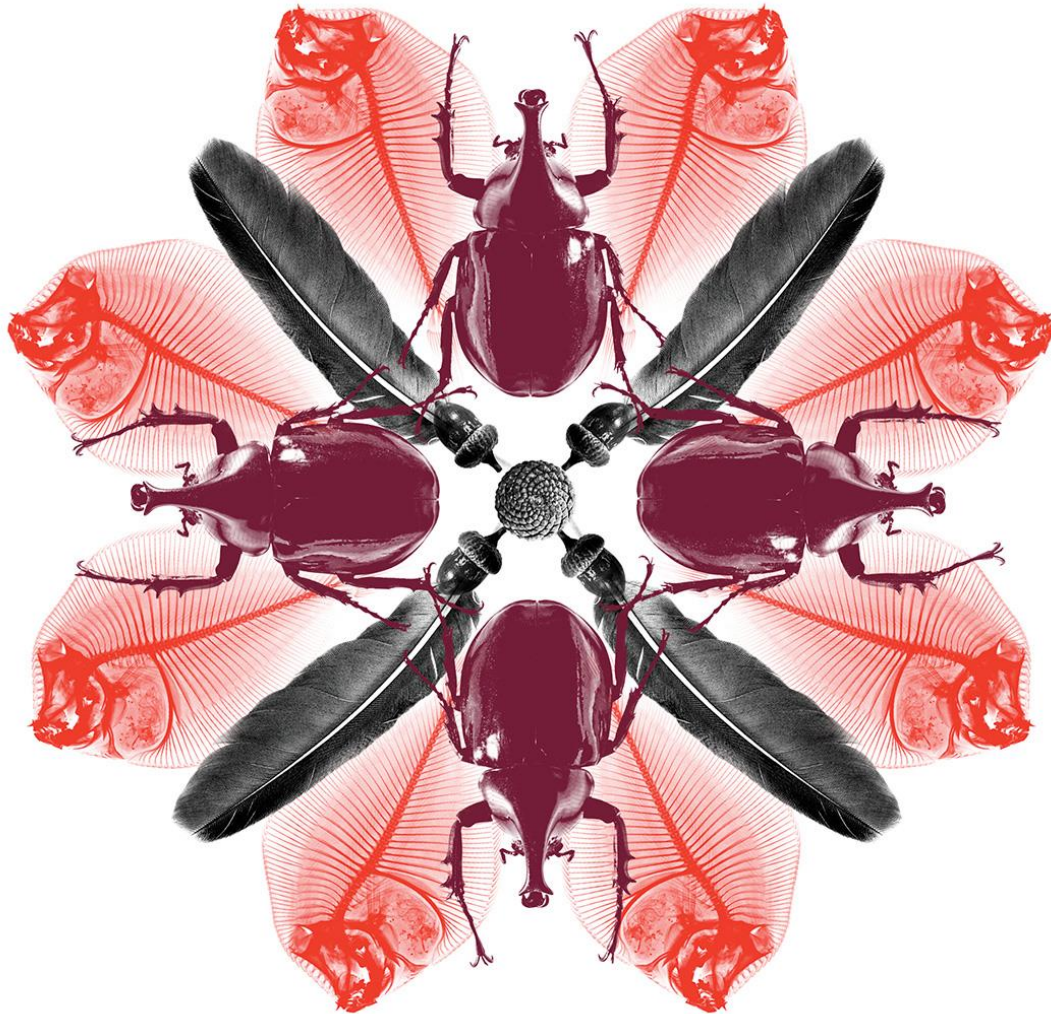




Australian Government
Department of Agriculture
and Water Resources

Final risk analysis report for the release of *Kordyana brasiliensis* for the biological control of *Tradescantia fluminensis*

December 2018



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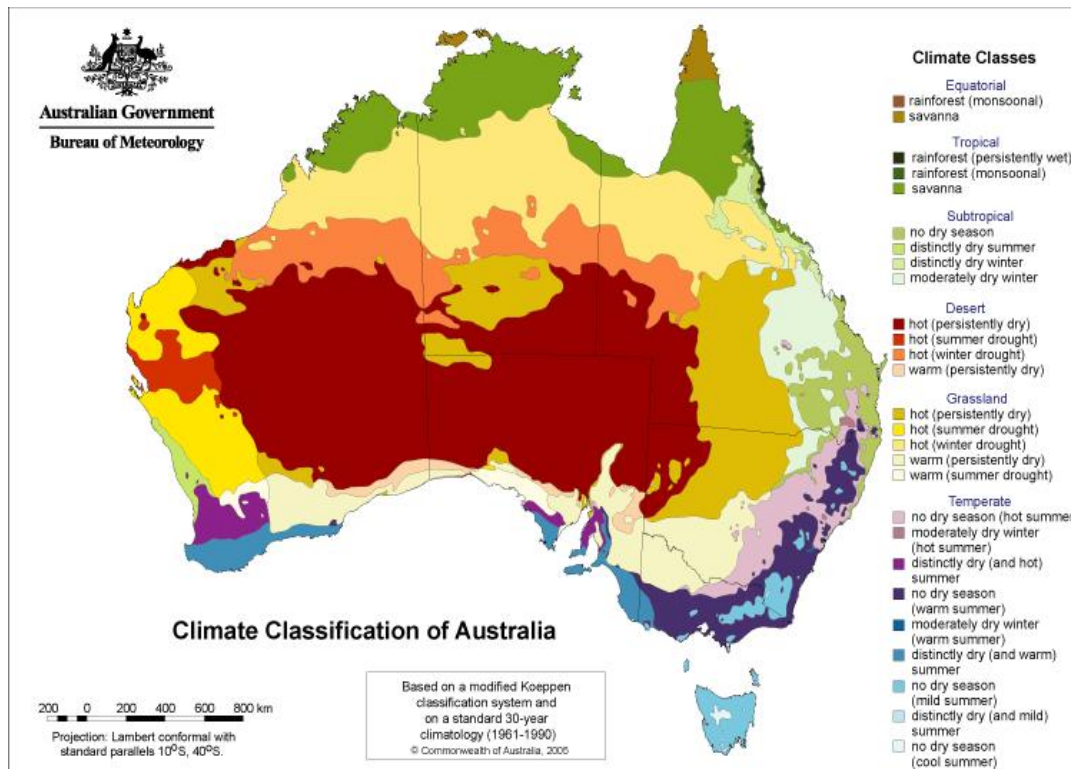
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Map 1 Map of Australia



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	Australia's Biosecurity Import Conditions System
BIRA	Biosecurity Import Risk Analysis
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FAO	Food and Agriculture Organization of the United Nations
IPAC	The Invasive Plants and Animals Committee
IPC	International Phytosanitary Certificate
IPPC	International Plant Protection Convention
ISPM	International Standard for Phytosanitary Measures
NPPO	National Plant Protection Organisation
PRA	Pest risk analysis
SPS Agreement	WTO agreement on the Application of Sanitary and Phytosanitary Measures
the department	The Australian Government Department of Agriculture and Water Resources
WTO	World Trade Organization

Summary

The Australian Government Department of Agriculture and Water Resources has prepared this final report to assess the proposal by CSIRO to release *Kordyana brasiliensis* for the biological control of *Tradescantia fluminensis* in Australia.

This final report recommends that the release of *K. brasiliensis* should be permitted, subject to standard quarantine conditions associated with the import and release of biological control agents.

The risk associated with the release of a biological control agent is a combination of the likelihood of off-target effects and the potential magnitude of the consequences of any off-target effects. This final report has taken into account the results of the host specificity testing submitted in the release application to assess whether the risk meets Australia's appropriate level of protection (ALOP).

Kordyana brasiliensis has been satisfactorily demonstrated to be highly host specific to *T. fluminensis*. The proposed fungal agent is considered to successfully complete its life cycle only on *T. fluminensis*, and no basidiospore-producing lesions have been observed to develop on tested non-target plant taxa. The risk estimate for release of *K. brasiliensis* achieves the ALOP for Australia.

The application and supporting documents from CSIRO that were provided to the Department of Agriculture and Water Resources have been included with this final report (Attachment 1).

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 level of biosecurity risk that may be associated with proposals to import goods or biological materials into Australia. If the biosecurity risks do not achieve the appropriate level of protection (ALOP) for Australia, risk management measures are proposed to reduce the risks to an acceptable level. If the risks cannot be reduced to an acceptable level, the goods or biological materials will not be imported into Australia until suitable measures are identified.

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 the ALOP for Australia, which is defined in the *Biosecurity Act 2015* as providing a high level of protection aimed at reducing risk to a very low level, but not to zero.

Australia's risk analyses are undertaken by the Australian Government Department of Agriculture and Water Resources using technical and scientific experts in relevant fields, and involve consultation with stakeholders at various stages during the process.

Risk analyses may take the form of a biosecurity import risk analysis (BIRA) or a non-regulated risk analysis (such as scientific review of existing policy and import conditions, pest-specific assessments, weed risk assessments, biological control agent assessments or scientific advice).

Further information about Australia's biosecurity framework is provided in the *Biosecurity Import Risk Analysis Guidelines 2016* located on the [Australian Government Department of Agriculture and Water Resources website](#).

1.2 This risk analysis

1.2.1 Background

An application has been submitted by CSIRO to release a biological control agent (Attachment 1). The biological control agent *Kordyana brasiliensis* (Exobasidiales: Brachybasidiaceae) is a white smut-like fungus proposed for the biological control of *Tradescantia fluminensis* (Commelinaceae). The applicant has followed the steps outlined in the [Biosecurity Guidelines](#) for the Introduction of Exotic Biological Control Agents for the Control of Weeds and Plant Pests.

Tradescantia fluminensis, commonly known as wandering trad, is a perennial, prostrate herb native to southeast Brazil and neighbouring areas. The species has established as a non-native weed in Australia, and is most common in the coastal regions of New South Wales, Victoria and southeast Queensland. This species is also naturalised in South Australia, Western Australia, Tasmania, North Queensland and inland Victoria. The species is not known to set seed in Australia, but is primarily spread via stem sections. It can form a dense carpet up to 6 centimetres deep that smothers native flora and kills regenerating seedlings, reducing forest

seedling species richness and abundance (Standish et al. 2001). *Tradescantia fluminensis* has been declared a target for biological control in Australia, approved by the Invasive Plants and Animals Committee (IPAC).

Kordyana brasiliensis was first described as a new species in 2016 after having been observed on *T. fluminensis* during a series of surveys in Brazil (Macedo et al. 2016). The fungal species has only been found on *T. fluminensis*, and observations of damage in the field and apparent host specificity led to the species being considered as a candidate agent for classical biological control of *T. fluminensis*. The fungus causes diffuse chlorotic spots on leaves of *T. fluminensis*, leading to development of whitish lesions on the under-surface of leaves that eventually become necrotic. Coalescing lesions lead to complete necrosis and death of infected leaves.

1.2.2 Scope

The scope of this risk analysis is to consider the biosecurity risk that may be associated with the release of an exotic biological control agent into the Australian environment. The primary risk associated with a release of this nature is the possibility of unwanted off-target effects on other species already present in Australia. The Department of Agriculture and Water Resources assesses the risk under the *Biosecurity Act 2015*. The Department of the Environment and Energy also has an approval process for the import and release of invertebrate biological control agents under the *Environment Protection and Biodiversity Conservation Act 1999*. Under section 303EE(4) of the *Environment Protection and Biodiversity Conservation Act 1999*, risk analysis reports prepared by the Department of Agriculture and Water Resources may be used by the Minister for the Environment and Energy in making a determination to include the species on the *List of specimens taken to be suitable for live import*. In the case of pathogen biological control agents the Department of the Environment and Energy may support the outcome of the risk analysis by acknowledging its findings and providing comments, however they have no formal role in the approval process.

Plants that are considered weeds are sometimes also considered to have value, for example, for purposes such as ornamental display, traditional medicine, feed for stock, etc. Consideration of the benefits and therefore any associated concerns about eradication of the target weed species are out of the scope of this analysis.

The Department of Agriculture and Water Resources will not commence an assessment to release a biological control agent unless the target has been approved by an appropriate government body. *Kordyana brasiliensis* was approved as a target for biological control by IPAC in December 2015.

1.2.3 Contaminating pests

There are other organisms that may arrive with imported exotic biological control agents. These organisms may include, for example, parasitoids, mites or fungi. The Department of Agriculture and Water Resources considers these organisms to be contaminating pests that could pose sanitary and phytosanitary risks. Should an application to release a biological control agent be approved, these risks will be addressed by existing operational procedures that apply to the importation and final release of the agents. These procedures include detailed examination of imported material, confirmation of identity, and breeding under containment conditions before release. For this reason, contaminating pests are not further considered in this risk analysis.

1.2.4 Consultation

In March 2018, a preliminary draft of this report was distributed to state and territory departments of primary industry and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) through the Plant Health Committee (PHC), and also to the Department of the Environment and Energy. Comments received via this consultation process were incorporated into the draft risk analysis report. There was no opposition to the release of *K. brasiliensis*.

On 11 October 2018, Biosecurity Advice 2018-27 informed stakeholders of the release of a draft risk analysis report for the release of *Kordyana brasiliensis* for the biological control of *Tradescantia fluminensis*. The draft report was released for a 30 day stakeholder consultation period that closed on 12 November 2018. Four stakeholder submissions were received. All comments supported release of *K. brasiliensis*.

2 Assessment of off-target risks

This section sets out the assessment of off-target risks that could be associated with the release of the biological control agent. Where appropriate, the methods followed those used for pest risk analysis (PRA) by the Department of Agriculture and Water Resources in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for pest risk analysis* (FAO 2016), ISPM 3: *Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms* (FAO 2017a) and ISPM 11: *Pest risk analysis for quarantine pests* (FAO 2017c) that have been developed under the SPS Agreement (WTO 1995). The methodology for a commodity-based PRA is provided in Appendix A.

The SPS Agreement defines the concept of an ‘appropriate level of sanitary or phytosanitary protection (ALOP)’ as the level of protection deemed appropriate by the WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory.

Like many other countries, Australia expresses its ALOP in qualitative terms. The ALOP for Australia, 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 2.1, marked ‘very low risk’, represents the upper boundary of the ALOP for Australia.

The risk associated with the release of a biological control agent is a combination of the estimates of likelihood of off-target effects and the potential consequences of any off-target effects. A risk estimation matrix (Table 2.1) is used to combine these estimates.

Table 2.1 Risk estimation matrix.

Likelihood of off-target effects	Consequences of off-target effects					
	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

2.1 Stage 1 Initiation

Initiation commences when an applicant provides a submission proposing the release of a biological control agent.

The risk analysis area is defined as all of Australia given that once released there will be no control of spread of the agent other than environmental constraints related to the biology of the organism.

2.2 Stage 2 Risk assessment

This assessment evaluates the likelihood of off-target effects and the potential economic and environmental consequences of any such effects.

Given that the proposal is for deliberate release, the likelihood of entry, establishment and spread is assumed to be certain, and therefore the assessment relates to the host specificity of the proposed agent.

A likelihood is assigned to the estimate of occurrence of off-target effects. Six descriptors are used: high; moderate; low; very low; extremely low; and negligible. Descriptive definitions for these descriptors and their indicative ranges are given in Appendix A, Table 1.

2.2.1 Host specificity testing methodology

The following information regarding host specificity testing has been sourced from the application provided by CSIRO (Attachment 1). For further details please refer to the application.

In order to predict whether any non-target species would be at risk from the candidate agent, a series of host specificity experiments were conducted with *K. brasiliensis* under contained conditions in Australia. The host test list consisted of 28 non-target plant taxa, all from the Commelinaceae family, and was based on the centrifugal phylogenetic method that places an emphasis on species more closely related to the target (Wapshere 1974). Each test species is known to be established in Australia, either as a native or introduced species, and identification was confirmed by an expert taxonomist (Table 2.2). *Tradescantia fluminensis* plants used in the tests were propagated using stem cuttings of Australian accessions of the species. Non-target plant species were propagated from cuttings from field plants, or obtained as whole plants from the field or nurseries.

Production of *Kordyana brasiliensis* inoculum

In order to maintain a continuous supply of the proposed agent for host-specificity tests, three *T. fluminensis* plants with abundant foliage were inoculated with *K. brasiliensis* every week. Infected *T. fluminensis* leaves with several lesions were excised and each deposited (upper surface down) onto the slightly melted surface of a 2% water agar block (c. 1 cm²) placed in the base of a 15 cm diameter plastic petri dish (five blocks per dish). Each dish containing the infected leaves was then fixed to the inside bottom of a 25 litre opaque plastic bucket, which was then inverted over the opening of another bucket containing one *T. fluminensis* plant misted with water. The double-bucket inoculation chambers were placed in a controlled-environment room at 20°C for 48 hours. Abundant basidiospores from lesions were naturally discharged onto the plant foliage, leading to subsequent infection.

Susceptibility of Australian *Tradescantia fluminensis*

The susceptibility of Australian accessions of *T. fluminensis* was determined in a single trial comprising two replicate plants per accession. A total of fourteen Australian accessions of *T. fluminensis* were used, sourced from Victoria, New South Wales, South Australia and

Queensland. *Tradescantia* sp. Giant leaf (Table 2.2) was also included in the trial because it was thought to be a large-leaved biotype of *T. fluminensis* at the time of the trial.

Three agar blocks, each with an attached *T. fluminensis* leaf with several lesions of *K. brasiliensis*, were placed in the base of a 9 centimetre petri dish. Each dish with infected leaves was fixed to the inside bottom of a 10 litre opaque plastic bucket, which was then inverted over the opening of another bucket containing one *T. fluminensis* plant misted with water. The double-bucket inoculation chambers were placed in a controlled-environment room at 20°C for 48 hours. After 48 hours each set-up was dismantled and the plant was removed and placed on the bench of the climate-controlled room. At 14 and 28 days after the inoculation period, all leaves on each plant were examined for visible disease symptoms.

Table 2.2 The plant host test list and the status of each taxon in Australia.

Tribe	Subtribe	Plant taxon	Status in Australia	
Cartonemateae		<i>Cartonema philydroides</i>	Native	
Commelineae		<i>Aneilema acuminatum</i>	Native	
		<i>Aneilema biflorum</i>	Native	
		<i>Commelina ciliata</i>	Native	
		<i>Commelina cyanea</i>	Native	
		<i>Commelina diffusa</i> (North Queensland accession)	Native	
		<i>Commelina diffusa</i> (Northern Territory accession)	Native	
		<i>Commelina ensifolia</i>	Native	
		<i>Commelina lanceolata</i>	Native	
		<i>Floscopa scandens</i>	Native	
		<i>Murdannia gigantea</i>	Native	
		<i>Murdannia graminea</i>	Native	
		<i>Pollia crispata</i>	Native	
		<i>Pollia macrophylla</i>	Native	
	Tradescantieae	Cyanotinae	<i>Cyanotis axillaris</i>	Native
Dichorisandrinae		<i>Dichorisandra thysiflora</i>	Introduced and horticultural	
Tradescantiinae			<i>Callisia repens</i>	Introduced and garden escape
			<i>Gibasis geniculata</i>	Introduced and horticultural
			<i>Tradescantia fluminensis</i>	Target weed
			<i>Tradescantia</i> sp. Giant leaf (Browns Reserve accession)	Introduced and garden escape
			<i>Tradescantia pallida</i>	Introduced and garden escape
			<i>Tradescantia zebrina</i>	Introduced and garden escape
			<i>Tradescantia spathacea</i>	Introduced and garden escape
			<i>Tradescantia</i> 'Cindy'	Introduced and horticultural
			<i>Tradescantia</i> 'Isis'	Introduced and horticultural
			<i>Tradescantia</i> 'J C Wegellin'	Introduced and horticultural
		<i>Tradescantia</i> 'Nutshell Rosy'	Introduced and horticultural	
	<i>Tradescantia</i> 'Snowflake'	Introduced and horticultural		

Tribe	Subtribe	Plant taxon	Status in Australia
		<i>Tradescantia</i> 'Sweet Kate' (<i>T. ohiensis</i> X (<i>subaspera</i> X <i>virginiana</i>) (Anderson Group)	Introduced and horticultural

Host-specificity tests

Each plant taxon was tested in two separate trials. Healthy plants (up to 30 centimetres in height including pot) were chosen for each trial (five plant replicates per taxon per trial unless indicated otherwise). Nine trials consisting of up to eight taxa each and including the positive *T. fluminensis* were performed.

Stage 1

Single leaves from test and control plants were inoculated. One agar block with a *T. fluminensis* leaf with several lesions of *K. brasiliensis* was placed in the base of a 5 centimetre petri dish. This dish was then attached to a fine bamboo stick with a metal clip and inverted above the surface of a single leaf or group of leaves of one plant of each test and control taxon.

Two single leaves were inoculated using different dishes in one of the replicate plants of each taxon. Narrow strips of masking tape were used to ensure that the underside of the leaf to be inoculated (where stomata are solely located or most abundant) was facing upwards and lined up with the inoculated leaf. The plant was then placed in a 10 litre opaque plastic bucket, misted with distilled water and covered with another 10 litre bucket and placed in a controlled-environment room at 20°C for 48 hours. After 48 hours each set-up was dismantled and the plant was removed and placed on the bench of the climate-controlled room. At 28 days after the inoculation period, each inoculated leaf was examined for visible symptoms of infection.

One of the two leaves, or groups of small leaves, inoculated in one of the replicate plants of each taxon was excised five days after the beginning of the inoculation period and cut into small pieces (0.5-1 cm²). The pieces were cleared and stained in a solution containing aniline blue, ethanol, chloroform, lactic acid, phenol and chloral hydrate for 48 hours. They were then rinsed in water, placed in a saturated solution of chloral hydrate for one day and transferred back to water for storage. Prior to microscopic examination, the pieces were placed in blue-lacto-glycerol stain on a microscope glass slide for 3 to 5 minutes. Excess stain was then gently removed with blotting paper and pieces were mounted in water and examined under a light microscope. At least 100 *K. brasiliensis* basidiospores were examined for each test species.

For taxa that developed visible symptoms, one of the inoculated leaves or groups of small leaves with symptoms from one of the replicate plants was excised at 28 days after the inoculation period and processed as described above for microscopic examinations.

Stage 2

The same plants used in Stage 1 were inoculated again using a whole-plant approach after their single inoculated leaves were examined for visible symptoms. The whole-plant inoculation approach was the same as that used in the trial to assess the susceptibility of Australian accessions of *T. fluminensis*. All leaves were examined for visible disease symptoms of infection at 28 days after the inoculation period.

Assessment of *K. brasiliensis* development

The microscopic development of *K. brasiliensis* on leaves of test plants and subsequent visible symptoms were assessed, and the susceptibility of the test plant species to the fungus was then classified according to visible symptoms observed (Table 2.3).

Table 2.3 The categories used to classify the susceptibility of each plant taxon to *K. brasiliensis*.

Categories	Visible symptoms	Developmental stage of fungus
Immune (I)	None.	No sign of penetration.
Highly resistant (HR)	None.	Some penetration with no or abnormal intercellular hyphae development.
Resistant (R)	Water-soaked, chlorotic or necrotic flecks or spots present.	Some penetration and abnormal/limited intercellular hyphae development. Plant host cell necrosis present.
Susceptible (S)	Normal lesions developed but restricted in size.	Network of intercellular hyphae present with interaction sites between hyphae and host cells observed. Sori with basidial layer present in stomatal chambers.
Highly susceptible (HS)	High numbers of normal, large lesions present.	Network of intercellular hyphae present with interaction sites between hyphae and host cells observed. Sori with basidial layer present in stomatal chambers.

2.2.2 Host specificity testing results

All Australian accessions of the target species *T. fluminensis* were equally susceptible to *K. brasiliensis*, and each developed a large number of lesions. *Tradescantia* sp. Giant leaf did not develop any lesions and was included in subsequent host specificity testing as a distinct test species.

Microscopic development of *Kordyana brasiliensis* on tested taxa

Microscopic examinations of excised *T. fluminensis* leaves five days after inoculation period revealed extensive basidiospore germination, development of surface hyphae and penetration through stomata (Table 2.4). Networks of intercellular hyphae with several interaction sites between intercellular hyphae and host cells were observed within leaves. Well-developed sori with a basidial layer, the precursor to basidia on which basidiospores are produced, were present in stomatal chambers.

Germinated basidiospores and surface hyphae were observed on all tested non-target plant taxa. However, the presence of penetration hyphae in stomata was detected in only some taxa, namely *A. acuminatum*, *A. biflorum*, *C. diffusa* (NT accession), *G. geniculata*, *P. crispata*, *P. macrophylla* and *Tradescantia* sp. Giant leaf (Table 2.4). Limited or necrotic/collapsed intercellular hyphae within the leaf tissue underneath stomata were observed in all of these species, except in *A. biflorum* where no intercellular hyphae were detected.

Development of visible symptoms of *Kordyana brasiliensis* on tested taxa

Tradescantia fluminensis was the only plant taxon to develop abundant, normal and large lesions on leaves across the host specificity trials, and was rated as 'highly susceptible' to *K. brasiliensis* (Table 2.4). When exposed to high humidity, basidiospores were produced on basidia that protruded through stomata on the under surface of leaves, giving lesions a 'woolly white' appearance. Lesions coalesced and became greyish-brown as the disease progressed, and entire leaves eventually died.

No other tested plant taxon developed normal disease symptoms of *K. brasiliensis*. However, several taxa did develop small flecks, either water-soaked in appearance or necrotic, following single-leaf or whole plant inoculations, and these were rated as 'resistant'. These taxa were *A. acuminatum*, *C. diffusa* (NT accession), *P. crispata*, *P. macrophylla* and *Tradescantia* sp. Giant leaf. All other tested plant taxa did not develop any visible symptoms.

Table 2.4 The susceptibility rating of each test plant taxon based on visible symptoms and developmental stage of *K. brasiliensis*.

Species ¹	Microscopic observations																Visible symptoms				Rating ²	
	Germination			Surface		Penetration			Colonisation				Reproduction			17	18	19	20			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14					15		16
<i>Aneilema acuminatum</i>	-	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	R
<i>Aneilema biflorum</i>	-	-	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	+	-	-	-	HR
<i>Callisia repens</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Cartonema philydroides</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Commelina ciliata</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Commelina cyanea</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Commelina diffusa</i> (QLD)	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Commelina diffusa</i> (NT)	-	-	+	-	+	+	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	R
<i>Commelina ensifolia</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Commelina lanceolata</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Cyanotis axillaris</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Dichorisandra thysiflora</i> ³	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Floscopa scandens</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Gibasis geniculata</i>	-	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	+	-	-	-	HR
<i>Murdannia gigantea</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Murdannia graminea</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Pollia crispata</i>	-	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	R
<i>Pollia macrophylla</i>	-	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	R
<i>Tradescantia fluminensis</i>	-	-	+	-	+	-	-	+	-	-	+	-	-	+	-	-	+	-	-	-	+	HS
<i>Tradescantia</i> sp. Giant leaf	-	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	R
<i>Tradescantia pallida</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Tradescantia zebrina</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Tradescantia spathacea</i>	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Tradescantia</i> 'Cindy'	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Tradescantia</i> 'Isis'	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I

Species ¹	Microscopic observations																	Visible symptoms				Rating ²
	Germination			Surface		Penetration				Colonisation				Reproduction				17	18	19	20	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16					
<i>Tradescantia</i> 'J C Wegellin'	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Tradescantia</i> 'Nutshell Rosy'	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Tradescantia</i> 'Snowflake'	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I
<i>Tradescantia</i> 'Sweet Kate'	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	I

¹ All taxa were tested in two separate trials (five plant replicates per taxon per trial unless indicated otherwise).

² R = resistant, HR = highly resistant, I = immune (see Table 2.3 for more detail).

³ Three and four replicates were used in each of the trials for this taxon, respectively.

2.2.3 Comments on host specificity testing

Host specificity testing in Australia used 28 non-target taxa. Each taxon is known to be established in Australia and is from the Commelinaceae family, to which *T. fluminensis* belongs. This host test list is representative of the most closely related plant taxa to the target species in Australia. By testing confamilial Australian species of increasing phylogenetic distance to the target, the applicant has satisfactorily assessed the potential for off-target effects to occur in the Australian environment. Inoculations of tested plant taxa with *K. brasiliensis* occurred under optimal climatic conditions for the fungal pathogen, increasing the probability of infection. Trials also included both the inoculation of single leaves and use of a whole-plant approach. Each plant taxon, with the exception of *Dichorisandra thysiflora*, was tested in two separate trials with five replicates per trial. These factors in testing methodology are considered to be adequately scientifically robust to address variation in non-target response to inoculation, and assess the host specificity of the proposed fungal agent.

Tradescantia fluminensis was the only plant taxon to be rated as ‘highly susceptible’ throughout the series of host specificity tests, which suggests a high degree of host specificity in *K. brasiliensis*. The target species developed a large number of lesions, and microscopic examinations revealed extensive basidiospore germination, development of surface hyphae and penetration through stomata. Networks of intercellular hyphae with several interaction sites between intercellular hyphae and host cells were observed within leaves.

Kordyana brasiliensis infects its host via stomatal cells. Basidiospores first germinate on the leaf surface, which leads to the development of surface hyphae. Intercellular hyphae are then produced within the leaf that attach to host cells to form a complex interaction apparatus. The fungus extracts nutrients from the host through these apparatus, compromising the health of the plant.

No plant taxon other than *T. fluminensis* developed normal disease symptoms of *K. brasiliensis*. However, germinated basidiospores and surface hyphae were observed on all tested taxa—these being precursors to the intercellular infection process. The presence of penetration hyphae in stomata was detected in only some taxa, namely *A. acuminatum*, *A. biflorum*, *C. diffusa* (NT accession), *G. geniculata*, *P. crispata*, *P. macrophylla* and *Tradescantia* sp. Giant leaf (Table 2.4). Limited or necrotic/collapsed intercellular hyphae within the leaf tissue underneath stomata were observed in all of these species, except in *A. biflorum* where no intercellular hyphae were detected.

Several non-target taxa did develop small flecks, either water-soaked in appearance or necrotic, following single-leaf or whole plant inoculations, and were rated as ‘resistant’. These taxa were *A. acuminatum*, *C. diffusa* (NT accession), *P. crispata*, *P. macrophylla* and *Tradescantia* sp. Giant leaf. No other tested plant taxon developed any visible symptoms; lesions never developed and *K. brasiliensis* could not complete its life cycle on these taxa. All other tested plant taxa were either rated as ‘immune’ or ‘highly resistant’ to *K. brasiliensis*.

Host specificity tests in Australia were complemented by tests in Brazil using the same accession of *Kordyana brasiliensis*. Tests in Brazil used a total of 20 non-target species, six of which were members of five families other than the Commelinaceae (see Attachment A, Table 2 and Appendix C). Six of those species were also tested in the trials in Australia, with complete concordance of results. None of the 20 species tested in Brazil were found to be susceptible to *K.*

brasiliensis. Results of tests done in Brazil formed the basis of a successful application for use of the pathogen as a biological control agent for *T. fluminensis* in New Zealand. *Kordyana brasiliensis* was released in New Zealand in March 2018. Following release, disease symptoms caused by the agent have been observed in the field on *T. fluminensis* plants at four of the five release sites assessed (Dr Louise Morin [CSIRO] 2018, pers. comm., 6 June).

2.2.4 Likelihood of off-target effects

The likelihood of off-target effects is determined on the basis of the host specificity testing and other relevant information presented in the application (Attachment 1), along with the results of testing conducted outside Australia.

Tradescantia fluminensis was the only tested plant taxon to be rated as ‘highly susceptible’ and to host normal lesions caused by *K. brasiliensis* infection. Although minor visible symptoms did occur in five non-target plant taxa, *K. brasiliensis* was observed to only successfully complete its life cycle on *T. fluminensis*. Hence, the likelihood of off-target effects of *K. brasiliensis* in the Australian environment is assessed as: **Negligible**.

2.2.5 Assessment of potential consequences of off-target effects

The potential consequences of the off-target effects of this biological control agent have been assessed using the same methodology (Appendix A) as used in the import risk analysis process for pests associated with imported fresh produce.

Criterion	Estimate and rationale
Direct	
Plant life or health	A—indiscernible There are a number of Australian native species within Commelinaceae. However, host specificity testing demonstrated that <i>K. brasiliensis</i> only developed normal disease symptoms on <i>T. fluminensis</i> . No direct off-target effects on plant life or health of economic or environmental importance are expected to occur.
Other aspects of the environment	A—indiscernible No direct effects on any other aspects of the environment are anticipated.
Indirect	
Eradication, control	A—indiscernible <i>Kordyana brasiliensis</i> is a biological control agent proposed for the biological control of <i>T. fluminensis</i> . As there are no predicted off-target impacts of economic or environmental significance it would be very unlikely to meet the criteria for eradication. Therefore, the need for eradication and or control is not anticipated.
Domestic trade	A—indiscernible <i>K. brasiliensis</i> is a biological control agent proposed for the biological control of <i>T. fluminensis</i> , a weed of environmental

	importance. Host specificity testing indicates that this agent is host specific, therefore <i>K. brasiliensis</i> is unlikely to impact on any other plant species to the extent that domestic trade would be affected.
International trade	A—indiscernible <i>Tradescantia fluminensis</i> has no known economic benefit either in its native range or other areas where it is now established. <i>Kordyana brasiliensis</i> is a biological control agent proposed for the biological control of <i>T. fluminensis</i> , a weed of environmental importance. No off-target impacts are expected to occur on any plants of significance to international trade.
Environmental and non-commercial	A—indiscernible <i>Tradescantia fluminensis</i> is an introduced weed in Australia. The reduction of this species in the environment is not anticipated to have any negative indirect environmental or non-commercial effects.

Based on this assessment the potential consequences of off-target effects are assessed as: **Negligible.**

2.2.6 Off-target risk estimate

Unrestricted risk is the result of combining the likelihood of off-target effects with the outcome of potential consequences. Off-target effects and consequences are combined using the risk estimation matrix shown in Table 2.1.

Risk estimate for <i>Kordyana brasiliensis</i>	
Likelihood of off-target effects	Negligible
Consequences	Negligible
Risk	Negligible

As indicated, the risk estimate for release of *Kordyana brasiliensis* has been assessed as 'Negligible', which achieves Australia's ALOP.

3 Recommendation on release

The potential for off-target effects and overall consequences for all criteria considered are assessed as Negligible, and the risk estimate for release of *K. brasiliensis* achieves the ALOP for Australia. Therefore, it is recommended that this biological control agent be permitted to be released, subject to standard import and release conditions to ensure that the released material is free of other organisms. This recommendation is made on the basis that *K. brasiliensis* has been satisfactorily demonstrated to be highly host specific to *T. fluminensis*.

4 Stakeholder responses to draft risk analysis report

Four submissions were received from stakeholders; all supported release of *K. brasiliensis*.

5 Attachments

Attachment 1 – Information package to support application by CSIRO to release the white smut-like fungus *Kordyana brasiliensis* for the biological control of wandering trad (*Tradescantia fluminensis*) in Australia.

Appendix A: Method for pest risk analysis

This chapter sets out the method used for the pest risk analysis (PRA) in this report. The Department of Agriculture and Water Resources has conducted this PRA in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for pest risk analysis* (FAO, 2016) and ISPM 11: *Pest risk analysis for quarantine pests* (FAO, 2017c) that have been developed under the SPS Agreement (WTO, 1995).

A PRA is ‘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, 2017b). A pest is ‘any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products’ (FAO, 2017b). This definition is also applied in the *Biosecurity Act 2015*.

Biosecurity risk consists of two major components: the likelihood of a pest entering, establishing and spreading in Australia from imports; and the consequences should this happen. These two components are combined to give an overall estimate of the risk.

Unrestricted risk is estimated taking into account the existing commercial production practices of the exporting country and that, on arrival in Australia, the department will verify that the consignment received is as described on the commercial documents and its integrity has been maintained.

Restricted risk is estimated with phytosanitary measure(s) applied. A phytosanitary measure is ‘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, 2017b).

A glossary of the terms used in the risk analysis is provided at the end of this report.

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

Stage 1 Initiation

Initiation identifies the pest(s) and pathway(s) that are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area.

For this risk analysis, the ‘PRA area’ is defined as Australia for pests that are absent, or of limited distribution and under official control. For areas with regional freedom from a pest, the ‘PRA area’ may be defined on the basis of a state or territory of Australia or may be defined as a region of Australia consisting of parts of a state or territory or several states or territories.

For pests that had been considered by the department in other risk assessments and for which import conditions already exist, this risk analysis considered the likelihood of entry of pests on the commodity and whether existing policy is adequate to manage the risks associated with its import. Where appropriate, the previous risk assessment was taken into consideration in this risk analysis.

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, 2017b).

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

Pest categorisation

Pest categorisation identifies which of the pests with the potential to be on the commodity are quarantine pests for Australia and require 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, 2017b).

The pests identified in Stage 1 were categorised using the following primary elements to identify the quarantine pests for the commodity being assessed:

- identity of the pest
- presence or absence in the PRA area
- regulatory status
- potential for establishment and spread in the PRA area
- potential for economic consequences (including environmental consequences) in the PRA area.

Assessment of the probability 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 11 (FAO, 2017c). 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 here, followed by a description of the qualitative methodology used in this risk analysis.

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. It is based on pathway scenarios depicting necessary steps in the sourcing of the commodity for export, its processing, transport and storage, its use in Australia and the generation and disposal of waste. In particular, the ability of the pest to survive is considered for each of these various stages.

The likelihood of entry estimates for the quarantine pests for a commodity are based on the use of the existing commercial production, packaging and shipping practices of the exporting country. Details of the existing commercial production practices for the commodity are set out in the report. These practices are taken into consideration by the department when estimating the likelihood of entry.

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.
- **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 to be considered in the likelihood of importation may 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
- commercial procedures (for example, refrigeration) applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors to be considered in the likelihood of distribution may include:

- commercial procedures (for example, refrigeration) applied to consignments during distribution in Australia
- dispersal mechanisms of the pest, including vectors, to 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 import takes place
- intended use of the commodity (for example, for planting, processing or consumption)
- 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, 2017b). In order to estimate the likelihood of establishment of a pest, reliable biological information (for example, lifecycle, host range, epidemiology, 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 to be considered in the likelihood of establishment in the PRA area may include:

- availability of hosts, alternative hosts and vectors
- suitability of the environment
- reproductive strategy and potential for adaptation
- minimum population needed for establishment
- 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, 2017b). 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 likelihood 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 to be considered in the likelihood of spread may include:

- 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
- potential vectors of the pest in the PRA area
- potential natural enemies 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 probability ranges are only provided to illustrate the boundaries of the descriptors and are not used beyond this purpose in qualitative PRAs. These indicative probability ranges provide guidance to the risk analyst and promote consistency between different pest risk assessments.

Table 1 Nomenclature of likelihoods

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

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 the likelihood of entry and establishment is then 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. The likelihood for entry is then combined with the likelihood assigned for establishment of 'high' to give a likelihood for entry and establishment of 'low'. The likelihood for entry and establishment is then combined with the likelihood assigned for spread of 'very low' to give the 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 x establishment = [EE]

low x high = low

[EE] x spread = [EES]

low x very low = very low

Table 2 Matrix of rules for combining 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. This is a convenient value for the analysis that is relatively easy to estimate and allows for expert consideration of seasonal variations in pest presence, incidence and behaviour to be taken into account. The consideration of the likelihood of entry, establishment and spread and subsequent consequences takes into account events that might happen over a number of years even though only one year's volume of trade is being considered. This difference reflects biological and ecological facts, for example where a pest or disease may establish in the year of import but spread may take many years.

The use of a one year volume of trade has been taken into account when setting up the matrix that is used to estimate the risk and therefore any policy based on this analysis does not simply apply to one year of trade. Policy decisions that are based on the department's method that uses the estimated volume of one year's trade are consistent with Australia's policy on appropriate level of protection and meet the Australian Government's requirement for ongoing quarantine protection. If there are substantial changes in the volume and nature of the trade in specific commodities then the department will review the risk analysis and, if necessary, provide updated policy advice.

Assessment of potential consequences

The objective of the consequence assessment is to provide a structured and transparent analysis of the potential consequences if the pests 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 5 (FAO, 2017b) and ISPM 11 (FAO, 2017c).

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

- plant life or health

- other aspects of the environment.

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

- eradication, control
- domestic trade
- international trade
- non-commercial and environmental.

For each of these six criteria, 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

Estimation of the unrestricted risk

Once the assessment of the likelihood of entry, establishment and spread and for potential consequences are completed, the unrestricted risk can be determined for each pest or groups 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 combination of likelihood and consequence.

When interpreting the risk estimation matrix, note the descriptors for each axis are similar (for example, low, moderate, 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

The appropriate level of protection (ALOP) for Australia

The SPS Agreement defines the concept of an ‘appropriate level of sanitary or phytosanitary protection (ALOP)’ as the level of protection deemed appropriate by the WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory.

Like many other countries, Australia expresses its ALOP in qualitative terms. The ALOP for Australia, 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 the ALOP for Australia.

Stage 3 Pest risk management

Pest risk management describes the process of identifying and implementing phytosanitary measures to manage risks to achieve the ALOP for Australia, while ensuring that any negative effects on trade are minimised.

The conclusions from pest risk assessment are used to decide whether risk management is required and if so, the appropriate measures to be used. Where the unrestricted risk estimate does not achieve the ALOP for Australia, risk management measures are required to reduce this risk to a very low level. The guiding principle for risk management is to manage risk to achieve the ALOP for Australia. The effectiveness of any proposed phytosanitary measures (or combination of measures) is evaluated, using the same approach as used to evaluate the unrestricted risk, to ensure the restricted risk for the relevant pest or pests achieves the ALOP for Australia.

ISPM 11 (FAO, 2017c) provides details on the identification and selection of appropriate risk management options and notes that the choice of measures should be based on their effectiveness in reducing the likelihood of entry of the pest.

Examples given of measures commonly applied to traded commodities include:

- options for consignments—for example, inspection or testing for freedom from pests, prohibition of parts of the host, a pre-entry or post-entry quarantine system, specified conditions on preparation of the consignment, specified treatment of the consignment, restrictions on end-use, distribution and periods of entry of the commodity
- options preventing or reducing infestation in the crop—for example, treatment of the crop, restriction on the composition of a consignment so it is composed of plants belonging to resistant or less susceptible species, harvesting of plants at a certain age or specified time of the year, production in a certification scheme
- options ensuring that the area, place or site of production or crop is free from the pest—for example, pest-free area, pest-free place of production or pest-free production site
- options for other types of pathways—for example, consider natural spread, measures for human travellers and their baggage, cleaning or disinfestations of contaminated machinery
- options within the importing country—for example, surveillance and eradication programs
- prohibition of commodities—if no satisfactory measure can be found.

Risk management measures are identified for each quarantine pest where the level of biosecurity risk does not achieve the ALOP for Australia.

Glossary

Term or abbreviation	Definition
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).
Appropriate level of protection (ALOP) for Australia	The <i>Biosecurity Act 2015</i> defines the appropriate level of protection (or ALOP) for Australia as a high level of sanitary and phytosanitary protection aimed at reducing biosecurity risks to very low, but not to zero.
Australian territory	Australian territory as referenced in the <i>Biosecurity Act 2015</i> refers to Australia, Christmas Island and Cocos (Keeling) Islands.
Biological control agent	A natural enemy, antagonist or competitor, or other organism, used for pest control (FAO 2017b).
Biosecurity	The prevention of the entry, establishment or spread of unwanted pests and infectious disease agents to protect human, animal or plant health or life, and the environment.
Biosecurity measures	The <i>Biosecurity Act 2015</i> defines biosecurity measures as measures to manage any of the following: biosecurity risk, the risk of contagion of a listed human disease, the risk of listed human diseases entering, emerging, establishing themselves or spreading in Australian territory, and biosecurity emergencies and human biosecurity emergencies.
Biosecurity import risk analysis (BIRA)	The <i>Biosecurity Act 2015</i> defines a BIRA as an evaluation of the level of biosecurity risk associated with particular goods, or a particular class of goods, that may be imported, or proposed to be imported, into Australian territory, including, if necessary, the identification of conditions that must be met to manage the level of biosecurity risk associated with the goods, or the class of goods, to a level that achieves the ALOP for Australia. The risk analysis process is regulated under legislation.
Biosecurity risk	The <i>Biosecurity Act 2015</i> refers to biosecurity risk as the likelihood of a disease or pest entering, establishing or spreading in Australian territory, and the potential for the disease or pest causing harm to human, animal or plant health, the environment, economic or community activities.
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO 2017b).
The department	The Australian Government Department of Agriculture and Water Resources.
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 2017b).
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 2017b).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2017b).
Fumigation	A method of pest control that completely fills an area with gaseous pesticides to suffocate or poison the pests within.
Genus	A taxonomic category ranking below a family and above a species and generally consisting of a group of species exhibiting similar characteristics. In taxonomic nomenclature the genus name is used, either alone or followed by a Latin adjective or epithet, to form the name of a species.
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, 2017b).

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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 2017b).
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 2017b).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2017b).
International Plant Protection Convention (IPPC)	The IPPC is an international plant health agreement, established in 1952, that aims to protect cultivated and wild plants by preventing the introduction and spread of pests. The IPPC provides an international framework for plant protection that includes developing International Standards for Phytosanitary Measures (ISPMs) for safeguarding plant resources.
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 2017b).
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO 2017b).
Larva	A juvenile form of animal with indirect development, undergoing metamorphosis (for example, insects or amphibians).
National Plant Protection Organization (NPPO)	Official service established by a government to discharge the functions specified by the IPPC (FAO 2017b).
Non-regulated risk analysis	Refers to the process for conducting a risk analysis that is not regulated under legislation (Biosecurity import risk analysis guidelines 2016).
Nymph	The immature form of some insect species that undergoes incomplete metamorphosis. It is not to be confused with larva, as its overall form is already that of the adult.
Pathogen	A biological agent that can cause disease to its host.
Pathway	Any means that allows the entry or spread of a pest (FAO 2017b).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2017b).
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 2017b).
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 2017b).
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 2017b).
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 2017b).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2017b).
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 2017b).
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

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	the basis of current and historical pest records and other information (FAO 2017b).
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 2017b).
Phytosanitary certification	Use of phytosanitary procedures leading to the issue of a phytosanitary certificate (FAO 2017b).
Phytosanitary measure	Phytosanitary relates to the health of plants. 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 2017b). In this risk analysis the term 'phytosanitary measure' and 'risk management measure' may be used interchangeably.
Phytosanitary procedure	Any official method for implementing phytosanitary measures including the performance of inspections, tests, surveillance or treatments in connection with regulated pests (FAO 2017b).
Phytosanitary regulation	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 2017b).
Polyphagous	Feeding on a relatively large number of hosts from different plant family and/or genera.
Practically free	Of a consignment, field or place of production, without pests (or a specific pests) in numbers or quantities in excess of those that can be expected to result from, and be consistent with good cultural and handling practices employed in the production and marketing of the commodity (FAO 2017b).
Pupa	An inactive life stage that only occurs in insects that undergo complete metamorphosis, for example butterflies and moths (Lepidoptera), beetles (Coleoptera) and bees, wasps and ants (Hymenoptera).
Quarantine	Official confinement of regulated articles for observation and research or for further inspection, testing or treatment (FAO 2017b).
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 2017b).
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 2017b).
Regulated non-quarantine pest	A non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party (FAO 2017b).
Regulated pest	A quarantine pest or a regulated non-quarantine pest (FAO 2017b).
Restricted risk	Restricted risk is the risk estimate when risk management measures are applied.
Risk analysis	Refers to the technical or scientific process for assessing the level of biosecurity risk associated with the goods, or the class of goods, and if necessary, the identification of conditions that must be met to manage the level of biosecurity risk associated with the goods, or class of goods to a level that achieves the ALOP for Australia.
Risk management measure	Are conditions that must be met to manage the level of biosecurity risk associated with the goods or the class of goods, to a level that achieves the ALOP for Australia. In this risk analysis, the term 'risk management measure' and 'phytosanitary measure' may be used interchangeably.
Saprophyte	An organism deriving its nourishment from dead organic matter.

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Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO 2017b).
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 2017b).
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.
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalisation (FAO 2017b).
Unrestricted risk	Unrestricted risk estimates apply in the absence of risk management measures.
Vector	An organism that does not cause disease itself, but which causes infection by conveying pathogens from one host to another.
Viable	Alive, able to germinate or capable of growth.

References

- FAO 2016, *International Standards for Phytosanitary Measures (ISPM) no. 2: Framework for pest risk analysis*, Food and Agriculture Organization of the United Nations, Rome, available at ippc.int/en/core-activities/standards-setting/ispms/.
- FAO 2017a, *International Standards for Phytosanitary Measures (ISPM) no. 3: Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms*, Food and Agriculture Organization of the United Nations, Rome, available at ippc.int/en/core-activities/standards-setting/ispms/.
- FAO 2017b, *International Standards for Phytosanitary Measures (ISPM) no. 5: Glossary of phytosanitary terms*, Food and Agriculture Organization of the United Nations, Rome, available at ippc.int/en/core-activities/standards-setting/ispms/.
- FAO 2017c, *International Standards for Phytosanitary Measures (ISPM) no. 11: Pest risk analysis for quarantine pests*, Food and Agriculture Organization of the United Nations, Rome, available at ippc.int/en/core-activities/standards-setting/ispms/.
- Macedo, DM, Pereira, OL, Hora Junior, BT, Weir, BS & Barreto, RW 2016, 'Mycobiota of the weed *Tradescantia fluminensis* in its native range in Brazil with particular reference to classical biological control', *Australasian Plant Pathology*, vol. 45, pp. 45-56.
- Standish, RJ, Robertson, AW & Williams, PA 2001, 'The impact of an invasive weed *Tradescantia fluminensis* on native forest regeneration', *Journal of Applied Biology*, vol. 38, no. 6, pp. 1253-1263.
- Wapshere, AJ 1974, 'A strategy for evaluating the safety of organisms for biological weed control', *Annals of Applied Biology*, vol. 77, no. 2, pp. 201-211.
- WTO 1995, 'The WTO agreement on the application of sanitary and phytosanitary measures (SPS Agreement)', World Trade Organisation, Switzerland, available at wto.org/english/tratop_e/sps_e/spsagr_e.htm.