed through the trade of cucurbit seeds across Australia. Its ability to survive on, or in, host seeds acts to ensure its viability during distribution across Australia.
- The commercial and retail trade of host cucurbit seeds for sowing facilitates the distribution of the virus to multiple destinations throughout the PRA area.
- CGMMV is likely to survive transportation and storage within Australia. Cucurbit propagative material is likely to be transported, stored and maintained under conditions that are unlikely to have any impact on the survival of CGMMV. Asymptomatic plants that develop from infected seeds may be overlooked and sold to commercial producers and households.

#### ***Risks from by-products and waste***

- The intended use of cucurbit seeds is for propagation, and all imported seeds would be grown under ideal conditions. Cucurbit seeds that do not survive transportation and storage may not be used for sowing. Therefore, waste material may be generated. As CGMMV is seed-borne, any such material that is discarded may contain the virus.
- CGMMV is capable of surviving in host plant debris for long periods of time. Therefore, infected plant debris may pose a risk for the introduction of CGMMV in the environment. Transmission of the virus via roots in soil contaminated with infected plant debris has been reported (Hollings et al. 1975; Rao & Varma 1984).
- The transfer of CGMMV from a seedling established at a waste depot or in the backyard, to a host may occur through contact between host plants as the virus is sap- and mechanically-transmissible.
- CGMMV can spread through surface water and water for irrigation (Dorst 1988; Vani & Varma 1993). CGMMV therefore has the potential to spread from infected seeds, seedlings or debris to a healthy host plant through water.
- Insect vectors may help transfer CGMMV from infected to healthy plants. Hollings et al. (1975) found transmission of CGMMV by *Myzus persicae*, *Aphis gossypii* and *Aulacophora femoralis* was not successful (Hollings et al. 1975). However, later studies demonstrated CGMMV transmission through *A. femoralis* (Rao & Verma 1984). While *A. femoralis* is not present in Australia, it is unknown if related species that are present in Australia (for

example, *A. abdominalis* and *A. hilaris*) would play a role in transferring CGMMV to healthy host plants.

#### Overall likelihood of entry (importation x distribution)

The overall likelihood of entry of CGMMV is determined by combining the likelihood of importation with the likelihood of distribution using the matrix of rules for combining qualitative likelihoods (Table 2).

- The likelihood that CGMMV will enter Australia with imported seed for sowing and transfer to a suitable host is **MODERATE**.

#### 4.1.2 Likelihood of establishment

The likelihood that CGMMV, having entered on imported seeds for sowing, will establish within Australia based on a comparison of factors in the source and destination areas considered pertinent to its survival and reproduction is **HIGH**.

##### *Availability of suitable hosts, alternative hosts and vectors in the PRA area*

- CGMMV is seed-borne, seed-transmissible (Choi 2001; Liu et al. 2014) and infects host plants systemically (Moreno et al. 2004). Therefore, the introduction and establishment of plants from imported host cucurbit seeds promotes the establishment of CGMMV with the propagative material.
- Association with the host seeds will facilitate the establishment of CGMMV, as the pathogen is already established with, or within, a suitable host. In addition, host plant seeds are likely to be maintained in places with similar climates to the area of production. Climatic conditions are expected to favour the establishment of the pathogen.
- Seeds are intended for propagation and are deliberately introduced, distributed and aided to establish. Seeds will be sown, and the resultant seedlings maintained, in a suitable habitat, potentially in substantial numbers and for an indeterminate period of time. Therefore, the introduction and establishment of plants from imported seeds in essence establishes CGMMV associated with the propagative material.
- Natural hosts of CGMMV are widely cultivated throughout Australia, with many commercial, semi-rural and residential properties in metropolitan areas growing host fruit and vegetables. Therefore, the availability of host material throughout Australia will help establish CGMMV.
- Alternative hosts include weed species (Boubourakas et al. 2004), some of which are widely distributed in Australia. Contact between infected cucurbits and weed species will help transfer CGMMV from its cucurbit crop host to an alternative host. Consequently, weed hosts may help to establish CGMMV.
- The latent period of CGMMV infection before visible symptoms appear (up to 14 days has been reported in cucumber (*Cucumis sativus*; Smith 1972)) may result in non-detection of the virus. Asymptomatic leaves and symptomless fruits are often observed in CGMMV infected cucurbit hosts (Hollings et al. 1975; Liu et al. 2014). Therefore, CGMMV may have ample time to establish in new areas before being detected.
- CGMMV is efficiently transmitted by mechanical means such as workers' hands, clothing and tools (Broadbent & Fletcher 1963; Reingold et al. 2015). The virus is very stable and can survive for long periods on equipment surfaces and tools (ASTA 2014). Therefore, it is highly

likely that mechanical transmission could spread the virus from infected plants, resulting from infected seeds, to healthy host plants.

- Vectors can play an important role in the transmission of viruses to new host plants. However, CGMMV, like other mechanically- or sap- transmitted viruses, is capable of moving to new host plants through direct contact. Therefore, this virus has the potential to establish and spread without vectors.
- Establishment of CGMMV could be aided by the presence of insect vectors in the PRA area. The cucumber leaf beetle (*Aulacophora femoralis*) has been shown to transmit CGMMV directly to 10 percent of tested plants (Rao & Verma 1984). Infective virus particles were detected in regurgitated fluid and excreta (Rao & Verma 1984). While *A. femoralis* is not present in Australia, it is unknown if related species that are present in Australia (for example, *A. abdominalis* and *A. hilaris*) would play a role in transferring CGMMV to healthy host plants.

### ***Suitability of the environment***

- CGMMV has established in areas with a wide range of climatic conditions (Map 3). The current reported distribution of CGMMV indicates that climatic conditions would be suitable for its establishment in outdoor crops in parts of Australia.
- The origin of CGMMV is not known and is difficult to determine; however, this virus was first reported from the UK (Ainsworth 1935). Subsequently, CGMMV has been reported to occur in most continents and over 30 countries, including but not limited to China, Finland, Germany, Greece, India, Israel, Japan, Korea, Pakistan, Saudi Arabia and Spain (Komuro et al. 1968; Francki et al. 1986; Lee et al. 1990; Lee 1996; Shang et al. 2011). The climatic regions across its range are diverse and there are similar climatic regions in parts of Australia that would be suitable for the establishment of CGMMV.
- In September 2014, CGMMV was confirmed to occur in commercial watermelon farms near Katherine and Darwin, in the Northern Territory, Australia, demonstrating that parts of Australia have suitable environmental conditions for the survival of this virus.
- Intensive cultivation, high plant density and frequent crop handling facilitate the spread of mechanically transmitted tobamoviruses, including CGMMV, in greenhouse grown cucurbit crops. Field grown cucurbits are less intensively handled and the crops are not in the field for more than four months a year (NSCFS 2008). Therefore, glasshouse grown cucurbit crops may be even more vulnerable to mechanically transmitted viruses such as CGMMV.

### ***The reproductive strategy and survival of the pest***

- Viruses in general are obligate parasites and reproduce within host cells (Persley et al. 2010). CGMMV multiplies and survives in the tissues of infected host plants (Moreno et al. 2004); however, it is not reliant on a living host for survival.
- CGMMV is able to survive long periods in plant debris and soil without a living host (Reingold et al. 2015). Transmission of the virus via roots in soil contaminated with infected plant debris has been reported (Hollings et al. 1975; Rao & Varma 1984). Therefore, survival in plant debris is likely to assist in the establishment of this virus.
- Generally, plant viruses rapidly lose their infectivity in seed coats during the process of seed drying; however, CGMMV is very stable and can remain infectious in dried seed coats for a long period of time (Lecoq & Katis 2014). CGMMV can survive in an infective state on the surface of seeds for months to a few years without invading the inner tissues of the seeds (Reingold et al. 2015).



- In addition to association with the seed coat, CGMMV has been detected in the inner tissue (endopleura) of CGMMV-infected seeds (Reingold et al. 2015). Infection of the inner tissues of seeds may make CGMMV more difficult to eliminate from seeds, which may assist in the survival and establishment of this virus.
- New cucurbit seeds being produced from the infected imported cucurbit seeds will assist in the survival and establishment of CGMMV.

#### 4.1.3 Likelihood of spread

The likelihood that CGMMV, having entered on seeds for sowing and established, will spread in Australia, based on a comparison of factors in the source and destination areas, considered pertinent to the expansion of the geographic distribution of the pest is **MODERATE**.

##### *The suitability of the natural or managed environment for natural spread*

- CGMMV was first discovered in the UK (Ainsworth 1935; Ugaki et al. 1991) and since then it has been recorded in many countries, including but not limited to China, Finland, Germany, Greece, India, Israel, Japan, Korea, Pakistan, Saudi Arabia and Spain (Komuro et al. 1968; Francki et al. 1986; Lee et al. 1990; Lee 1996; Shang et al. 2011). The climatic regions across this range are diverse and there are similar climatic regions in parts of Australia that would be suitable for the establishment and spread of CGMMV.
- In September 2014, CGMMV was confirmed to occur in commercial watermelon farms near Katherine and Darwin, in the Northern Territory, Australia, demonstrating that parts of Australia have suitable environmental conditions for the survival of this virus.
- The managed environment in cucurbit farms, nurseries, propagation houses and private gardens are all favourable for the natural spread of CGMMV, as host plants are abundantly available. Plants are often closely placed, which will favour the natural spread of CGMMV through sap and mechanical transmission.
- Intensive cultivation, high plant density and frequent crop handling may facilitate the spread of CGMMV in greenhouse grown cucurbit crops. Therefore, greenhouse grown cucurbit crops may be even more vulnerable to this mechanically transmitted virus.
- CGMMV is very stable and can survive for long periods on equipment and on tools (ASTA 2014). The virus can be spread through standard cultivation practices and harvesting (Lecoq & Desbiez 2012), when plants are handled by farm personnel, and when infected equipment or machinery is used (Boubourakas et al. 2004; Reingold et al. 2015). The pattern of spread observed is primarily along the same nursery row, which indicates that mechanical transmission plays a major role in the spread of CGMMV to new hosts plants once the virus has been introduced into an area. Therefore, crop management practices are likely to be suitable for CGMMV spread.
- CGMMV can survive for long periods of time on plant debris. CGMMV may spread locally through contact via roots in soil contaminated by infected plant debris (Hollings et al. 1975).
- CGMMV is seed-borne and seed-transmissible (Choi 2001; Liu et al. 2014). This increases its dispersal potential over time and distance, and is an important aspect of its epidemiology (Liu et al. 2014). CGMMV has been reported on contaminated seeds transported between countries (Antignus et al. 1990; Varveri et al. 2002; Ali et al. 2004). Seed and seedling trade networks, which are common between Australian nurseries and farmers, will favour a wider spread of CGMMV.

- CGMMV can also spread through contaminated irrigation water or nutrient solutions (Dorst 1988; Lecoq & Desbiez 2012) in natural and managed environments.

#### **Presence of natural barriers**

- Hosts of CGMMV are present in many parts of Australia. Natural barriers, such as arid areas, mountain ranges, climatic differentials and possible long distances exist between suitable hosts and may prevent long-range natural spread of this virus.
- Cucurbit crops are grown across Australia, with long distances often separating commercial production fields. This would be likely to aid in the containment of CGMMV if establishment occurs in an isolated cucurbit growing region.
- Alternative hosts include weed species (Boubourakas et al. 2004), some of which are widely distributed in Australia. Consequently, weed hosts may help to spread CGMMV from cucurbit production areas to other parts of Australia.
- While pollen transmission may play a role in the spread of CGMMV (Liu et al. 2014), there is no confirmed report that CGMMV can spread naturally via pollen. Under experimental conditions, artificial pollination of cucumber flowers with pollen infected with CGMMV resulted in up to 51.2 percent fruit infection. Seed samples from infected fruit also tested positive for the virus (Liu et al. 2014). Therefore, pollen may play a role in spreading CGMMV to other areas.
- CGMMV has spread from its initial detection in the UK (Ainsworth 1935; Ugaki et al. 1991) to Asia, Europe, the Mediterranean region and North America (Tian et al. 2014; Ling et al. 2014; CABI 2015; See Appendix B). This suggests that the virus is capable of overcoming natural barriers through other means of dispersal such as human-mediated transport of infected seeds.
- It is unknown if insect vectors would assist in the distribution of CGMMV across Australia. Cucumber leaf beetles (*Aulacophora femoralis*) are probable vectors of CGMMV, as they transmitted CGMMV directly to 10 percent of tested plants and their regurgitated fluid and excreta contained infective virus particles (Rao & Verma 1984). Therefore, *A. femoralis* may act as a potential vector for spreading CGMMV (Rao & Verma 1984). *Aulacophora femoralis* is not recorded in Australia; however, two species of *Aulacophora* (*A. abdominalis* and *A. hilaris*) have been recorded feeding on commercial cucurbit crops in Australia (Napier 2009). Therefore, these beetles may be potential vectors of CGMMV.

#### **Potential for movement with commodities or conveyances**

- Spread of CGMMV via human-mediated means will be rapid, and is significant through the commercial movement of infected seeds or seedlings for planting (Kobayashi 1990; Lecoq & Katis 2014; Liu et al. 2014). Other possible pathways for spread through human-mediated means include soil and debris contaminating the seeds (Lecoq & Katis 2014).
- Human-mediated movement of plants and plant products is considered the primary mode for the introduction of plant pathogens. CGMMV infects cucurbits systemically (Moreno et al. 2004). Therefore, multiplication and marketing of infected host seedlings will facilitate the spread of this virus.
- As visual symptoms of CGMMV may not be present, and in the absence of specific testing regimes, infected propagative material could easily be moved into new areas. The introduction of infected planting material establishes the pathogen in new areas and unregulated movement will accelerate the spread of CGMMV.

- Increased trade in seed within and between countries has led to new opportunities for plant pathogens to be moved to new areas or countries (Dehnen-Schmutz et al. 2010; Wingfield et al. 2010; Stenlid et al. 2011). Since its description in the 1930s from the UK, CGMMV has spread to many countries, potentially through the cucurbit seed trade. CGMMV is thought to have been introduced to Japan through *Lagenaria siceraria* seeds imported from India (Tochihara & Komuro 1974; Kobayashi 1990).
- CGMMV could spread with the movement and trade of infected host plant material including seeds. Seeds present a higher probability of spread. Spread of the CGMMV through movement of infected seeds will result in the establishment of new foci and further spread may occur through sap transmission or mechanical transmission.
- In the absence of statutory control, there is a high probability that CGMMV will spread quickly in Australia through the trade of host cucurbit seeds for planting. Planting of infected seeds will bring CGMMV into the environment. Climatic conditions, such as those found in the field and in propagation houses, are likely to be sufficient for its survival and spread.

#### **Potential natural enemies**

- CGMMV is not known to have any natural enemies that could hamper its spread.

#### **4.1.4 Overall likelihood of entry, establishment and spread**

The overall likelihood of entry, establishment and spread is determined by combining the likelihoods of entry, establishment and spread using the matrix of 'rules' for combining qualitative likelihoods shown in Table 2.

- The likelihood that CGMMV will enter Australia on host cucurbit seeds, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia is **LOW**.

#### **4.1.5 Consequences**

The potential consequences of the introduction and spread of CGMMV in Australia have been estimated according to the methods described in Table 3. In assessing the potential impact of CGMMV in Australia, the economic losses caused by this pathogen overseas were considered. Reasoning for these ratings is provided below:

Criterion	Estimate and rationale
<b>Direct</b>	
Plant life or health	<p>E – Significant at the regional level</p> <p><i>Cucumber green mottle mosaic virus</i> (CGMMV) has a significant effect on the health, life and yield of economically important cucurbit species, such as watermelon, melon, cucumber, zucchini and pumpkin (Vani &amp; Varma 1993; Liu et al. 2014; Reingold et al. 2015). A variety of CGMMV symptoms are described in the literature, including light-yellow to green leaf spots, vein clearing, deformation of young leaves, leaf-bleaching, chlorotic mottling, stunted growth, necrosis, fruit mottling and fruit distortion (Hollings et al. 1975; Boubourakas et al. 2004; ASTA 2014; Ling et al. 2014; AMA 2015; Reingold et al. 2015). CGMMV is generally reported to cause yield losses of 15 percent in cucurbit crops (Shang et al. 2011); however, significantly higher yield losses are reported in some crops (Zhou et al. 2008).</p> <ul style="list-style-type: none"> <li>• In cucumber, CGMMV infection is reported to cause 15 percent yield reduction (Reingold et al. 2015). Nilsson (1977) reported a higher crop loss of up to 33 percent of first grade cucumber fruits. Fruit quality can also be severely affected and the</li> </ul>

Criterion	Estimate and rationale
	<p>associated financial loss has been calculated to be in the range of 2 to 24 percent (Nilsson 1977; Reingold et al. 2015).</p> <ul style="list-style-type: none"> <li>Watermelon yield losses of up to 48 percent have been reported (Zhou et al. 2008). Watermelon fruit symptoms can occur simultaneously with necrotic spots on the peduncle, but obvious symptoms are often only revealed after harvest (Reingold et al. 2013). Symptoms on watermelon fruit include exocarp deterioration and mesocarp rotting and yellowing, while the inner pulp can be water soaked and without dietary value (Zhou et al. 2008; Reingold et al. 2013). This renders the fruit unmarketable and can cause severe economic losses to growers (Reingold et al. 2013).</li> </ul>
Other aspects of the environment	<p>B – Minor significance at the local level</p> <p>There may be some impact on insect or vertebrate animal species that feed on host plants due to the reduced availability or vigour of these host plants.</p> <ul style="list-style-type: none"> <li>In general, newly established species may affect the environment in a number of ways. Introduced species may reduce biodiversity, disrupt ecosystem function, jeopardize endangered or threatened plants, degrade critical habitat or stimulate the use of chemicals or biological controls. <ul style="list-style-type: none"> <li>CGMMV associated with cucurbits is unlikely to affect the environment in these ways, as the virus is mainly reported to infect and multiply in cucurbit crops. Some weed species are reported as alternate hosts of the virus. However, the impact of the virus on weed species is not clear.</li> </ul> </li> </ul>
<b>Indirect</b>	
Eradication, control, etc.	<p>F – Major significance at the regional level</p> <p>The ability of CGMMV to survive for long periods in plant debris and soil without a living host (Reingold et al. 2015), combined with its potential human-mediated spread (trade in propagative material), are likely to make this a difficult pathogen to eradicate.</p> <ul style="list-style-type: none"> <li>There are no effective agri-chemicals available for the control of CGMMV in host crops. Once the virus is established, CGMMV is difficult to eradicate as it can survive for long periods on plant debris in the soil. It can also survive on alternate hosts, including various cucurbit and non-cucurbit weeds.</li> <li>Removal and destruction of all infected hosts may help in the management of the disease. However, this is likely to be labour intensive and increase production costs. Furthermore, CGMMV can survive in soil and debris, so removal of the host plants may not eliminate CGMMV from the growing area.</li> <li>CGMMV can spread through mechanical transmission (Lecoq &amp; Desbiez 2012). Therefore, strict controls for the movement of potentially contaminated equipment and people from affected farms, and increased use of labour and consumables for washing and disinfection, are likely to be required to manage the spread of the virus, which would increase production costs.</li> </ul>
Domestic trade	<p>D – Significant at the district level</p> <ul style="list-style-type: none"> <li>The presence of CGMMV is likely to result in domestic movement restrictions for cucurbit propagative material. Interstate restrictions on seeds, nursery stock and other plant products may lead to a loss of markets, which would be likely to require industry adjustment.</li> <li>Stringent controls on domestic trade may be required if CGMMV became established in Australia. Restrictions might apply to domestic trade in seeds, tissue cultures and seedlings.</li> </ul>
International trade	<p>E – Significant at the regional level</p> <ul style="list-style-type: none"> <li>If CGMMV became established and widespread in Australia, restrictions on Australian exports of host cucurbit seed may occur. Several countries have established quarantine policies and protocols against plant material from areas known to have CGMMV. The establishment of CGMMV in Australia may therefore reduce access to international markets and result in additional requirements to achieve phytosanitary conformity, which will impose a cost burden.</li> </ul>

Criterion	Estimate and rationale
Environmental and non-commercial	<p>B – Minor significance at the local level.</p> <ul style="list-style-type: none"> <li>Increased use of consumables for washing and disinfection of infected equipment, tools and machinery may be required to manage the spread of the virus, which may have some negative impacts on the environment.</li> <li>The potential use of herbicides to control alternate weed hosts may have a negative impact on native plants.</li> <li>Any broad-scale chemical treatments directed against a possible insect vector may have some negative impacts on native insects.</li> </ul>

Based on the decision rules described in Table 4, that is, where the potential consequences of a pest with respect to one or more criteria have an impact of 'F', the overall consequences are estimated to be **HIGH**.

#### 4.1.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the likelihoods of entry, establishment and spread with the outcome of overall consequences. Likelihood and consequences are combined using the risk estimation matrix (Table 5) and results are shown in Table 7.

**Table 7 Unrestricted risk estimates of CGMMV for seed pathway**

Overall likelihood of entry, establishment and spread	LOW
Consequences	HIGH
Unrestricted risk	MODERATE

The unrestricted risk estimate for CGMMV has been assessed as 'moderate', which is above Australia's ALOP. Therefore, risk management measures against CGMMV are required to meet Australia's ALOP.

## 5 Pest risk management

The IPPC and the WTO recognise the phytosanitary concerns associated with expanding world trade in plant propagative material, including seeds for sowing. Consequently, international standards have been developed for the safe movement of plants and plant products. The aim of these standards is to reduce the likelihood of the accidental introduction of pests associated with plant material into new areas through the application of phytosanitary measures. Measures may be applied only where necessary to prevent the introduction and/or spread of quarantine pests. Phytosanitary measures should be applied in a transparent and non-discriminatory manner, and phytosanitary restrictions used only where technically justified and not in lieu of barriers to protect an industry from competition.

The ultimate goal of the phytosanitary measures proposed in this review is to protect Australian agriculture, the economy and environment from the introduction of CGMMV associated with host cucurbit propagative material. To effectively prevent the introduction of CGMMV associated with host cucurbit propagative material, a series of important safeguards, conditions or phytosanitary measures must be in place.

Australia has had emergency measures in place to protect the Australian cucurbit industry from CGMMV since October 2014. These measures were amended in December 2015 to regulate the seeds of additional hosts. This PRA identifies the unrestricted risk of CGMMV as moderate which is above Australia's ALOP and as such reviews the appropriateness of the existing emergency measures, in accordance with ISPM No. 1: *Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade* (FAO 2016d).

### 5.1 Introduction of emergency measures

The introduction of emergency measures by Australia is consistent with ISPM No. 1 (FAO 2016d) and IPPC article VII.6 (FAO 1997). ISPM No. 1 states that 'contracting parties may adopt and/or implement emergency actions, including emergency measures, when a new or unexpected phytosanitary risk is identified (FAO 2016a). Emergency measures should be temporary in their application. The continuance of the measures should be evaluated by pest risk analysis or other comparable examination as soon as possible, to ensure that the continuance of the measure is technically justified'. ISPM No. 5 defines an emergency measure as a phytosanitary measure established as a matter of urgency in a new or unexpected phytosanitary situation (FAO 2016c). An emergency measure may or may not be a provisional measure.

CGMMV is seed-borne and seed-transmissible in several cucurbit seeds (Yoon et al. 2008; Liu et al. 2014; Reingold et al. 2015), infects host plants systemically (Moreno et al. 2004), is an economically important pathogen (Nilsson 1977; Reingold et al. 2015) and was confirmed to occur in commercial watermelon farms near Katherine and Darwin, in the Northern Territory, Australia in September 2014. The introduction of this exotic virus into Australia was a new phytosanitary situation.

CGMMV has been reported to be seed-borne in *Citrullus lanatus* (Yoon et al. 2008), *Cucumis melo* (Reingold et al. 2015), *Cucumis sativus* (Liu et al. 2014), *Cucurbita maxima*, *Cucurbita maxima* x *Cucurbita moschata*, *Cucurbita moschata* (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December), *Cucurbita pepo* (Kwon et al. 2014), *Lagenaria siceraria* (Boubourakas et al. 2004)

and *Trichosanthes cucumerina* (Ariyaratne et al. 2005). Therefore, the seeds of these hosts provide a pathway for the introduction of this virus into Australia. This pathway is direct as the end-use is sowing. Consequently, Australia introduced emergency measures to prevent the further introduction of CGMMV through the seed pathway.

### 5.1.1 Emergency measures for host seeds for sowing

The introduced emergency measures require that seeds for sowing of *Cucumis sativus*, *Cucumis melo*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Citrullus lanatus*, *Lagenaria siceraria*, *Trichosanthes cucumerina* and any hybrid of these species from all sources should be subject to the following conditions.

#### Commercial seed lots

Commercial seed lots of natural seed-borne hosts of CGMMV (*Cucumis sativus*, *Cucumis melo*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Citrullus lanatus*, *Lagenaria siceraria*, *Trichosanthes cucumerina* and any hybrid of these species) must be subject to the following conditions:

- **Testing**—mandatory testing by Enzyme-Linked Immunosorbent Assay (ELISA) using a sample size of 9,400 seeds following the protocol of the International Seed Testing Association (ISTA) '7-026 Detection of *Squash mosaic virus*, *Cucumber green mottle mosaic virus* and *Melon necrotic spot virus* in cucurbits'. The testing for commercial lots of the seeds may be conducted off-shore or onshore; and
- **Certification**—commercial seed lots tested off-shore must be accompanied by an official government Phytosanitary Certificate endorsed with the following additional declaration:  

'The consignment of [botanical name (genus/species)] was tested by ELISA using a sample size of 9,400 seeds following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*'.
- **On-arrival inspection**—commercial seed lots must be subject to on-arrival inspection to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material (e.g. leaf, stem material, fruit pulp, pod material), animal material (e.g. animal faeces, feathers) and any other extraneous contamination of quarantine concern.

#### Small seed lots

Small seed lots of natural seed-borne hosts of CGMMV (*Cucumis sativus*, *Cucumis melo*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Citrullus lanatus*, *Lagenaria siceraria*, *Trichosanthes cucumerina* and any hybrid of these species) are defined by seed lot weight (Table 8) and must be subject to the following conditions:

- **On-arrival inspection**—small seed lots must be subject to on-arrival inspection to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material (e.g. leaf, stem material, fruit pulp, pod material), animal material (e.g. animal faeces, feathers) and any other extraneous contamination of quarantine concern.
- **Testing**—mandatory on-shore testing by ELISA using a sample size of 20 percent of the seed lots weight or 9,400 seeds following the protocol of the International Seed Testing Association (ISTA) '7-026 Detection of squash mosaic virus, *Cucumber green mottle mosaic virus* and *Melon necrotic spot virus* in cucurbits'.

**Table 8 Small seed lot weights for host cucurbit seeds under the emergency measures**

Scientific name	Common name	Seed lot weight
<i>Cucumis sativus</i>	Cucumber	2 kg or less
<i>Cucumis melo</i>	Melon (Rockmelon & Honeydew)	2 kg or less
<i>Citrullus lanatus</i>	Watermelon	3 kg or less
<i>Cucurbita maxima</i>	Pumpkin	10 kg or less
<i>Cucurbita moschata</i>	Pumpkin	10 kg or less
<i>Cucurbita pepo</i>	Zucchini, Squash, Pumpkin	10 kg or less
<i>Lagenaria siceraria</i>	Bottle gourd	5 kg or less
<i>Trichosanthes cucumerina</i>	Serpent gourd	5 kg or less

## 5.2 Evaluation of emergency measures

Under the IPPC and WTO SPS Agreement, phytosanitary measures against the introduction of new pests must be technically justified. ISPM No. 1 states that countries may take appropriate emergency action on a pest posing a potential threat to its territories; however, continuance of the measures should be evaluated by pest risk analysis or other comparable examination as soon as possible, to ensure that the continuance of the measure is technically justified (FAO 2016d). As part of this PRA, the department has evaluated the appropriateness of the emergency measures to determine if alternative or additional measures are required for cucurbit propagative material.

### 5.2.1 Seeds for sowing from all sources (commercial or small lots)

- **Testing**—the existing requirements for mandatory testing by ELISA (using a sample size of 20 percent of the seed lots weight or a 9,400 seed sample) is an appropriate phytosanitary measure for the safe introduction of host seeds. The ultimate goal of testing or treatment is to manage the risk of introducing CGMMV through trade in seed and to achieve Australia's ALOP. Therefore, the existing requirement for mandatory testing is supported.
- **Certification**—consistent with ISPM No. 7 and 12, Australia requires that if seed testing is performed off-shore, the exporting country should certify that each consignment has been tested and found free of CGMMV. Phytosanitary certification is used to attest that consignments meet the phytosanitary requirements of the importing country and are conducted in accordance with ISPM No. 12: *Phytosanitary Certificates*. Phytosanitary certification facilitates safe international trade in plants, plant products and other regulated articles by providing internationally agreed documentation and procedures. Therefore, the existing requirement of certification is supported.
- **On-arrival inspection**—the existing requirement of on-arrival inspection for seeds for sowing to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material, animal material and any other extraneous contamination of quarantine concern is supported.

## 5.3 Proposed risk mitigation measures

Australia considers that the emergency measures, introduced in October 2014 and amended in December 2015, are adequate to mitigate the risk posed by CGMMV. Therefore, these emergency measures will become standard conditions to import host cucurbit seeds for sowing into



Australia from all sources. The only proposed change is to allow the option for small seed lots to be tested off-shore for freedom from CGMMV.

The proposed import conditions for seed-borne hosts of CGMMV (*Cucumis sativus*, *Cucumis melo*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Citrullus lanatus*, *Lagenaria siceraria*, *Trichosanthes cucumerina* and any hybrid of these species) are detailed below.

### 5.3.1 Seeds for sowing from all countries

#### Commercial seed lot testing (off-shore or on-shore)

Commercial seed lots of natural hosts of CGMMV (where the virus is seed-borne) are proposed to be subject to the following conditions.

- **Testing**—mandatory testing by ELISA using a sample size of 9,400 seeds following the protocol of the ISTA '7-026 Detection of *Squash mosaic virus*, *Cucumber green mottle mosaic virus* and *Melon necrotic spot virus* in cucurbits'; and
- **Certification**—commercial seed lots tested off-shore must be accompanied by an official government Phytosanitary Certificate endorsed with the following additional declaration:  

‘The consignment of [botanical name (genus/species)] was tested by ELISA using a sample size of 9,400 seeds following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*’.
- **On-arrival inspection**—commercial seed lots must be subject to on-arrival inspection to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material (e.g. leaf, stem material, fruit pulp, pod material), animal material (e.g. animal faeces, feathers) and any other extraneous contamination of quarantine concern.

#### Small seed lots testing (off-shore or on-shore)

It is proposed that small seed lots continue to be defined by weight (Table 8).

Small seed lots of natural hosts of CGMMV (where the virus is seed-borne) are proposed to be subject to the following conditions.

- **Testing**—mandatory testing off-shore or on-shore by ELISA using a sample size of 20 percent of the seed lot weight (Table 8) or a 9,400 seed sample.
- **Certification**—small seed lots tested off-shore must be accompanied by an official government Phytosanitary Certificate endorsed with one of the following additional declarations:  

‘The consignment of [botanical name (genus/species)] was tested by ELISA using a sample size of 20 percent of the seed lot weight following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*’.

‘The consignment of [botanical name (genus/species)] was tested by ELISA using a sample size of 9,400 seeds following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*’.
- **On-arrival inspection**—small seed lots must be subject to on-arrival inspection to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material (e.g. leaf, stem material, fruit pulp, pod material), animal material (e.g. animal faeces, feathers) and any other extraneous contamination of quarantine concern.

## 6 Conclusion

The findings of this pest-initiated risk analysis are based on a comprehensive analysis of relevant scientific and other appropriate literature on CGMMV. CGMMV meets the IPPC definition of a quarantine pest, that is '*a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled*' (FAO 2016c).

Australia introduced emergency measures in October 2014 to mitigate the risk of further introduction of CGMMV into Australia. In April 2015, CGMMV was found on a single property near Charters Towers in Queensland and the infected property remains under quarantine. The emergency measures were amended in December 2015 to update the host list for CGMMV in response to the detection of this virus in the seeds of additional hosts. Although, the Northern Territory government formally revoked the CGMMV quarantine zone in February 2016, risk management measures have been implemented to contain the spread of this virus. Therefore, the virus is under official control. Consequently, CGMMV remains a quarantine pathogen for Australia. This PRA identifies the unrestricted risk of CGMMV as moderate which is above Australia's ALOP. Therefore, risk management measures against CGMMV are required to meet Australia's ALOP.

This PRA provides technical justification that the introduction of emergency measures were in accordance with international standards. The department considers that the emergency measures are adequate to mitigate the risk posed by CGMMV associated with host cucurbit seeds. Therefore, these emergency measures are proposed to become the standard conditions to import host cucurbit seeds into Australia. However, it is proposed to allow an option for off-shore testing of small seed lots.

Seeds for sowing of seed-borne hosts of CGMMV (*Cucumis sativus*, *Cucumis melo*, *Cucurbita maxima*, *Cucurbita moschata*, *Cucurbita pepo*, *Citrullus lanatus*, *Lagenaria siceraria*, *Trichosanthes cucumerina* and any hybrid of these species) are proposed to be subject to the following import conditions.

### Commercial seed lots

- **Testing**—mandatory off-shore or on-shore testing by ELISA for CGMMV using 9,400 seeds; and
- **Certification**—consignments tested off-shore must be accompanied by an official government Phytosanitary Certificate endorsed with the following additional declaration:  
     'The consignment of [botanical name (genus/species)] was tested by ELISA using a sample size of 9,400 seeds following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*'; and
- **On-arrival inspection**—to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material, animal material and any other extraneous contamination of quarantine concern.

### Small seed lots

- **Testing**—mandatory off-shore or on-shore testing by ELISA for CGMMV using 20 percent of the seed lot weight or 9,400 seeds; and
- **Certification**—consignments tested off-shore must be accompanied by an official

government Phytosanitary Certificate endorsed with one of the following additional declarations:

‘The consignment of [botanical name (genus/species)] was tested by ELISA using 20 percent of the seed lot weight following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*’.

‘The consignment of [botanical name (genus/species)] was tested by ELISA using a sample size of 9,400 seeds following the protocol of the ISTA 7-026 and found free from *Cucumber green mottle mosaic virus*’; and

- **On-arrival inspection**—to verify freedom from live insects, soil, disease symptoms, prohibited seeds, other plant material, animal material and any other extraneous contamination of quarantine concern.

## Appendix A: Stakeholders comments on emergency measures

The Department of Agriculture and Water Resources (the department) notified international trading partners on 23 October 2014 that emergency measures would be introduced immediately against *Cucumber green mottle mosaic virus* associated with host cucurbit seeds from all countries (G/SPS/N/AUS/347). These emergency measures were amended in December 2015 to regulate additional hosts in response to new scientific evidence on the seed-borne hosts of CGMMV (G/SPS/N/AUS/347/Add.3).

The department received several written comments on the emergency measures from stakeholders, including National Plant Protection Organisations, seed companies and international and domestic seed federations. A summary of responses to issues raised by the stakeholders is provided below.

### Issues raised by stakeholders in response to the emergency measures

#### Questions in relation to *Cucumber green mottle mosaic virus*

##### 1. Taxonomy

*Cucumber green mottle mosaic virus* (CGMMV) belongs to the genus *Tobamovirus* within the family *Virgaviridae*. Several closely related *Tobamovirus* species are reported to infect cucurbits globally, which has caused some taxonomic confusion. To date, Australia recognises the following cucurbit-infecting tobamoviruses as distinct virus species, based on their current acceptance by the International Committee on Taxonomy of Viruses:

- *Cucumber fruit mottle mosaic virus* (CFMMV)
- *Cucumber green mottle mosaic virus* (CGMMV)
- *Cucumber mottle virus* (CuMoV)
- *Kyuri green mottle mosaic virus* (KGMMV)
- *Tobacco mosaic virus* (TMV)
- *Zucchini green mottle mosaic virus* (ZGMMV).

##### 2. Host range

Australia's phytosanitary measures for the importation of CGMMV hosts complies with Australia's international obligations under the WTO SPS Agreement and the IPPC, for example:

- Under ISPM No. 2, the 'taxonomic level for organisms considered in PRA is usually the species. The use of a higher or lower taxonomic level should be supported by scientifically sound rationale' (FAO 2011b). Consequently, Australia is regulating the hosts of CGMMV at the species level.
- Under ISPM No. 5, host range is defined as a 'species capable, under natural conditions, of sustaining a specific pest or other organism' (FAO 2015). Therefore, Australia is only regulating plant species that are reported to be hosts under natural conditions.
- Under Article 2 of the SPS Agreement, phytosanitary measures must be based on scientific principles and not maintained without sufficient scientific evidence. Therefore, Australia's

phytosanitary measures do not regulate a plant species if there is insufficient scientific evidence that it is a host of CGMMV.

The natural hosts of CGMMV include *Benincasa hispida*, *Citrullus lanatus*, *Cucumis anguria*, *Cucumis sativus*, *Cucumis melo*, *Cucurbita maxima*, *Cucurbita maxima* x *Cucurbita moschata*, *Cucurbita moschata*, *Cucurbita pepo*, *Lagenaria siceraria*, *Luffa acutangula*, *Luffa cylindrica*, *Momordica charantia* and *Trichosanthes cucumerina* (Noda et al. 1993; Choi 2001; Boubourakis et al. 2004; Ariyaratne et al. 2005; Rashmi et al. 2005; Yoon et al. 2008; Kwon et al. 2014; Liu et al. 2014; Reingold et al. 2015; Fiona Constable [DEDJTR] 2015, pers. comm., 2 December; Stephen West [NT DPIF] 2015, pers. comm., 9 September).

While it is well established that CGMMV naturally infects many cucurbit crops, there also is growing evidence that CGMMV also infects non-cucurbit plants. For example, CGMMV was recently reported to naturally infect *Heracleum moellendorffi* (Apiaceae) (Cho et al. 2015). Boubourakis et al. (2004) detected the virus in several weeds in Greece, including *Amaranthus retroflexus* (Amaranthaceae), *A. blitoides* (Amaranthaceae), *Heliotropium europaeum* (Boraginaceae), *Chenopodium album* (Chenopodiaceae), *Portulaca oleracea* (Portulacaceae) and *Solanum nigrum* (Solanaceae). Four of these weed species have subsequently been found to be naturally infected with CGMMV during recent surveillance activities in the Northern Territory, including *A. retroflexus*, *C. album*, *P. oleracea* and *S. nigrum* (Stephen West [NT DPIF] 2015, pers. comm., 9 September 2015). In addition, CGMMV has been detected for the first time on *A. viridis* (Amaranthaceae) in the Northern Territory (Stephen West [NT DPIF] 2015, pers. comm., 9 September 2015).

Australia considers that the evidence of CGMMV infecting some plant species is insufficient. For example, Polischuk et al. (2007) detected a CGMMV-like virus in mosses (*Polytrichum* species) in Antarctica. There is also a historic record of CGMMV infecting apricot and peach seedlings (*Prunus* species) (Blatný & Janecková 1981); however, there have been no recent reports of the virus infecting these hosts. Additionally, several cucurbit species are only reported to be experimental hosts of the virus, such as *Citrullus colocynthis* (Horváth 1985).

Australia's phytosanitary measures do not apply to cucurbit species that are not reported to be natural hosts of CGMMV. However, the department will review the host list as new scientific evidence becomes available.

### 3. Seed-borne hosts

Australia's emergency measures regulate the importation of seeds of all hosts for which CGMMV is reported to be seed-borne. Equally, if there is no evidence that the seed of a plant species carries CGMMV, then the seed of that plant species is not subject to phytosanitary measures against this virus. Australia's phytosanitary measures comply with Australia's international obligations under the WTO SPS Agreement and the IPPC, for example:

- Under ISPM No. 2, the 'taxonomic level for organisms considered in PRA is usually the species. The use of a higher or lower taxonomic level should be supported by scientifically sound rationale' (FAO 2011b). Consequently, Australia is regulating the seed-borne hosts of CGMMV at the species level.
- Under ISPM No. 5, pathway is defined as 'any means that allow the entry or spread of a pest' (FAO 2015) and ISPM No. 11 (FAO 2013) requires that to assess the probability of entry, an association of the pest with the import pathway is required. Australia has therefore defined

the pathway as seed of a species which has been shown to be a host of CGMMV and the virus is known to be seed-borne in that species.

- Under Article 2 of the SPS Agreement, phytosanitary measures must be based on scientific principles and not maintained without sufficient scientific evidence. Therefore, Australia's phytosanitary measures do not regulate seeds of a plant species for which there is insufficient scientific evidence that it may carry CGMMV.

*Cucumber green mottle mosaic virus* mainly occurs externally on the seed (Lecoq & Desbiez 2012); however, it has also been detected in the inner tissues of cucurbit seeds (Reingold et al. 2015). When the emergency measures were introduced in October 2014, CGMMV was reported to be seed-borne in several cucurbit hosts, including *Citrullus lanatus* (watermelon), *Cucumis sativus* (cucumber), *Cucumis melo* (muskmelon), *Cucurbita pepo* (zucchini, squash and pumpkin), *Lagenaria siceraria* (bottle gourd) and *Trichosanthes cucumerina* (serpent gourd) (Choi 2001; Ariyaratne et al. 2005; Yoon et al. 2008; Al-Tamimi et al. 2009; Baderinwa 2012; Kwon et al. 2014; Liu et al. 2014; Tian et al. 2014; Reingold et al. 2015). Consequently, the seeds of these species were subject to the emergency measures to prevent the further introduction of CGMMV into Australia. Since the introduction of the emergency measures, two additional pumpkin species (*Cucurbita maxima* and *Cucurbita moschata*) have been identified as seed-borne hosts of CGMMV (Fiona Constable [DEDJTR] 2015, pers. comm., 2 December). Therefore, the emergency measures were amended on 18 December 2015 (G/SPS/N/AUS/347/Add.3) to regulate these pumpkin species. In addition, the seeds of any hybrid that has a parent that is a host of CGMMV is subject to the emergency measures against CGMMV.

Australia is not regulating the seeds of CGMMV host species if there is no evidence of this virus being associated with the seeds of that species. However, the department will review the seed-borne host list as new scientific evidence becomes available.

#### **4. Seed transmission**

*Cucumber green mottle mosaic virus* has been demonstrated to be seed transmitted in several cucurbit hosts. There are conflicting reports in the literature regarding the rates of CGMMV transmission in cucurbit seeds. While some reports show low rates of transmission from seed to seedlings in bottle gourd (2.0 percent), watermelon (2.25 percent), muskmelon (2.83 percent) and cucumber (3.0 percent) (Choi 2001; Wu et al. 2011), a recent study found high rates of transmission from seeds to seedlings in cucumber (76.7 percent) (Liu et al. 2014). Even low levels of infection and transmission may lead to the introduction of the virus into new areas. Therefore, the regulation of host seeds is justified to prevent further incursions of CGMMV into Australia.

#### **5. Role of seeds in spreading CGMMV**

Infected seeds are likely to play an important role in the long-distance spread of CGMMV to new areas and countries. The association of CGMMV with seeds can increase its potential to disperse over greater time periods and distances (Liu et al. 2014). For instance, tobamoviruses can survive in an infective state on the surface of seeds for several months to a few years (Reingold et al. 2015). This increases the likelihood that CGMMV on seeds will remain infectious throughout transport and storage; therefore, it is likely to be infectious at the time of sowing.

It is likely that the seed-borne nature of CGMMV has contributed to its rapid spread to many countries. CGMMV was thought to be introduced through *Lagenaria siceraria* seed imported from India to Japan (Tochihara & Komuro 1974). In commercial greenhouses, CGMMV has been

detected in plants grown from seeds during the first cycle of growing cucurbits, indicating that seeds were a primary source of inoculum (Reingold et al. 2015). In addition, since Australia introduced emergency measures in October 2014, Australia has detected CGMMV in imported seed lots through on-arrival ELISA testing. Therefore, risk mitigation measures for the seed pathway are justified to address the risk of CGMMV.

## Questions in relation to emergency measures

### 1. Molecular testing methods for seeds

Australia's emergency measures require that host seed consignments must be ELISA tested with a sample size of 9,400 seeds using the protocol of the International Seed Testing Association (ISTA) 7-026 Detection of *Squash mosaic virus*, *Cucumber green mottle mosaic virus* and *Melon necrotic spot virus* in cucurbits (ISTA 2014). Testing of commercial consignments of seeds may be conducted off-shore or on-shore. The department specified that this protocol be used as it is an internationally accepted method for detecting CGMMV.

Australia also notified trading partners that it was developing a PCR testing protocol that would eventually replace ELISA testing for CGMMV in seeds (G/SPS/N/AUS/347), but this would not be implemented until further notice (G/SPS/N/AUS/347/Add.2).

Australia proposes to continue to use the ISTA 7-026 ELISA testing protocol on 9,400 seeds as it is an internationally accepted method for detecting CGMMV in seeds and to date has been adequate in detecting CGMMV in seed lots imported into Australia. As further scientific information becomes available, Australia may review this testing method and propose an alternative method such as PCR, if appropriate. If this were to occur, trading partners would be notified through an SPS notification and a transition period would apply to minimise trade disruption.

### 2. Sample size of 9,400 seeds for commercial seed lots

The emergency measures require a 9,400 seed sample for CGMMV testing using the ISTA 7-026 protocol. This sample size is consistent with the ISTA protocol, which recommends that a **minimum** of 2,000 seeds be sampled for testing and does not specify an upper limit for the sample size. To detect infected seeds in seed lots that are contaminated at very low levels, large numbers of seeds need to be tested. Any infected seed has the potential to cause an outbreak. The ISTA 7-026 protocol uses a minimum 2,000 seed sample size and achieves a 95 percent level of confidence for detecting infected seeds, if the infected seeds make up at least 0.15 percent of a seed lot. However, departmental specialists have examined the statistical level of confidence for a 2,000 seed sample and found that it reduces appreciably if the level of contamination is much smaller than 0.15 percent.

The 9,400 seed sample was chosen for several reasons, including empirical findings and statistical and operational reasons, consistent with ISPM No. 31 (FAO 2011c). ISPM No. 31 indicates that statistical estimation is appropriate using a hypergeometric distribution. Using a hypergeometric distribution and a seed lot of 100,000 seeds, when 9,400 seeds are tested, there is a 99 percent confidence level for the detection of an infection rate of 0.05 percent (one infected seed in 2,000 seeds). When 2,000 seeds of a 100,000 seed lot are tested, this confidence level drops to 63 percent for the detection of an infection rate of 0.05 percent. Table 9 illustrates the additional reliability achieved by sampling 9,400 seeds. The figures in the tables were

calculated statistically. Reliability is equated with the detection of lower levels of contamination; that is, fewer infected seeds in a lot.

**Table 9 Effect of seed sample size on the confidence level in detecting infected seeds**

Number of infected seeds in 100,000 seed lot	Confidence level to detect in 100,000 using a 2,000 seed sample	Confidence level to detect in 100,000 using a 9,400 seed sample
150	0.951814	1
140	0.941009	0.999999
130	0.927782	0.999997
120	0.911591	0.999993
110	0.891773	0.999981
100	0.867514	0.999949
90	0.837822	0.999862
80	0.801479	0.999629
70	0.756997	0.999005
60	0.702554	0.997328
50	0.635921	0.992824
40	0.554371	0.980735
30	0.454564	0.948281
20	0.332418	0.861172
10	0.182935	0.627384

Tests for other seed-borne pathogens are conducted on samples of between 10,000 and 50,000 seeds to detect low levels of infection. For example, testing samples of 30,000 crucifer seeds is the industry standard for detecting *Xanthomonas campestris* pv. *campestris*, and 10,000 to 20,000 carrot seeds for detecting *Xanthomonas campestris* pv. *carotae* (APHIS 2001; De Boer et al. 2007). Testing samples of 20,000 bean seeds is the standard for detecting *Pseudomonas syringae* pv. *phaseolicola* (Agarwal & Sinclair 1996). A test of 10,000 to 50,000 tomato seeds is used to detect *Clavibacter michiganensis* subsp. *michiganensis* (van Vaerenbergh et al. 2013). A test of 30,000 lettuce seeds is used to detect *Lettuce mosaic virus* (APHIS 2001). Australian laboratories test tomato and capsicum seeds for viroids using samples of 20,000 seeds. Samples of 20,000 seeds are also used by Australian laboratories to detect '*Candidatus Liberibacter solanacearum*' in carrot seeds.

Seed lots with very low levels of infection have been detected on-shore by Australia's emergency measures. It is unlikely that a sample size of 2,000 seeds would have been sufficient to detect these low levels of infection; therefore, a sample size of 9,400 seeds is necessary to reduce the risk of CGMMV to a very low level as required to meet Australia's Appropriate level of protection (ALOP). Therefore, Australia considers that a sample size of 9,400 seeds continues to be an appropriate measure to protect Australia from further incursions of CGMMV through infected seed.

### 3. Small seed lots

The department has developed separate import conditions for small seeds lots, as requested by industry. The definition of a small seed lot is based on the lot weight and varies between cucurbit species (Table 8). If the small seed lots definition is met, the importer has the option to test a 20 percent sample per small seed lot or to test 9,400 seeds per small seed lot. The 20 percent sample is generally calculated by weight; however, it can be calculated from the number of seeds if the lot is very small (less than 200 seeds).



Please refer to Section 5 (Pest risk management) of this PRA for the full import conditions for small seed lots.

#### **4. On-shore and off-shore seed testing**

The department currently allows commercial seed consignments to be tested on-shore or off-shore for CGMMV. If seed consignments undergo off-shore testing and the requirements of the Phytosanitary Certificate are met, then the consignment may be imported into Australia without requiring testing on-shore.

The emergency measures require that small seed lots to be tested on-shore only. Australia considers that providing the accepted ELISA testing method is used (20 percent or 9,400 seeds using the ISTA 7-026 protocol), then off-shore testing for CGMMV provides an acceptable level of protection against this virus. Australia is therefore proposing that small seed lots may be tested off-shore or on-shore.

Please refer to Section 5 (Pest risk management) of this PRA for further information on on-shore off-shore testing for cucurbit seeds.

#### **5. Treatment options**

Seed disinfection treatments can reduce the supply of primary CGMMV inoculum in seeds; however, the effectiveness of these treatments is variable. For instance, a study by Reingold et al. (2015) found that all infected seeds treated with 10 percent trisodium phosphate (TSP) still contained the entire viral genome after treatment and had an infectivity rate of 83.3 percent after treatment. In addition, heat treatment of seeds at 72 °C for 72 hours did not eliminate the virus from seeds, which had an infectivity rate of 66.6 percent after treatment (Reingold et al. 2015). Reingold et al. (2015) found that the combination of treating seeds with 10 percent TSP then heat treatment was more effective in disinfecting seeds from this virus than either individual treatment, but still had an infectivity rate of 31.5 percent after treatment. Any infected seed has the potential to cause an outbreak. Therefore, the department considers that seed treatments are not currently a suitable phytosanitary measure against CGMMV in cucurbit host seed imports.

#### **6. Detection and differentiation of infectious and non-infectious viral particles**

Australia acknowledges that ELISA can detect and quantify the viral genome but does not differentiate between infectious or non-infectious viral particles. However, the detection of non-infectious particles in a seed lot may indicate that infectious particles may be present. For example, a study by Reingold et al. (2015) found that all infected seeds that had undergone heat treatment (72 °C for 72 hours) or chemical disinfection treatment (10 percent TSP) had the entire viral genome after treatment. Although the genome was present in all seeds after treatment, infectivity was 83.3 percent after chemical treatment and 66.6 percent after heat treatment (Reingold et al. 2015). This indicates that infectious and non-infectious particles can be present in the same seed lot. Therefore, Australia considers that it is not appropriate to differentiate between infectious and non-infectious particles when testing for the presence of CGMMV in host seeds.

#### **7. Emergency measures to cover seeds from all countries**

CGMMV is an important seed-borne virus and is responsible for devastating losses of cucurbit crops worldwide (Yoon et al. 2008; Zhang et al. 2009; Reingold et al. 2015). The association of

CGMMV with cucurbit crops was first reported in the 1930s in the UK (Ainsworth 1935; Ugaki et al. 1991) and since then the virus has spread and is reported to occur in most continents and in over 30 countries.

In recent years, seed production (breeding, testing, multiplication and counter seasonal multiplication) frequently occurs at multiple locations, rather than a single country of origin. Global trade in seeds has the potential for the introduction of pathogens to new locations. The movement of seeds between countries may result in the unintentional spread of CGMMV, particularly if other countries do not have phytosanitary measures in place to address this virus. Therefore, applying risk mitigation measures against CGMMV for seeds for sowing from all countries is considered justified.

## Appendix B: Additional quarantine pest data

Quarantine pest	<i>Cucumber green mottle mosaic virus</i> (CGMMV)
Synonyms	<i>Bottlegourd Indian mosaic virus</i> ; <i>Cucumber mottle virus</i> ; <i>Cucumber virus 2</i> ; <i>Cucumber virus 3</i> ; <i>Cucumber virus 4</i> ; <i>Cucumis virus 2</i> ; <i>Tobacco mosaic virus</i> Watermelon strain-W
Common name(s)	Cucumber green mottle mosaic; White break mosaic
Main hosts	<p><b>Cucurbit hosts:</b> <i>Benincasa hispida</i> (Noda et al. 1993), <i>Citrullus lanatus</i> (Lee et al. 1990; Yoon et al. 2008; Reingold et al. 2015), <i>Cucumis anguria</i> (Rashmi et al. 2005), <i>Cucumis sativus</i> (Liu et al. 2014), <i>Cucumis melo</i> (Sugiyama et al. 2006; Tian et al. 2014; Reingold et al. 2015), <i>Cucurbita maxima</i> (Stephen West [NT DPIF] 2015, pers. comm., 9 September), <i>Cucurbita maxima</i> x <i>Cucurbita moschata</i> (Fiona Constable [DED]TR] 2015, pers. comm., 2 December), <i>Cucurbita moschata</i> (Noda et al. 1993; Zhang et al. 2009), <i>Cucurbita pepo</i> (Qin et al. 2005; Al-Tamimi et al. 2009), <i>Lagenaria siceraria</i> (Boubourakas et al. 2004; Zhang et al. 2009), <i>Luffa acutangula</i> (Noda et al. 1993; Sharma et al. 2014), <i>Luffa cylindrica</i> (Noda et al. 1993), <i>Momordica charantia</i> (Pandey &amp; Joshi 1989; Noda et al. 1993) and <i>Trichosanthes cucumerina</i> (Ariyaratne et al. 2005; Nagendran et al. 2015).</p> <p><b>Weed hosts:</b> <i>Amaranthus retroflexus</i>, <i>A. blitoides</i>, <i>A. viridis</i>, <i>Chenopodium album</i>, <i>Heliotropium europaeum</i>, <i>Heracleum moellendorffii</i>, <i>Portulaca oleracea</i> and <i>Solanum nigrum</i> (Boubourakis et al. 2004; Cho et al. 2015; Stephen West [NT DPIF] 2015, pers. comm., 9 September).</p>
Distribution	<p>Austria, Bulgaria (CABI 2015), Canada (Ling et al. 2014), China (Liu et al. 2009), Czechoslovakia (CABI 2015), Denmark (NSCFS 2008), Finland (NSCFS 2008), Georgia, Germany (CABI 2015), Greece (Varveri et al. 2002), Hungary (CABI 2015), India (Vani &amp; Varma 1993), Indonesia (Daryono et al. 2014), Iran (Nematollahi et al. 2014), Israel (Reingold et al. 2015), Japan (Ugaki et al. 1991), Korea (Kim et al. 2003), Latvia (Zitikaitė 2002), Lebanon (CABI 2015), Lithuania (Zitikaitė 2002), Myanmar (Kim et al. 2010), the Netherlands (CABI 2015), Norway (NSCFS 2008), Pakistan (Ali et al. 2004), Russia (Slavokhotova et al. 2007), Saudi Arabia (Al-Shahwan &amp; Abdalla 1992), Spain (Celix et al. 1996), Sri Lanka (Ariyaratne et al. 2005), Taiwan (Hseu et al. 1987), Thailand (Noda et al. 1993), Turkey (CABI 2015), Ukraine (Budzanivska et al. 2007), the United Kingdom (Ainsworth 1935), the United States (California) (Tian et al. 2014) and Yugoslavia (CABI 2015).</p> <p>This virus was first reported in Australia in 2014, where it has a restricted distribution and is under official control.</p>

## Glossary

Term or abbreviation	Definition
Additional declaration	A statement that is required by an importing country to be entered on a phytosanitary certificate and which provides specific additional information on a consignment in relation to regulated pests (FAO 2015).
Appropriate level of protection (ALOP)	The level of protection deemed appropriate by the Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (WTO 1995).
Area	An officially defined country, part of a country or all or parts of several countries (FAO 2015).
Area of low pest prevalence	An area, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest occurs at low levels and which is subject to effective surveillance, control or eradication measures (FAO 2015).
Arthropod	The largest phylum of animals, including the insects, arachnids and crustaceans.
Consignment	A quantity of plants, plant products or other articles being moved from one country to another and covered, when required, by a single phytosanitary certificate. A consignment may be composed of one or more commodities or lots. (FAO 2015).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO 2015).
Endangered area	An area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss (FAO 2015).
Endemic	Belonging to, native to, or prevalent in a particular geography, area or environment.
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 2015).
Equivalence (of phytosanitary terms)	The situation where, for a specified pest, different phytosanitary measures achieve a contracting party's appropriate level of protection (FAO 2015).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2015).
Host	An organism that harbours a parasite, mutual partner, or commensal partner, typically providing nourishment and shelter.
Host range	Species capable, under natural conditions, of sustaining a specific pest or other organism (FAO 2015).
Import permit	An official document authorising the importation of a commodity in accordance with specified phytosanitary import requirements (FAO 2015).
Import risk analysis	An administrative process through which quarantine policy is developed or reviewed, incorporating risk assessment, risk management and risk communication.
Infection	The internal 'endophytic' colonisation of a plant, or plant organ, and is generally associated with the development of disease symptoms as the integrity of cells and/or biological processes are disrupted.
Infestation (of a commodity)	Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection (FAO 2015).
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present or to determine compliance with phytosanitary regulations (FAO 2015).

<b>Term or abbreviation</b>	<b>Definition</b>
Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced or used (FAO 2015).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2015).
International Standard for Phytosanitary Measures (ISPM)	An international standard adopted by the Conference of the Food and Agriculture Organization, the Interim Commission on Phytosanitary Measures or the Commission on Phytosanitary Measures, established under the IPPC (FAO 2015).
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO 2015).
Life cycle	Cyclical progression of stages in the growth and development of an organism (plant, animal, or pathogen) that occur between the appearance and reappearance of the same stage of the organism (Shurtleff & Averre 1997).
National Plant Protection Organization (NPPO)	Official service established by a government to discharge the functions specified by the IPPC (FAO 2015).
Official control	The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests (FAO 2015).
Pathogen	A biological agent that can cause disease to its host.
Pathway	Any means that allows the entry or spread of a pest (FAO 2015).
Pest	Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (FAO 2015).
Pest categorisation	The process for determining whether a pest has the characteristics of a quarantine pest or regulated non-quarantine pest (FAO 2015).
Pest free area (PFA)	An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained (FAO 2015).
Pest free place of production	Place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period (FAO 2015).
Pest free production site	A defined portion of a place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period and that is managed as a separate unit in the same way as a pest free place of production (FAO 2015).
Pest risk analysis (PRA)	The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (FAO 2015).
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and of the magnitude of the associated potential economic consequences (FAO 2015).
Pest risk assessment (for regulated non-quarantine pests)	Evaluation of the probability that a pest in plants for planting affects the intended use of those plants with an economically unacceptable impact (FAO 2015).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2015).
Pest risk management (for regulated non-quarantine pests)	Evaluation and selection of options to reduce the risk that a pest in plants for planting causes an economically unacceptable impact on the intended use of those plants (FAO 2015).
Pest status (in an area)	Presence or absence, at the present time, of a pest in an area, including where appropriate its distribution, as officially determined using expert judgement on the basis of current and historical pest records and other information (FAO 2015).

<b>Term or abbreviation</b>	<b>Definition</b>
Phytosanitary certificate	An official paper document or its official electronic equivalent, consistent with the model of certificates of the IPPC, attesting that a consignment meets phytosanitary import requirements (FAO 2015).
Phytosanitary certification	Use of phytosanitary procedures leading to the issue of a phytosanitary certificate (FAO 2015).
Phytosanitary measure	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO 2015).
Phytosanitary procedure	Any official method for implementing phytosanitary measures including the performance of inspections, tests, surveillance or treatments in connection with regulated pests (FAO 2015).
Phytosanitary regulation	An official rule to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests, including establishment of procedures for phytosanitary certification (FAO 2015).
PRA area	Area in relation to which a pest risk analysis is conducted (FAO 2015).
Quarantine	Official confinement of regulated articles for observation and research or for further inspection, testing or treatment (FAO 2015).
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO 2015).
Regulated article	Any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved (FAO 2015).
Restricted risk	Risk estimate with phytosanitary measure(s) applied.
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO 2015).
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures.
Stakeholders	Government agencies, individuals, community or industry groups or organizations, whether in Australia or overseas, including the proponent/applicant for a specific proposal, who have an interest in the policy issues.
Surveillance	An official process which collects and records data on pest occurrence or absence by surveying, monitoring or other procedures (FAO 2015).
Systems approach(es)	The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests.
The department	The Commonwealth Department of Agriculture and Water Resources.
Tissue culture	The products of 'an in vitro technique of cultivating (propagating) cells, tissues, or organs in a sterile synthetic medium' (Shurtleff & Averre 1997); comprising plant cells, tissues or organs, sterile synthetic medium, and the vessel in which cells have been propagated.
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalisation (FAO 2015).
Unrestricted risk	Unrestricted risk estimates apply in the absence of risk mitigation measures.
Viable	Alive, able to germinate or capable of growth.

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