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Ministry of Economic affairs

Pest Risk Analysis for *Xanthomonas axonopodis* pv. *dieffenbachiae* pathogenic to *Anthurium*

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Pest Risk Analysis for *Xanthomonas axonopodis* pv. *dieffenbachiae* pathogenic to *Anthuriumi*

Dirk Jan van der Gaag[1] & Maria Bergsma-Vlami[2]

[1] Office for Risk Assessment and Research, Netherlands Food and Consumer Product Safety Authority
[2] National Reference Laboratory, Netherlands Food and Consumer Product Safety Authority

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Summary

Reason for performing the PRA
Xanthomonas axonopodis pv. *dieffenbachiae* (Xad) is the causative agent of bacterial blight of Araceae causing most severe problems in Anthurium. In the Netherlands, emergency measures are in place for propagation material of Anthurium since the first finding of Xad in the 1997. In this pest risk analysis (PRA) the risk of *Xanthomonas axonopodis* pv. *dieffenbachiae* (Xad) for Anthurium is re-evaluated after an earlier PRA completed in 2003.

PRA area
The PRA-area is the Netherlands

Distribution of *Xanthomonas axonopodis* pv. *dieffenbachiae* (Source: EPPO-PQR, 2014)

Continent	Country
Africa	Reunion, South Africa
Asia	China, Philippines, Taiwan
Europe	Germany, Italy, Netherlands[1], Poland, Romania, Turkey
Americas	Barbados, Bermuda, Brazil, Canada, Costa Rica, Dominica, Guadeloupe, Jamaica, Martinique, Puerto Rico, St Vincent and the Grenadines, Trinidad and Tobago, USA (California, Florida, Hawaii, New Jersey), Venezuela
Oceania	Australia (Queensland), French Polynesia

[1)] Xad is absent from companies producing propagation material (official surveys and inspections by the NPPO) and is probably absent from the entire production chain.

Host plants and strains
Xanthomonas axonopodis pv. *dieffenbachiae* (Xad) is mainly known as a pathogen of *Anthurium* but can also affect other Araceae. Strains have been isolated from other Araceae that were not or only weakly pathogenic to *Anthurium* and host differentiation may exist within the current pathovar *dieffenbachiae.* The present PRA only assesses the risk of strains that are pathogenic to *Anthurium*.

Area of potential establishment
Glasshouses growing *Anthurium* spp. and to lesser extent glasshouses growing Araceae other than *Anthurium* spp.

Probability of introduction (entry and establishment)
Xad possibly originates from South or Central America, the native area of origin of the main host plant *Anthurium*. Xad has spread to different continents by movement of (latently) infected plant material. Without any precautionary measures, the probability of introduction is (very) high. However, the actual probability of new introductions into the Netherlands will very much depend on companies awareness of the pathogen and the measures taken to prevent introductions. Most likely, Xad was introduced into the Netherlands by import of infected plant material in the 1990s. Since the last 10 years, no findings of Xad are known which could be related to import of plants and the probability of entry has probably significantly decreased due to changes in production strategies in the Netherlands and/or the kind of plant material (e.g. plants raised from in vitro culture) and origin of the plant material imported. Currently, the probability of introduction seems low (medium uncertainty)

Spread
Xad can be spread by human assistance through trade of (latently) infected plants and through contaminated tools, clothes, infested soil etc. Spread between glasshouses without human assistance is unlikely to occur.

Potential consequences

Endangered area: The endangered area includes primarily glasshouse companies growing *Anthurium*. Araceae other than *Anthurium* grown in glasshouses might also be endangered (high uncertainty).

Economic impact: potentially 'massive'. Xad can destroy whole *Anthurium* crops and control measures are expensive once the pathogen is present in a glasshouse. For the whole sector (production of *Anthurium* cut flowers and plants) the impact is assessed 'medium' (medium uncertainty). Despite the introduction of Xad in the 1990s, the total acreage of *Anthurium* cut flowers increased from 36 ha in 1990 to 72 ha in 1995 and 90 ha in 2000. Use of pathogen free plant material and hygiene measures are effective measures to avoid introduction of Xad.

Export markets: Xad is officially present in the Netherlands but only in end products. It is assessed that the probability of introduction of the pest on young plant nurseries will not increase significantly by deregulation because the nurseries apply voluntary measures to prevent introduction of the pest. Therefore, the effect of deregulation is assessed to have a minimal effect on export (medium uncertainty)

Environmental impact: not relevant. Host plants are usually not grown outdoors. They may incidentally be present in e.g. private gardens or on balconies during summer.

Social impact: minimal (medium uncertainty). No significant loss of employment expected. For individual companies the social impact can be massive because high costs related to introduction of the pest may lead to bankruptcy.

Risk reduction options

Options to reduce the probability of introduction
The most likely pathway is import and trade of plants of symptomlessly infected host plants especially *Anthurium* spp.. The probability of introduction can be strongly reduced by use of (certified) pathogen free plant material (plant material derived from mother plants that have been tested and found free of Xad and produced under strict hygiene measures).

Xad may also be spread by contaminated materials and splashing water; the probability of introduction of the pathogen through contaminated materials can be strongly reduced by implementation of strict hygiene measures.

Eradication after introduction
The pathogen can be eradicated from a glasshouse by application of strict hygiene measures after removal of all host plants. Eradication measures can be very costly especially when the company produces host plants year round.

Uncertainties

The main uncertainties in the present PRA are:

- Xad isolates that are pathogenic to *Anthurium* have been shown to be pathogenic to other Araceae in inoculation tests. However, symptoms and yield losses have mainly reported for *Anthurium* spp. and the impact of Xad strains pathogenic to *Anthurium* seems, therefore, minor or minimal for other Araceae. It is, however, uncertain if strains exist or may develop that are highly virulent to both *Anthurium* spp. and other Araceae under practical conditions.

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Methodology

The set-up of the present PRA follows partly the PRA-scheme of the European and Mediterranean Plant Protection Organisation (EPPO, http://www.eppo.org/). The present PRA scheme asks for:

- the host plants and pest distribution;
- the probability of entry (including transfer to a suitable place or habitat where the pest can establish) according to a 4-point qualitative scale (low, medium, high, very high; see explanation below);
- the area of potential establishment (description, no rating);
- the rate of spread once the pest has established (description, preferably with estimated distances, no rating);
- the probability of introduction (the probability that the pest enters and establishes according to a 4-point qualitative scale (the same scale as for the probability of entry).
- the economic, environmental and social impact according to a 5-point qualitative scale (minimal, minor, moderate, major, massive);
- the endangered area (description, no rating);
- the identification and evaluation of risk reduction options;
- the main uncertainties.

Rating guidance is provided in Annex I. For entry, a 4-point scale was used and not a 5-point scale as in the EPPO-scheme. In the present PRA-scheme, the rating levels corresponds with a quantitative interval while the EPPO-scheme has no rating guidance for "entry". It was considered that a 5-point scale would suggest a too high level of accuracy for the "entry-assessment". The information available to assess the probability of entry in PRAs is often very limited. The lowest rating level in the present PRA-scheme ("low") corresponds to an average of less than one entry in 10 years. In many cases, it is not considered possible to assess lower probabilities in a more accurate way (e.g. to make a difference between for example one entry in 10 – 25 years and one entry in less than 25 years). Also, the use of more narrow intervals for the three highest rating levels and to split them in four rating levels was not considered appropriate (see Annex I for the full rating guidance).

Similar to the EPPO-scheme, the level of uncertainty is rated according to a 3-point qualitative scale (low, medium and high). Adapted from IPPC definitions, low, medium and high uncertainty are defined as expressing 90, 50 and 35% confidence, respectively, that the score selected is the correct one (Mumford *et al*., 2010).

1. Pest Risk Initiation

1.1 What is the reason for performing the PRA?

In 1997, *Xanthomonas axonopodis* pv. *dieffenbachiae* (Xad) was reported in the Netherlands for the first time (EPPO, 1997). After the first finding, a survey was carried out and the pathogen was found at 10 companies producing *Anthurium*. In 2003, a Pest Risk Assessment was completed for Xad (Janse & Lammers, 2003). The Pest Risk Assessment concluded that Xad qualifies as a quarantine organism on breeding and propagation material (plant material for commercial purposes) of *Anthurium* for the EU. Since then, Xad has not been listed as a quarantine organism in EU directive 2000/29, neither has the pathogen been found on breeding and propagation material in the Netherlands anymore. Apparently, young plant nurseries have managed to keep their nurseries free of Xad. In the present update of the first PRA, we include these experiences with the pathogen since 2003. Xad is mainly known as a pathogen of *Anthurium* but can also affect other Araceae (e.g. Chase, 1987). Strains have been isolated from other Araceae that were not or only weakly pathogenic to *Anthurium* (Lipp et al., 1992; Roubène-Soustrade et al., 2006; Chase et al., 2008). Apparently, host differentiation exists within the currently called pathovar *dieffenbachiae* and isolates from different genera within the Araceae might constitute different pathovars. The present PRA only assesses the risk of strains that are pathogenic to *Anthurium* and may also be pathogenic to other Araceae (see 2.1.1 for more details on host specialization).

1.2 Scientific name, taxonomy and type of pest

Xanthomonas axonopodis pv. *dieffenbachiae* (McCulloch & Pirone) Vauterin *et al.*

Synonyms:
- *Xanthomonas campestris* pv. *dieffenbachiae* (McCulloch & Pirone) Dye
- *Xanthomonas dieffenbachiae* (McCulloch & Pirone) Dowson 1943
- *Bacterium dieffenbachiae* McCulloch & Pirone 1939
- *Phytomonas dieffenbachiae* McCulloch & Pirone 1939
- *Xanthomonas campestris pv. syngonii* Dickey & Zumoff 1987

Taxonomic Tree

Kingdom: Bacteria
Phylum: Proteobacteria
Class: Gammaproteobacteria
Order: Xanthomonadales
Family: Xanthomonadaceae
Genus: Xanthomonas

1.3 PRA area

The risk assessment area is the Netherlands.

1.4 Does a relevant earlier PRA exist?

Yes, the present PRA is an update of the PRA for Xad (Janse & Lammers, 2003) with the difference that the PRA area of the present PRA is limited to the Netherlands.

2. Pest Risk Assessment

2.1 Host plants and pest distribution

2.1.1 Specify all the host plant species (for pests directly affecting plants). Indicate the ones which are present in the PRA area.

Host plant species
The main host plants of Xad are *Anthurium* spp. but various species within the family of Araceae have been indicated as host plants (Chase, 1987). However, plant species within the Araceae other than *Anthurium* spp. appear much less often infected. Lipp et al. (1992) found that isolates from *Anthurium* had a broader host range and were generally more aggressive than isolates from other aroids. Roubène-Soustrade et al. (2006) tested isolates from various Araceae species and tested their pathogenicity on the host from which they were isolated and on *Anthurium andreanum*. Most isolates were pathogenic to the host from which they had been isolated. Isolates from *Syngonium*, *Aglaonema*, *Alocasia*, *Dieffenbachia* and *Xanthosoma* were not pathogenic to *Anthurium*. One isolate from *Caladium* was pathogenic on *Anthurium* but another was not. Isolates originating from *Anthurium* in Brazil were pathogenic to *Anthurium*, *Dieffenbachiae* and *Syngonium*. The pathogencity of many other isolates from *Anthurium* and pathogenic to *Anthurium* were not tested on *Dieffenbachiae* and *Syngonium.* Chase et al. (2008) reported on a *Xanthomonas* bacterium that was specific for *Syngonium*; inoculation test on several other aroids including *Anthurium andreanum*, were unsuccessfull. Anonymous (2009a) distinguishes at least two groups of strains affecting Araceae: '(1) strains highly virulent to *Anthurium*, and with a broad host range. These strains are the causal agent of *Anthurium* bacterial blight' and '(2) strains originating from other Araceae genera that are primarily pathogenic to their host or origin and weakly or not pathogenic to *Anthurium*'. Indeed, most of the isolates from naturally infected Araceae other than *Anthurium* do not seem to be (highly) virulent on *Anthurium* (Lipp et al., 1992; Roubène-Soustrade et al., 2006; Chase et al., 2008). These observations also suggest that strains that are highly virulent to *Anthurium* (although able to infect other Araceae under artificial conditions) do usually not infect other Araceae. As stated above (see 1.2). the present PRA only assesses the risk of Xad strains that are pathogenic to *Anthurium*.

In the Netherlands *Anthurium* and also other aroids are commercially grown in glasshouses:

- breeding material and young plants
- pot plants
- cut flowers

Outdoors, host plants might incidentally be present in private gardens during summer.

2.1.2 Specify the pest distribution

Xad has been reported (mainly from *Anthurium*) from various countries on all continents (except Antarctica) including the EU-countries Germany, Italy, the Netherlands, Poland and Romania (EPPO, 2014). Eradication measures were taken to eradicated the pest in Germany and Romania EPPO, 2005, 2007). In the Netherlands, the pest has been eradicated from companies producing propagation material and has not been found during plant passport inspections for more than 10 years (NVWA, 2013) and is also absent from companies producing pot plants or cut flowers of *Anthurium* according to the grower's association LTO Glaskracht the Netherlands (July, 2014).

2.1.3 What is the international phytosanitary status?

Xad is a regulated pest in Argentina, Jordan, Norway and Turkey and listed as an A2-pest by the regional plant protection organizations CPPC (Caribbean Plant Protection Commissions) and EPPO (European and Mediterranean Plant Protection Organizaton) (EPPO, 2014).

2.2 Probability of entry

Identification and analysis of pathways

Propagation material and plants intended for commercial production of entire plants (plant material)
Import and trade of plant material including in tissue culture plants of *Anthurium* spp. is considered to be the most relevant pathway. The bacterium can be latently present in plants which increase the probability that infected plants are imported without being noticed during import inspections (Alvarez & Norman, 1994; Norman & Alvarex, 1996; Alvarez et al., 2006). Plants are imported from third countries where Xad is present and is also known to be present in other EU member states (Table 1; question 2.1.2). Examples of findings or outbreaks related to import of infected plant material:

- In 1993, the NPPO of the Netherlands repeatedly found Xad in plants of *A. andreanum* from South Africa (EPPO, 1995)
- Interception of *Xanthomonas campestris* pv. *dieffenbachiae* on *Anthurium* plants from the Netherlands (Sathyanarayana et al., 1998)
- An outbreak in *A. andreanum* in Reunion Island was linked with import of planting material from the Netherlands (Soustrada et al., 2000).

No notifications of interceptions were found in Europhyt (last access 20th May 2014). It should, however, be noted that plant material is usually not tested at import by the NPPO and the bacterium is more likely spread by latently infected material than diseased material because bad-looking material will usually be removed by industry for quality reasons.

In general, the probability of entry will largely depend on the disease management strategy applied at the production sites where plant material is being produced (e.g. mother plants tested and found free of Xad, hygiene measures etc.). During the last 10 years, no import related findings of Xad are known and the probability of entry has probably significantly decreased as compared to the 1990s due to measures taken by industry. For example, certified plant material of *Anthurium* is currently available (http://www.naktuinbouw.nl/onderwerp/naktuinbouw-elite-siergewassen; last access 22nd April 2014).

Entry with infected plant material of Araceae other than *Anthurium* spp. may also be possible but seems less likely. They are less frequent host plants and (many of the) strains naturally occurring on plant species other than *Anthurium* spp. may not or only be weakly pathogenic to *Anthurium* (see 2.1.1). As far as known, Xad has only been found on *Anthurium* spp. in the Netherlands. Xad has been reported on a few plants of *Dieffenbachia picta* on a market in Romania (Vlad et al., 2004; EPPO, 2007) but it is uncertain if this strain was pathogenic to *Anthurium* (e.g. Robène-Soustrade et al., 2006).

Cut flowers
Cut flowers are considered much less relevant than plant material intended for commercial growers because of the low probability that the pathogen will be transferred from a private residence to a commercial glasshouse.

Tabel 2. Import volume of plants for planting of *Anthurium* spp.[1]

Origin[2]	2011		2012		2013	
	No. of lots	No. of plants	No. of lots	No. of plants	No. of lots	No. of plants
China*	10	183,562	13	266,281	5	55,901
India	0	0	0	0	7	88,780
Vietnam	0	0	1	1,000	1	2,000
Sri Lanka	0	0	1	10	1	40
Thailand	1	45	0	0	0	0
USA*	1	490	2	20	1	72
Costa Rica*	1	2	0	0	0	0
Honduras	0	0	0	0	1	62
Ghana	2	3,240	0	0	0	0
Kenia	4	25,096	0	0	1	3,900
Tanzania	1	3,300	0	0	0	0
Zwitserland	0	0	0	0	1	8,145

[1] Plants imported through the Netherlands; data also include imports of companies located in other EU member states. In 2012 and 2013, the majority of plants was imported by companies from other EU member states.

[2] An asterisk (*) indicates that *Xanthomonas* pv. *dieffenbachiae* is present in the country (EPPO-PQR, 2014).

Conclusion on the probability of entry

Xad can enter by import of (latently) infected plant material including tissue culture plants of *Anthurium* spp. and less likely by other species of Araceae. The probability of entry will largely depend on the origin of the plant material imported (absence/presence of the pathogen) and the measures growers take to prevent infections (e.g. hygiene measures and testing for latent infections). Without such precautionary measures the probability of entry is assessed “high” or even “very high” (medium uncertainty).

Since the last 10 years, no findings of Xad are known which could be related to import of plants and the probability of entry has probably significantly decreased due to changes in production strategies in the Netherlands and/or the type and origin of the plant material imported. Currently, the probability of entry seems low (medium uncertainty).

2.3 Area of potential establishment

2.3.1. Factors affecting the limits and suitability of the area of potential establishment

Protected conditions
Host plants are grown in commercial glasshouses and are present as pot plants in offices, private houses etc. No publications of experimental data were found on the effect of climatic conditions on the bacterium. RPD (2001) states that the bacterium is favoured by warm (21° to 32°C) and moist conditions. The climate and management practices (host plants present year round) in commercial glasshouses are likely suitable for establishment. There are no registered pesticides available that can control bacterial diseases.

Suitability of climate (outdoors)
Not relevant; host plants are not grown outdoors (except that private persons may place host plants outdoors during summer.

2.3.2. Reproductive strategy and transient populations

How likely can the pest establish starting from a low initial inoculum level/a few individuals? (take into account the reproductive strategy of the pest)
Bacteria reproduce asexually and one infected cutting or plantlet will be sufficient to start an epidemic. An infected leaf tissue often contains $>10^6$ cells of the pathogen per cm2 (Fukui et al., 1996), and a single infected leaf (100 cm2) produces as much as 10^7 cells of inoculum per ml under simulated rain (Nishijima, 1989; Fukui et al., 1998).In symptomless plant tissue, populations sizes as low as 10^3 CFU/ ml could be detected by PCR (Robene-Soustrade et al., 2006).

How likely will transient populations occur?
Not relevant; Xap can be present in commercial glasshouses throughout the year (year round cultivation).

2.3.3 Description of the area of potential establishment
Glasshouses with *Anthurium* spp. and possibly glasshouses growing Araceae other than *Anthurium* spp. (see also 2.1.1).

2.3.4 How often has the pest been introduced into new areas outside its original area of distribution? (specify the instances, if possible)
Xad was reported for the first time in 1939 on *Dieffenbanchia maculate* in USA (McCulloch & Pirone, 1939) and on *Anthurium* as the major host in Brazil in 1952 (Robbs, 1955). It possibly originates from South or Central America, the native area of origin of the main host plant *Anthurium* (Toves, 2008). It has now been reported from North America, Australia, Africa, Asia and Europe (see above) and is believed to have been introduced with infected plant material many times outside its original area of distribution.

2.4 Spread

2.4.1 Natural spread

Xad can be spread by splashing water over short distances and possibly by insects and nematodes (Huettel et al., 1986; Nishijima, 1989; EPPO/CABI, 1997; RPD, 2001). Some growers observed that root damage by nematodes may be associated with symptomless systemic infection in adult plants in the field (Fukui et al., 1998). However, no supporting experimental evidence was found that nematodes contributed to spread of the bacterium.

Natural spread between glasshouse companies is very unlikely to occur and is even less likely from infected plants (e.g. pot plants) at consumer's places.

2.4.2 Spread by human assistance

Xad can be spread by human assistance through contaminated tools, clothes, infested soil etc. and by trade of (latently) infected plants (EPPO/CABI, 1997). The bacterium can even be present in tissue-culture plants (RPD, 2001). The pathogen can survive in or on callus for over 4 months without producing symptoms in the callus or turbidity in the medium. It can also survive for more than 1 year on or within stage II shoots of in tissue culture plants (increase/multiplication stage) without producing symptoms (Norman and Alvarez, 1994).

2.5 Probability of introduction

The probability of introduction is potentially very high. However, the probability of introduction may currently be lower due to voluntary measures by companies exporting and importing plants of host plants. Since 2003 (preparation of the former risk assessment), Xad has not been found on breeding companies and companies producing propagation material (plants of Araceae rooted of with growing medium attached or associated are subject to plant passport inspections in the EU; art. 2.3 in Annex V part A of directive 2000/29/EC).

Conclusions on the area of potential establishment, probability of introduction (entry + establishment) and the probability and rate of spread

Area of potential establishment: Glasshouses growing *Anthurium* spp. and to a lesser extent glasshouses growing Araceae other than *Anthurium* spp.

Probability of introduction (entry + establishment): The probability of introduction is difficult to rate. The pathogen has spread to different continents by movement of infected plant material. However, the actual probability of new introductions into the Netherlands will very much depend on the measures exporters and importers take to prevent such introductions. Currently, the probability of introduction seems low (medium uncertainty).

Spread after introduction: Natural spread between glasshouses is unlikely to occur. The pathogen can be spread by (latently) infected plant material or less likely contaminated equipment or clothes.

2.6 Potential consequences

Economic impact

2.6.1 What is the economic impact of the pest in its current area of distribution?
Alvarez et al. (2006) described the impact of the pest after its introduction into Hawaii where it destroyed the production of approximately 200 small farms in 1985 – 1989. The cut flower production dropped from a record high of approximately 30 to 15.6 million stems per year in 1990. After the implementation of an integrated disease management programme, losses were eventually reduced to 5% or less. Due to the high costs of disease management, a few large farms now dominate the market.

Information on impact of Xad in other states or countries is limited. Zoina et al. (1999) reported that of the most severely affected cultivars in a commercial glasshouse in Italy, 80 to 100% of the plants showed symptoms. Soustrada et al. (2000) reported on the first observation of Xad in Reunion Island. They described that the disease rapidly spread in the nursery and caused severe damage. Infestations were found at three nurseries and measures were adopted to prevent spread and new introductions. In Turkey, an outbreak was reported in *Anthurium* pot plants in a commercial glasshouse in 2001; disease incidences of 20 – 25% occurred (Aysan & Sahin, 2003). Pulawska et al. (2008) found a 10% disease incidence at time of inspection in a commercial *Anthurium* glasshouse in Poland.

It should be noted that pests or pathogens often have a higher impact shortly after introduction into new areas than after some time when growers have learned how to control the pest or pathogen (see also below 2.6.4). Therefore, the impact in its current area of distribution is generally rated as "major" but the impact for individual companies may be "massive" (medium uncertainty because of limited information available).

2.6.2 What is the potential direct economic impact in the PRA area? *(without any control measures)*
Potentially, Xad has a "massive" impact for the production of *Anthurium* cut flowers en pot plants but the actual impact after introduction will depend on the number of companies that become infested and the cost-effectiveness of control measures (see questions 2.6.3 and 2.6.4).

2.6.3 Which control measures are available in the PRA area?

Monitoring methods: crops can be inspected for disease symptoms regularly but the bacterium can be latently present.

Pesticides: not available for bacteria

Biological control agents: Bacteria have been experimentally tested as biocontrol agents against Xad (Toves, 2008). However, as far as known no commercial products are available with high efficacy against Xad at least not in the Netherlands.

Cultivation methods:
Use of pathogen-free planting material (certified plant material is available). Additionally, overhead irrigation must be avoided (in the Netherlands, overhead irrigation is normally not used in the production of *Anthurium* cut flowers or pot plants). Hygiene measures to prevent introduction of the bacterium by infested materials and to limit spread or even eradicate the bacterium in case of an infestation.

Conclusion on control measures
Control measures currently available are: use of pathogen-free planting material and strict hygiene measures.

2.6.4 What is the expected direct economic impact when the pest would become introduced? *(with the use of control measures)*

Xad was present in the Netherlands. The pathogen was introduced in the 1990s. Yield losses in the Netherlands have not been documented but the following information was provided by the grower's association LTO Glaskracht the Netherlands (July, 2014): cut flower companies that became infested got bankrupt (partly) because of Xad. Despite expensive hygiene measures yield losses sometimes exceeded 10 – 15%. The cost of the control measures taken were much higher than the total costs for crop protection against other pests and pathogens. Currently, Xad is absent in the production of *Anthurium* pot plants and cut flowers and has never been reported from other crops (LTO Glaskracht, July 2014). Thus, the impact was "massive" at the level of individual companies. However, the impact in general has been less dramatic than in Hawaii after the pest's introduction: the pest was found for the first time in 1997 but the acreage of *Anthurium* cut flowers did not decrease between 1995 and 2000; the acreage even increased between 1995 and 2007 (Table 3). The decrease in acreage after 2007 was possibly due to lower prices due to larger supplies from other European countries (Staalkaart Bloemisterij, 2010). The decrease is unlikely due to infestations by Xad because the disease is currently absent in the Netherlands according to information from growers (LTO Glaskracht, the Netherlands, July, 2014). Thus, although the impact for individual companies was "massive" (companies got bankrupt), the economic impact for the entire production in the Netherlands appeared absent or limited. It is, however, difficult to assess to which extent the official measures in the Netherlands contributed to the prevention of further spread of the pathogen to other companies and thereby limiting the impact of the pathogen. Before the official measures were in place, the pathogen had already been introduced to at least 10 companies growing *Anthurium* (EPPO, 1997). Generally, after the first introduction of a destructive pathogen like Xad yield losses can be (locally) very high but because of the high potential impact growers will take measures to reduce losses and in this case introduction of the pathogen can be avoided by the use of (certified) pathogen-free plant material and strict hygiene measures.

The production value per ha for *Anthurium* cut flowers and pot plants (flowering pot plants) is currently approximately EUR 398,000 and 977,000, respectively (http://www3.lei.wur.nl/NEG/RPT_SO.aspx; 22nd April 2014) and the total production value approximately EUR 33 and 82 million, respectively.

In conclusion: the expected direct economic impact is "massive" for individual companies (yield and/or quality losses will be severe; high mortality of plants is expected) but for the entire Dutch production the impact is expected to be moderate (yield and/or quality losses are limited). The uncertainty is medium because of lack of documented data on economic impact in areas where the pest is or was present.

Table 3. Acreage of *Anthurium* cut flowers and pot plants in the Netherlands

Year	Cut flowers		Pot plants	
	No. of companies	Acreage (ha)	No. of companies	Acreage (ha)
1990	n.a.	36	n.a.	n.a.
1995	n.a.	72	n.a.	n.a.
2000	78	90	n.a.	n.a.
2001	76	90	n.a.	n.a.
2002	70	86	n.a.	n.a.
2003	73	95	n.a.	n.a.
2004	69	96	n.a.	n.a.
2005	66	95	32	47
2006	72	111	37	56
2007	75	120	38	58
2008	51	78	39	67
2009	53	95	41	74
2010	51	86	40	83
2011	45	84	n.a.	n.a.

Sources: LEI/CBS, 2008; http://www3.lei.wur.nl/ltc/Classificatie.aspx (last access 18th April 2014); n.a. = not available in the sources indicated.

Indirect economic impacts

2.6.5 What is the expected impact on export markets for the PRA area?

Quarantine status outside the EU
Xad is a regulated pest in Argentina, Jordan, Norway and Turkey and listed as an A2-pest by the regional plant protection organizations CPPC (Caribbean Plant Protection Commissions) and EPPO (European and Mediterranean Plant Protection Organizaton) (EPPO, 2014). In Norway and Turkey, Xad is regulated for plants for planting (Anonymous, 2009b; EPPO, 2003).

Export from the Netherlands
No export figures were found for *Anthurium* but the majority of the propagation material, cut flowers and pot plants produced in the Netherlands is possibly sold to companies and consumers in the Netherlands and other EU member states.. Xad is regulated in many countries outside the EU (NVWA-Client export). In some countries, the species is regulated for plants for planting of *Anthurium* only while in others it is regulated for several genera within the Araceae. In more than 10 countries, it is also regulated for cut flowers. Usual requirements are mother plants tested and found free of Xad, pest free crop or pest free production place. A few countries require country or area freedom (Malaysia, French Polynesia, Réunion for *Anthurium* sp.). Currently, the official pest status in NL is "present, only in end products, but managed. Absent in plants for planting, pest eradicated confirmed by survey." Companies producing young plants can keep their production place free of the pest by voluntary measures (which they already do) and it is assessed that the effect of Xad on export market size if Xad would be deregulated would be "minimal" (medium uncertainty).

Environmental impact

2.6.6 What is the expected environmental impact in the PRA area?
Not relevant. Host plants are not present outdoors (except may be in private gardens during the summer).

Social impact

2.6.7 What is the expected social impact in the PRA area?

Social impact can be massive for companies that become infested. The uncertainty is medium because actual information on social impact is lacking. Overall, employment is not expected to change significantly due to introduction of Xad on individual companies. This conclusion is based on the changes in cropping acreage after introduction of Xad between 1995 and 2000 (Table 3).

Endangered area

2.6.8 What is the endangered area?

Glasshouses growing *Anthurium* plants (propagation material, cut flowers and pot plants) are endangered. Glasshouses growing plants of Araceae other than *Anthurium* may also be endangered. However, there is uncertainty about the host range of Xad (see question 2.1.1) and Xad is primarily known as a pathogen of *Anthurium.*

Conclusions on impact

Endangered area: The endangered area includes primarily glasshouse companies growing *Anthurium*. Glasshouses growing plants of Araceae other than *Anthurium* might also be endangered (high uncertainty).

Economic impact: potentially "massive" but due to preventive measures the impact is generally assessed to be medium (medium uncertainty)

Export markets: the pest is officially present in the Netherlands but only in end products. It is assessed that the probability of introduction of the pest on young plant nurseries will not increase significantly by deregulation because the nurseries apply voluntary measures to prevent introduction of the pest. Therefore, the effect of deregulation is assessed to have a minimal effect on export (medium uncertainty)

Environmental impact: not relevant, Xad cannot establish outdoors in the Netherlands.

Social impact: minimal (medium uncertainty). No significant loss of employment expected. For individual companies the social impact can be massive because high costs related to introduction of the pest may lead to bankruptcy.

3. Identification and evaluation of risk reduction options

3.1 Indicate the pathway: import and trade of plant material including tissue culture plants of host plants (Araceae, especially *Anthurium* spp.)

3.2 Identification of risk reduction options

Table 3.1. overview of possible risk reduction options for the pathway “import of plants for planting including tissue culture plants” from areas where the pest is present.

Risk Reduction Option	Reduction of risk	Justification[1]
I. options at the place of production		
a. Detection of the pest at the place of production by inspection or testing	Yes but to limited extent	Xad can be latently present. Efficiency of testing is limited by sample size.
b. Prevention of infestation of the commodity at the place of production: • use of resistant cultivars, • growing the crop in specified conditions (e.g. physical protection), • crop treatments, and/or • harvest at certain times of the year or growth stages	Yes in combination with the use of pathogen-free planting material	Hygiene measures can reduce the probability of infestation
c. Establishment and maintenance of a pest-free production site, pest- free production place or pest-free production area	Yes	Use of plants derived from mother plants tested free for Xad in combinations with strict hygiene measures (e.g. certification system).
II. options after harvest, at pre-clearance or during transport		
a. Detection of the pest in consignments by inspection or testing	Yes but to limited extent	Xad can be latently present. Efficiency of testing is limited by sample size
b. Removal of the pest from the consignment by treatment or other phytosanitary procedures (remove certain parts of the plant or plant product, handling and packing methods)	Yes	Thermal heat treatment of cuttings (Tsang et al., 2010)
III. options that can be implemented after entry of consignments		
a. Detection during post-entry quarantine	Yes but to limited extent because of very long latency periods).	Xad can be latently present in tissue culture for over a year (Norman & Alvarex, 1994)
b. Consider whether consignments that may be infested should be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice	No	
c. Effective measures that could be taken by the importing country (surveillance, eradication, containment) to prevent establishment and/or economic or other impacts	Yes but high costs for eradication	At the time Xad is detected the pathogen may already have spread throughout the glasshouse and large investments will be needed to eradicate the pathogen.

[1] a more detailed justification for those options which reduce the risk is given below.

I. options at the place of production

a. Inspection or testing

Visual inspections are not very effective because of latent infections. Also, testing will have limited efficiency because of limitations of the sample size. A nested PCR test (N-PCR) has recently been validated to specifically detect and identify *X. axonopodis* pv. *dieffenbachiae* strains pathogenic to *Anthurium* spp. (Chabirand et al., 2014). However, even for very sensitive assays, the detection efficiency will be largely limited by the size of the sample that can be reasonably taken.

b. Prevention of infestation of the commodity at the place of production

Cultivars vary in their degree of resistance but cultivars that are fully resistant are (currently) not available (Alvarez, 2006; Elibox & Umaharan). See further below (c. pest-free production area, place or site)

c. Pest-free production area, place or site

Xad has a limited capacity of natural spread and a pest free production site can be established by use of pathogen free planting material (e.g. derived from a certification scheme) in combination with very strict hygiene measures. In the Netherlands, propagation material of *Anthurium* is available that is produced in a certification scheme (http://www.naktuinbouw.nl/onderwerp/naktuinbouw-elite-siergewassen; last access 22nd April 2014).

II. options after harvest, at pre-clearance or during transport

a. Detection of the pest in consignments by inspection or testing

See Ia

b. Removal of the pest from the consignment by treatment or other phytosanitary procedures

Thermal heat treatment of cuttings (hot water bath, 50°C for 24 min) will likely kill the bacterium without affecting the quality of the cuttings (Tsang et al., 2010).

III. options that can be implemented after entry of consignments

a. Detection during post-entry quarantine

Xad can be latently present in tissue culture for over a year (Norman & Alvarex, 1994) which makes a post-entry quarantine period not feasible.

b. Certain end uses, limited distribution in the PRA area, or limited periods of entry

Plants are used to produce cut flowers, pot plants etc

c. Surveillance, eradication, containment

In principle, the pathogen can be eradicated because it cannot establish outdoors and has a limited natural dispersal capacity. However, eradication of the pathogen in a glasshouse producing year round can be very difficult and expensive. The whole crop may need to be removed.

3.3 Selection of and conclusions on risk reduction options

<u>Options to reduce the probability of introduction</u>
It is assessed that the risk of Xad will not increase significantly if the regulatory status of propagation material status were to be lifted because no specific requirements are in place and companies are aware of the risk. Currently, plants of (potential) host species are only tested if symptoms are observed during official import inspections and latently infected plants will, therefore, not be intercepted. According to information of grower's associations, companies that produce *Anthurium* cut flowers, pot plants or propagation material are aware of the risk posed by Xad and, therefore, take hygiene measures to prevent introduction of the pest. One company produce *Anthurium* propagation material following a certification system. In the past, Xad has been present at companies but eradicated.

Conclusions on risk reduction options

<u>Options to reduce the likelihood of introduction and spread</u>
The most likely pathway is import and trade of plant material of host plants especially *Anthurium* spp. and the probability of introduction can be strongly reduced by use of (certified) pathogen free plant material (plant material derived from mother plants that have been tested and found free of Xad and produced under strict hygiene measures).

Xad may also be spread by contaminated clothes or materials; the probability of introduction of the pathogen through this pathway can be strongly reduced by implementation of strict hygiene measures.

<u>Prospects for eradication</u>
In principle, the pathogen can be eradicated from a glasshouse but eradication measures can be very costly especially when the company produces host plants year round.

4. Uncertainties
The main uncertainties in the present PRA are:

- Xad isolates that are pathogenic to *Anthurium* have been shown to be pathogenic to other Araceae in inoculation tests. However, symptoms and yield losses have mainly reported for *Anthurium* spp. and the impact of Xad strains pathogenic to *Anthurium* seems, therefore, minor or minimal for other Araceae. It is, however, uncertain if strains are present or may develop that are highly virulent to both *Anthurium* spp. and other Araceae under practical conditions.

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Annex I: Rating guidance

Probability of entry (including transfer to a suitable host or habitat)

Rating level	Description
Low	On an average less than 1 "entry" in 10 years
Medium	On an average 1 "entry" per 5 – 10 years
High	On an average 1 "entry" per 2 – 4 years
Very high	On an average 1 or more "entries" per year

Establishment and probability if introduction

There is no rating for the probability of establishment but a description of the potential area of establishment is asked. The assessors should indicate where the pest can likely, possibly and/or may establish indicating a low, medium and high uncertainty, respectively.

A rating is asked for the probability of introduction (the probability of entry and establishment). For this the same rating levels and rating guidance as for the "probability of entry" is used (see above). The probability of introduction will depend on the probability of entry, the suitability of the environment for establishment and the biology of the pest (e.g. how likely the pest can establish starting from a low initial inoculum level/a few individuals).

Spread

No rating is asked but a description of the probability of spread and the rate of spread after introduction.

Impact

Rating guidance derived from the EPPO (European and Mediterranean Plant Protection Organisation) decision-support scheme for Pest Risk Analysis PM5/3(5) (http://www.eppo.int/QUARANTINE/Pest_Risk_Analysis/PRA_intro.htm)

2.5.1 What is the economic impact of the pest in its current area of distribution?

Rating level	Description
Minimal	no yield and/or quality losses recorded.
Minor	yield and/or quality losses recorded but pest is fully controlled by non-targeted measures and control costs cannot be distinguished from normal plant protection costs.
Medium	yield and/or quality losses are limited, some targeted measures needed, but additional control costs are limited.
Major	yield and/or quality losses are considerable, targeted measures are frequently needed and the treatment is costly.
Massive	yield and/or quality losses are severe; high mortality of plants may also occur which can only be reduced by very expensive measures.

2.5.2 What is the potential direct economic impact in the PRA area? *(without any control measures)*

Rating level	Description
Minimal	no yield and/or quality losses are expected.
Minor	yield and/or quality losses are expected but they cannot be distinguished from normal variation
Medium	yield and/or quality losses are limited but they exceed normal variation, some targeted measures may be necessary
Major	yield and/or quality losses can be considerable, targeted measures may frequently be needed
Massive	yield and/or quality losses will be severe; and/or high mortality of plants is expected

2.5.4 What is the expected direct economic impact when the pest would become introduced? *(with the use of control measures)*

Rating level	Description
Minimal	no yield and/or quality losses expected
Minor	yield and/or quality losses are expected but cannot be distinguished from normal variation
Medium	yield and/or quality losses are limited
Major	yield and/or quality losses can be considerable
Massive	yield and/or quality losses will be severe; high mortality of plants is expected.

2.5.5 What is the expected impact on export markets for the PRA area?

Rating level	Description
Minimal	no effect on market size is expected
Minor	the effect on market size is negligible and cannot be distinguished from normal variation
Medium	some effects on market size are expected
Major	considerable effects on market size are expected
Massive	severe effects on market size are expected

2.5.6 What is the expected environmental impact in the PRA area?
No rating guidance.

2.5.7 What is the expected social impact in the PRA area?

The maximum rating level should be taken from "landscape effects" and "loss of employment"

Rating level	Description landscape effects
Minimal	damage to landscape has no consequences for landscape value
Minor	some plants which are not scene setting are damaged or die
Medium	some scene setting plants are damaged or die
Major	a substantial part of the scene setting plants are damaged or die
Massive	the majority of the scene setting plants die

Rating level	Description loss of employment
Minimal	no loss of employment due to economic impact occurs
Minor	some loss of employment due to economic impacts may occur, but cannot be distinguished from normal loss of employment
Medium	loss of employment due to economic impacts occurs to a limited extent
Major	considerable loss of employment and bankruptcy due to economic impacts occurs
Massive	due to economic impacts, the majority of the affected producers go bankrupt and their employees loose there job