Pest Risk Assessment:

Orchid fleck virus associated with imported whole plants of *Oncidium* and other orchid genera

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Version 1.0

14 June 2021

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Approved for general release

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New Zealand is a member of the World Trade Organisation and a signatory to the Agreement on the Application of Sanitary and Phytosanitary Measures ("The Agreement"). Under the Agreement, countries must base their measures on an International Standard or an assessment of the biological risks to plant, animal or human health.

This document provides a scientific analysis of the risks associated with *Orchid fleck dichorhavirus* on whole plants of *Oncidium* and other genera of orchids. It assesses the likelihood of entry, exposure, establishment and spread of *Orchid fleck dichorhavirus* via the nursery stock pathway and assesses the potential impacts should the virus enter and establish in New Zealand. The document has been internally peer reviewed and approved for external release. Any significant new science information received that may alter the level of assessed risk will be included in a review, and an updated version released.

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1 Introduction

1.1 Purpose

This Pest Risk Assessment (PRA) is to enable the Plant Germplasm (ornamental) Imports team, of the Ministry for Primary Industries (MPI), to decide on whether *Orchid fleck dichorhavirus* (OFV) should be regulated as a quarantine pest for New Zealand, and if import health standard (IHS) 155.02.06 (Importation of Nursery Stock) should be amended to include additional measures against OFV in the *Calanthe* and other schedules (*Anubias*, *Epipremnum*, *Phalaenopsis*) under which orchid genera can be imported.

1.2 Background

Plant Germplasm (ornamental) Imports received a request for the addition of all *Oncidium* spp. and their hybrids to the plants biosecurity index (PBI) and made eligible for importation into New Zealand under the nursery stock import health standard 155.02.06: Importation of Nursery Stock. This request followed non-statutory advice given by the Environmental Protection Agency (EPA) under the application code BER00001, which determined that 'Oncidium species and cultivars' were present in New Zealand, and not new organisms. There are currently 131 *Oncidium* spp. listed in the PBI, as eligible for import under the *Calanthe* schedule in the Import Health Standard 155.02.06: Importation of Nursery Stock. Plant Risk Analysis was asked to determine if there were any pests or pathogens on *Oncidium*, which would require measures additional to those currently specified in the *Calanthe* schedule.

Broad searches of the literature and MPI's emerging risks system (ERS) were carried out to identify new or currently unmanaged pests and diseases on *Oncidium* whole plants, which are not known to be in New Zealand. The virus, *Orchid fleck dichorhavirus* (OFV) was found to be associated with *Oncidium* and determined to be potentially unmanaged by the *Calanthe* schedule. Therefore, a risk assessment for OFV on *Oncidium* was initiated.

However, during the course of the work, it became apparent that OFV can also infect at least 30 other genera of orchids, including some very popular and commonly imported genera such as *Cymbidium* and *Phalaenopsis*. As such, the scope of the assessment was broadened to include other orchid genera. The Plant Germplasm Import team agreed that this approach had added value, as it would inform IHS review to have a single schedule for importation of Orchidaceae, which is being considered. Currently, orchid genera (apart from *Oncidium*) can be imported under either basic requirements, or under *Anubias*, *Epipremnum* and *Phalaenopsis* schedules of the nursery stock IHS. Commodities imported under these schedules, for example *Phalaenopsis*, are often high volume pathways, with single consignments of up to 7000 plants (QuanCargo 2021). Thus, this pest risk assessment is undertaken to determine if OFV constitutes a risk to New Zealand on plants for planting of *Oncidium* and other orchid genera that are eligible for import under existing import requirements.

Under current provisions in the IHS, nursery stock (whole plants, cuttings and tissue culture) of *Oncidium* species and other orchid genera are approved for importation into New Zealand from any country. A phytosanitary certificate is required and, in most cases an import permit is also required. In addition, all cuttings and whole plants of *Oncidium* and other orchid genera must be treated for fungi, insects and mites prior to export and imported into post-entry quarantine level 2 (PEQ L2). Whole plants of *Oncidium* and other genera listed under the *Calanthe* schedule are required to spend a minimum growing and inspection period of 1 year in PEQ L2 and meet the requirements of the "additional declarations" listed in the schedule" in the IHS 155.02.06 (Importation of Nursery Stock). The minimum PEQ growing and inspection period is 3 months for orchid genera imported under the *Anubias*, *Epipremnum* and *Phalaenopsis* schedules. PEQ is not required for tissue culture, which are considered a lower risk for introduction of pests and diseases, given their production methods. They must, however, meet entry conditions for tissue culture in section 2.2.2 of the IHS.

1.3 Scope

The scope of this risk assessment is limited to *Orchid fleck dichorhavirus* (OFV) on the pathway – whole plants of *Oncidium* spp. and other orchid genera listed on the Plant Biosecurity Index (PBI), as eligible for import into New Zealand. Whole plants were chosen for assessment, given they present a higher level of risk for the introduction of OFV than cuttings and tissue culture. Cuttings are easier to inspect and tissue culture are (usually) considered a lower risk commodity due to their production methods. Seeds for sowing and cut flowers and foliage are out of scope.

This risk assessment includes the following:

- Brief notes on the biology and taxonomy of the pest.
- Hazard identification: name and taxonomy of the organism, New Zealand status, commodity association, potential for establishment in New Zealand and potential for impacts in New Zealand.
- Risk assessment: currently known geographic distribution, assessment of entry, transfer/exposure, establishment and spread, and assessment of impacts (economic, environmental, and social/cultural).

1.4 Risk management questions and existing measures

The risk management questions for this PRA are:

- Does *Orchid fleck dichorhavirus* (OFV) meet the requirements to be a regulated pest on plants for planting of *Oncidium* and other orchid genera?
- Does OFV meet the criteria for additional measures on plants for planting of *Oncidium* and other orchid genera?

OFV would meet the criteria for being a regulated quarantine pest if it is not present in New Zealand and has the potential to enter, establish and cause unacceptable impacts in New Zealand[1].

OFV would meet the criteria for additional measures on *Oncidium* and other orchid genera, if existing import requirements are deemed inadequate to prevent entry and establishment of OFV, leading to unacceptable impacts in New Zealand.

This risk assessment considers the likelihood of entry, exposure to a suitable host, establishment and spread, and the potential impacts in New Zealand, of OFV associated with whole plants of *Oncidium* and other orchid genera – given current measures (import requirements) in the nursery stock IHS.

1.5 Summary of conclusions

Orchid fleck dichorhavirus meets the criteria to be a regulated quarantine pest for New Zealand:

- OFV is not known to be present in New Zealand, is associated with *Oncidium* and other orchid genera, and has the potential to enter, establish and cause unacceptable impacts in New Zealand.

OFV may be considered for additional measures on plants for planting of *Oncidium* and other orchid genera, mainly due to potential impacts and the high level of uncertainty around spread and impacts:

[1] Refer to ISPM 5 for the definition of a quarantine pest under the IPPC, and the Biosecurity Act 1993, for factors to consider when defining "harm".

- The likelihood of OFV entering New Zealand associated with plants for planting of *Oncidium* and other orchid genera is low, with low uncertainty.
- The likelihood of exposure/transfer of OFV to host plants in New Zealand is low, but if exposure were to occur, the likelihood of OFV establishing in New Zealand is considered to be moderate-high, with low uncertainty, and the likelihood of spread is low, with high uncertainty.
- The level of economic impact caused by OFV is likely to be low for New Zealand overall, but could be high for the orchid industry and, potentially, the citrus industry, with high uncertainty. Eradication may be possible, especially if the virus establishes within a protected (glasshouse) environment.
- The likelihood of OFV causing social impacts is moderate, with low uncertainty.
- The likelihood of OFV causing environmental impacts is low-moderate, with high uncertainty.
- The likelihood of OFV causing human health impacts is negligible, with low uncertainty

2 *Orchid fleck dichorhavirus* (OFV)

Scientific name: *Orchid fleck dichorhavirus*
Order/Family/Genus: *Mononegavirales/Rhabdoviridae/Dichorhavirus*
Other names: orchid fleck virus, OFV, orchid fleck disease.

2.1 General notes biology and taxonomy

Orchid fleck dichorhavirus (OFV) is the type species of the genus *Dichorhavirus*, and it is recognised as an important viral pathogen that naturally infects commercial orchids, causing localised chlorotic and necrotic lesions. In severe cases, these lesions can result in the decline and death of infected plants (Peng et al. 2013; Kondo et al. 2017).

OFV has the ability to infect taxonomically distant plant hosts; about 75 plant species belonging to 48 genera of 12 families can be infected by OFV and of these, about 50 plant species in 31 genera, all of which are from the Orchidaceae, can be naturally infected (Peng et al. 2013). OFV is persistently transmitted by the false spider mite, *Brevipalpus californicus* (Maeda et al. 1998). The mite is very small (0.2–0.3mm long), globally widespread and has a wide host range; reported to have been collected from 316 wild and cultivated hosts in 67 genera from 33 families (Childers et al. 2003, cited in Vacante 2016). According to Ali (2013) global trade has likely expanded the distribution and host range of *B. californicus*, and this could, potentially, further increase the host range of OFV. Power (2000) notes that expansion in host range by this means has been observed many times before in viruses that are transmitted by insect vectors. Mechanical transmission of OFV has been demonstrated experimentally, via inoculation of sap from infected leaves, to seedlings of *Dendrobium*, tobacco, *Nicotiana glutinosa*, *Chenopodium amaranticolor*, *C. quinoa*, *Petunia hybrida*, *Nicotiana glutinosa*, and four varieties of *N. tabacum*, but only in summer when the temperature in the experimental greenhouse was higher than 30°C (Chang et al. 1976). There are no reports of mechanical transmission OFV via tools during pruning and other cultivation practices.

There are two types (nuclear and cytoplasmic) of Brevipalpus transmitted viruses (BTVs), and OFV is of the nuclear (N) type (Kubo et al 2009). The virus was described originally from chlorotic lesions on *Cymbidium* leaves in Japan, has short, rod-like non-enveloped particles of 32–40 nm diameter and 100–150 nm length, and is found in the nucleus of the plant cell (Chang et al. 1976; Doi et al. 1977; Kondo et al. 2003). Phylogenetic analysis has shown that OFV isolates separate into two subgroups, based on nucleotide sequences of N gene fragments (RNA 1). Subgroup 1 includes most isolates collected from Australia, Germany, South Africa, and the Americas. Subgroup 2 includes only five isolates from Germany, Costa Rica and East Asian countries (Kondo et al. 2017).

According to Kondo et al. (2017), there are two known strains of OFV: the orchid strain of OFV (subgroups 1 and 2), and the citrus strain of OFV. However, more recently, Cook et al. (2019) found the orchid strain of OFV infecting orange (*Citrus sinensis*) in South Africa and causing citrus leprosis symptoms on infected orange trees and fruit; there is more detail on this in Appendix 2. A distinct cytoplasmic (C) type virus causing orchid fleck symptoms was detected by transmission electron microscopy (TEM) in lesion fragments from plants of the orchid genera, *Jumellea* and *Coelogyne* (Kubo et al. 2009). This virus had bacilliform particles 70–80 nm in diameter and 110–120 nm in length, induced electron-dense viroplasm inclusions in infected cells, and resembled the cytoplasmic type of *Brevipalpus* transmitted virus (BTV), such as *Citrus leprosis virus C* (Kubo et al. 2009). Experiments have demonstrated that this cytoplasmic type (C) virus that clearly also infects orchids, is distinct from OFV, which is a nuclear (N) type virus (Kubo et al. 2009).

2.2 Hazard identification: Regulatory status and commodity association

Regulatory status

Orchid fleck dichorhavirus meets the criteria to be a quarantine pest for New Zealand, given that:

Orchid fleck dichorhavirus is not known to be present in New Zealand:

- OFV is not recorded in: Plant Pest Information Network (PPIN 2021), New Zealand Organisms Register (NZOR 2021), or Veerakone et al. (2015).
- Its regulatory status is listed as 'not assessed' in the Official New Zealand Pest Register (ONZPR 2021) and as 'undetermined' in the Biosecurity Risk Analysis Database (BRAD 2021).

Orchid fleck dichorhavirus has the potential to establish and spread in New Zealand:

- OFV is reported from many areas with a very similar climate to the whole of New Zealand, indicated by a Composite Match Index (CMI, a measure of similarity of climates) of ≥0.7 (Phillips et al. 2018). These areas include parts of Australia, Brazil, Japan and USA (Peng et al. 2013).
- The availability of host plants is not likely to be a barrier to establishment, as the host range of OFV includes *Oncidium* and 30 other orchid genera (Peng et al. 2013), many of which are commercially grown in glasshouses in New Zealand for use as houseplants and cut flowers. New Zealand also has 84 species of endemic orchids growing outdoors (NZ flora 2021) that could serve as hosts for OFV. Additionally, orange (*Citrus sinensis*), which is a commercial crop in New Zealand, has been reported to be infected by the orchid strain of OFV in South Africa (Cook et al. 2019).
- OFV is transmitted by the globally widespread false spider mite *Brevipalpus californicus* (Kondo et al. 2003; Peng et al. 2013) which is present in New Zealand (NZOR 2021), and vector transmission, as well as experimental mechanical inoculation of OFV has been shown in 25 species in 11 non-orchid families (Peng et al. 2013).

Orchid fleck dichorhavirus has the potential to cause economic, socio-cultural and environmental impacts to New Zealand:

- OFV has the potential to harm commercial orchids and citrus (oranges) of economic importance to New Zealand, as it causes chlorotic and necrotic leaf lesions which, in severe cases, can result in the decline and death of infected plants (Peng et al. 2013; Kondo et al. 2017).
- OFV has the potential to have social-cultural impacts – orchids are valued as cut flowers, indoor plants in homes and some businesses, and there are strong hobbyist grower groups (e.g. NZ Orchid Society) in New Zealand.
- The reported hosts of OFV are primarily orchid genera, and its vector, *B. californicus*, is present in New Zealand. It is, therefore, possible that the host range of the virus could expand to include some native orchids as well as species in other plant families in New Zealand, which fall within the host range of the vector.

Commodity association

Orchid fleck dichorhavirus is associated with whole plants of *Oncidium* and other orchid genera.

Oncidium and several other orchid genera are reported hosts of *Orchid fleck dichorhavirus*:

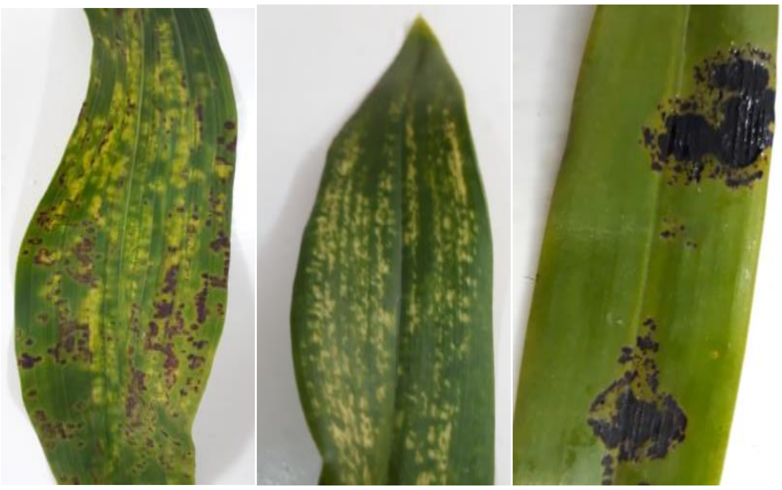
- OFV has been reported from *Oncidium* in Australia, Brazil, Colombia, Costa Rica, Germany, Japan and Korea (Kitajima et al. 2010).
- OFV is reported from 30 other genera of orchid including the very common and popular genera such as *Cattleya*, *Cymbidium*, *Dendrobium* and *Phalaenopsis* and their hybrids

(Bratsch et al. 2021; Peng et al. 2013; Kitajima et al. 2010). See Appendix 1 on page 14 for the currently known [as at March 2021] full host list).

Orchid fleck dichorhavirus can be present in the leaves of infected orchid plants:

- OFV is characterised by the presence of localised chlorotic and necrotic lesions (Figure 1) on the leaves of infected plants (Doi et al. 1977, cited in Kondo et al. 2003).
- OFV has been detected in plants showing these lesions, by electron microscopy (Kondo et al. 2013; Peng et al. 2013) and, using reverse transcription polymerase chain reaction (RT-PCR) (Blanchfield 2001; Ali et al. 2014; 2014; Bratsch et al. 2021).

Aceneta sp. *Brassia* sp. *Dendrochilum* sp.



Lycaste sp. *Oncidium* sp. *Cymbidium* sp.

Figure 1. Symptoms on various orchid species that tested positive for *Orchid fleck dichorhavirus* in South Africa. Photos are from Cook et al. (2019).

2.3 Risk assessment

2.3.1 Likelihood of entry

The likelihood of *Orchid fleck dichorhavirus* entering New Zealand on whole plants of *Oncidium* or other orchids is considered low, with low uncertainty.

Orchid fleck dichorhavirus is associated with 31 genera of orchid, including *Oncidium,* and causes visible lesions on the leaves of infected plants:

- Natural infections of OFV in orchid species are well reported in the literature (e.g. Chang et al 1976; Kondo et al. 2003; Peng et al. 2013; Cook et al 2019).
- OFV is not a systemic virus and causes localised chlorotic and necrotic lesions (Figure 1). And the virus has been reported to cause systemic leaf symptoms in experimentally infected hosts, this only occurred at high temperature (above 30°C) (Chang et al. 1976; Kondo et al. 2003).
- There is a very low likelihood of visibly infected plants being exported to New Zealand, as healthy-looking plants would be selected for export.

OFV is likely to be detected on imported infected plants, given current import requirements for nursery stock of *Oncidium* and other Orchidaceae:

- Visual inspection of plants is likely to detect plants with obvious lesions, but it is noted that symptoms of OFV infection in plants may not become visible until after 2-3 weeks (Kondo et al. 2003). So, should plants become infected just prior to export, they may be asymptomatic, on arrival, although the transport (shipping) duration may be sufficient to allow development of symptoms.
- Alternatively, if a lesion is new, small and in a tight or compacted position between leaves, it may go undetected and be imported into PEQ. However, the minimum period required in Level 2 PEQ for orchid genera (apart from *Oncidium*) is 3 months, and it is expected that any symptoms of OFV from infection prior to importation would be expressed and detected within that timeframe. For *Oncidium*, the minimum PEQ period is 1 year, which makes it even more likely that OFV-infected plants would be detected. Furthermore, there have been no reports of long term asymptomatic OFV infections.
- In addition, whole plants (*Oncidium*, other orchids and all other importable genera) are required to be treated with miticide before arriving in New Zealand or on arrival in PEQ. Therefore, any OFV-infected mites on an imported plant are expected to have been killed.
- However, if any OFV-infected mites were to survive, it is known that they can be difficult to contain or exclude in Level 2 PEQ (pers. comm. R. Lardner), given their small size; the holes in mesh over ventilation openings in Level 2 PEQ are 0.6 mm diameter (MPI 2017), whereas *B. californicus* is 0.2-0.3 mm long and <2 mm in diameter, and can be transported on clothing and equipment (Vacante et al. 2016).
- If viruliferous mites are not detected and escape quarantine, there is potential for OFV to be spread to another host outside of the quarantine.

2.3.2 Transfer (exposure)

Orchid fleck dichorhavirus has a low likelihood of exposure (transfer) from imported plants of *Oncidium* and other orchid genera to host plants in New Zealand

When a pest or pathogen arrives in a new area, it usually needs to find (or come into contact with) a growing host plant in order to establish. The process of a pest or pathogen coming into contact with a growing host plant is termed “exposure” in MPI risk assessments and “transfer” under the IPPC.

- Transfer/exposure of pathogens from nursery stock is usually considered to be highly likely, because imported material is maintained in a habitat favourable for plant growth and is often multiplied up to substantial numbers, which promotes the survival and persistence of both the plant material and associated pathogens, thus making the transfer/exposure of such pathogens highly likely.

However,

- OFV causes localized infections that are visually detectable on the leaf surface of infected hosts within 2-3 weeks (Chang et al, 1976; Kondo et al. 2003), and it is unlikely that an infected plant would be released from PEQ to allow transfer to host plants in New Zealand.
- Therefore, transfer of OFV from imported plants of *Oncidium* and other orchids would be largely dependent upon the presence of the mite vector, *Brevipalpus californicus*, in a PEQ facility where there are undetected OFV-infected plants.
- The vector must either already be in the PEQ facility or enter the facility and feed on OFV lesions on infected plants to acquire the virus. The mite would then need to exit PEQ and feed on other plant species susceptible to OFV.
- While *B. californicus* is small enough to move through ventilation mesh or small gaps and could also be carried on clothing and equipment, the likelihood of the mite entering PEQ, feeding on an OFV-infected plant, then exiting PEQ and landing and feeding on a suitable host, is considered to be low. This is attributed to the fact that *Brevipalpus* spp. have poor natural dispersal abilities and even if passively dispersed by wind, there is no guarantee that they will land on a suitable host, as they have no ability to control where they land (Alves et al. 2005).

Therefore, the likelihood of transfer/exposure for OFV on whole plants of *Oncidium* and other orchid genera is considered to be low, with low uncertainty

2.3.3 Likelihood of establishment and spread

If exposure were to occur, the likelihood of *Orchid fleck dichorhavirus* establishing in New Zealand is considered to be moderate-high, with low uncertainty.

Establishment and spread of *Orchid fleck dichorhavirus* would depend on a combination of several factors: the presence of suitable host plants, the presence of vectors and the suitability of the environment.

The suitability of the New Zealand environment for *Orchid fleck dichorhavirus* to establish is considered to be moderate (outdoors) to high (greenhouses):

- The current global distribution of OFV is shown below in Table 1 and the CMI range for each country/state is given.
- OFV is reported from many areas that have very similar climate conditions to the whole of New Zealand, indicated by a Composite Match Index (CMI, a measure of the similarity between two climates) of ≥0.7 modelled by Phillips et al. (2018). Climate is, therefore, unlikely to limit the establishment of OFV in New Zealand, because the virus is reported from many areas with very similar climates to New Zealand, e.g. southern regions of Brazil, Australia (Tasmania, Victoria, NSW etc.), some provinces of South Africa and areas of the USA (Table 1).
- Some orchid genera that are OFV hosts are often grown in greenhouses worldwide, including New Zealand. Greenhouses with temperature control can extend the geographic range within New Zealand, of the hosts for OFV and, therefore, that of the virus.

Table 1. The geographical distribution of OFV

Region	**Country**	**State/Province** (if recorded)	**Reference**	**CMI range** (Phillips et al 2018)
Africa	South Africa	Eastern Cape	Cook et al. (2019)	**0.7–0.9**
		Mpumalanga		**0.7–0.8**
		North West Province		0.6–**0.7**
Asia	China	Xiamen, Fujian Province	Peng et al. (2017)	0.6
	Japan		Kondo et al. (2003)	0.6–**0.8**
	Korea	Gyeonggi Province	Kim et al. (2010)	0.6
		Chungnam Province		0.6
		Gyeongbuk Province		**0.7**
Europe	Denmark		Kondo et al. (2003)	**0.8–0.9**
	France		Sauvêtre et al. (2018)	**0.9**
	Germany		Kondo et al. (2003)	**0.9**
North America	USA		Bratsch et al. (2015)	0.5–**0.8**
	Mexico	Zihuateutla, Edo. Puebla.	Ortero-Calina et al. (2021)	0.3–**0.8**
Central America	Costa Rica		Freitas-Astúa et al. (2002)	0.3–0.6
South America	Brazil	Paraná	Kubo et al. (2009)	0.6–**0.8**
		Rio Grande do Sul		**0.7–0.9**
		Santa Catarina		**0.7–0.9**
		São Paulo		0.5–**0.7**
	Colombia*		Kitajima & Freitas-Astúa (unpubl. data) in Kubo et al. (2009)	0.3–**0.8**
	Paraguay		Ramos-Gonzalez et al. (2015)	0.5–**0.7**
Oceania	Australia	Australian Capital Territory	Blanchfield et al. (2001)	**0.8–0.9**
		New South Wales		0.6–**0.9**
		Tasmania		**0.9–1.0**
		Victoria		**0.7–0.9**
		Queensland	Dietzgen et al. (2018)	0.4–**0.8**

CMI values of ≥0.7 show very similar climate conditions to the whole of New Zealand (Phillips et al. 2018).

*Ramos-Gonzalez et al. (2015) comment that molecular confirmation for OFV in Colombia hasn't been done, but citrus leprosis virus-N has been sequenced from sweet orange in Colombia (Roy et al. 2014).

Suitable hosts are available for the establishment of OFV in New Zealand

- Of the known orchid hosts (Appendix 1), about 27 are listed in the Plant Biosecurity Index (PBI 2021) as eligible for importation, and many of those orchids are likely to already be in New Zealand; *Cymbidium*, *Dendrobium*, *Oncidium*, *Phalaenopsis* and *Zygopetalum*, for example, are present in New Zealand (personal experience of the author).
- Of the non-orchid hosts listed in Appendix 1, most genera and/or species are present in New Zealand, e.g. *Liriope*, *Alcea*, *Citrus* and *Cordyline* species. Additionally, experimental hosts such as *Amaranthus lividus*, *Chenopodium* species, *Tetragonia tetragonoides* (syn= *T. expansa*, NZ spinach), beetroot, bean, *Petunia* and *Nicotiana* species are present in New Zealand (NZFlora 2021, NZPCN 2021; NZOR 2021).OFV has been reported from oranges (*Citrus sinensis*) in South Africa (Cook et al. 2019), and there are 783 hectares of commercial oranges in the northern parts of the North Island of New Zealand (Citrus New Zealand 2019).

- The full host range of OFV may, to a large extent, be determined by the host range of its mite vector, *B. californicus,* and so there is the possibility of new unidentified hosts.

Brevipalpus californicus, the known vector of *Orchid fleck dichorhavirus*, is present in New Zealand:

- Transmission of OFV by *B. californicus* is known to be persistent and very likely propagative (Kondo et al. 2003; Peng et al. 2013).
- The mite acquires the virus by feeding on infected tissue and the nymphs and adults efficiently transmit OFV even after moulting. Thus, once the virus is acquired, the mite can continue to transmit the virus to the end of its life (Kondo et al. 2003).
- However, the distribution of *B. californicus* within New Zealand is unclear; although for the purpose of this assessment, it is assumed to include most areas of the North Island, given how long the mite has been present in New Zealand – it was first reported from *Cymbidium* sp. in Tauranga, collected by C.S. Rondel on 30 June 1965 (Manson 1967). Its current distribution is unreported and therefore, very uncertain,
- No evidence was found of other mite or insect vectors of OFV.

If *Orchid fleck dichorhavirus* became established, the likelihood of spread is considered to be low, with high uncertainty

Spread may occur via the movement of infected plants, transmission by the mite vector and potentially, mechanical transmission:

- OFV spread within New Zealand is likely to be facilitated through movement of infected plants that are not yet showing symptoms or that have very minor symptoms, which might be misdiagnosed by less experienced growers. However, trade and movement of symptomatic plant material is unlikely.
- Mechanical transmission is thought to perhaps play a minor role in natural infections, although OFV particles are unstable outside the host cell (Wilson 1999 cited in Ali 2013).
- It is unreported (but possible) that mechanical transmission may facilitate plant to plant spread via sap on tools or equipment in a greenhouse within a narrow timeframe. Homogenate of the virus, in sap transmission studies, has been shown to remain infective for 7-8 minutes following homogenisation in summer and about 15 minutes in winter (Inouye et al. 1996 cited in Ali 2013). The experimental homogenate is assumed to be prepared in a pH stable buffer so that the virus infectivity should be much longer than that in the sap on tools.
- Viruliferous *B. californicus* may be moved on plant material, people, animals or by air currents to new hosts and thus facilitate OFV spread.

There is low uncertainty regarding the ability of the virus to survive outdoors in New Zealand conditions, and greenhouses are likely to be highly suitable. However, there is high uncertainty with regard to spread, as there is no up-to-date reporting on the geographical distribution, abundance and host range of the vector, *B. californicus*, in New Zealand.

2.3.4 The impacts in New Zealand

Orchid fleck dichorhavirus is likely to cause low-to-moderate impact to New Zealand, with high uncertainty

Damage and symptoms caused by OFV infection can reduce plant quality and may result in plant destruction, leading to economic losses:

- Chlorotic and necrotic lesions and reddening of leaves diminish the appearance of the orchid plant and consequently can reduce the value and saleability (Bratsch et al 2021).

- OFV reduces the number and quality of flowers and can reduce the fitness of the plant rendering it susceptible to secondary infections from fungal and bacterial pathogens (Bratsch et al 2021).
- There is no cure for OFV and other orchid viruses. Meristem tissue culture has been reported to eliminate viral infection from high value plants, but it is expensive and laborious with variable success rates. Thus, management of disease spread is usually by testing for virus and then removing[2] and destroying the infected plant (Ali 2013). Where multiple plants within a collection, especially a valuable or rare collection, are infected this can have a serious impact upon the grower. For citrus growers, it may mean removal and destruction of infected trees.

Establishment of OFV is likely to increase phytosanitary measures required for orchid exports to countries where OFV is absent or regulated, or potentially where citrus leprosis is absent/regulated:

- OFV is an A1 pest for the European Union (EPPO 2021). French Polynesia, India and Mauritius all have international quarantine regulations for OFV (ONZPR 2021).
- An incursion of OFV in New Zealand could cause impacts due to removal of productive plants, costs of surveillance and loss of income from sales of orchids (and potentially fresh citrus) in domestic and export markets.
- The exports of cut flowers and foliage, seed, bulbs and live plants were worth $164.0 million to New Zealand in 2019. Cut flower exports contributed $20.0 million, of which orchid flowers dominated earning $10.9 million (Plant and Food Research 2019).
- In 2019, export sales of fresh citrus fruit were worth $12 m and the value of domestic orange sales was $58.5 million (Plant and Food Research 2019).
- Containment and eradication of the virus would be possible if incursions are detected early, especially within individual glasshouses. Rate of spread is likely to be slow, as the virus is not systemic under normal growing temperature (<30°C) and transmission is vector dependent (Kondo et al. 2003)

There is a high level of uncertainty associated with economic impacts. The distribution and abundance of the vector, *B. californicus*, within New Zealand is unclear. If the mite is not currently present in citrus orchards this reduces the level of impact. Also, the OFV-orchid strain has only been found in citrus in South Africa (Cook et al. 2019) and it is uncertain whether this strain would necessarily affect citrus in New Zealand.

Environmental impacts from *Orchid fleck dichorhavirus* are likely to be low overall for New Zealand, with high uncertainty

- Environmental impacts are largely dependent on a viruliferous mite vector moving from infected cultivated host plants into native orchids.
- There are residential areas in New Zealand that border nature reserves and regional parks where native orchids occur. A good example is East Harbour Regional Park (Greater Wellington Region) where several species of native and endemic orchid species are found growing on track edges and banks that join with the gardens of residential properties. It is currently unknown if any of these native orchid genera are likely to become hosts of OFV.

There is a high degree of uncertainty associated with environmental impacts. This is because we do not know the current distribution or abundance of the vector, *B. californicus*, within New Zealand, and we do not know what the host plant range for it is in New Zealand.

Social impacts of *Orchid fleck dichorhavirus* are likely to be low to moderate, with moderate-high uncertainty:

- Orchid hobbyists have usually invested a considerable amount of time and money into their collections, especially when growing tropical species that require heated glasshouses. Infected plants would be a significant issue, especially if the mite vector is present and active.

[2] The term often used I for removing damaged/infected plants 'rogueing'.

There is moderate-high uncertainty about this conclusion as there are no readily available figures for the cost of orchid hobby-growing nor for the distribution of the mite vector.

Orchid fleck dichorhavirus is unlikely to cause any direct health impacts on human health:

- OFV is a plant pathogen and has not been reported to affect human or animal health.

2.4 Conclusions regarding risk management question

- *Orchid fleck dichorhavirus virus* (OFV) meets the criteria to be added to the regulated pest list for New Zealand
- Given existing import requirements, the likelihood of entry of OFV on *Oncidium* and other orchid genera into New Zealand on the nursery stock pathway is considered to be low. However, the virus may be considered for additional measures, given that the moderate likelihood of establishment and the high uncertainty around potential impacts, especially as such impacts could be higher than estimated

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Appendix 1

Table 2. Orchid genera and other plants reported as naturally infected by OFV

Family	Scientific name	Reference	Genus on PBI?	Number of species allowed into NZ (Includes synonyms)
Orchidaceae	*Amblostoma* sp.	In: Peng et al. 2013	no	n/a
	Angraecum sp.	In: Peng et al. 2013	yes	25
	A. sesquipedale	In: Peng et al. 2013	yes	yes
	Angulorea sp.	In: Peng et al. 2013	no	n/a
	Baptistonia echinata	In: Peng et al. 2013	yes	yes
	Bulbophyllum sp.	In: Peng et al. 2013	yes	41
	B. elbertii	In: Peng et al. 2013	no	Not listed
	Calanthe sp.	In: Peng et al. 2013	yes	24
	C. bicolor	In: Peng et al. 2013	yes	yes
	C. discolor	In: Peng et al. 2013	yes	yes
	C. hizen	In: Peng et al. 2013	no	Not listed
	C. triplicate	In: Peng et al. 2013	no	Not listed
	C. longicalcorata	In: Peng et al. 2013	no	Not listed
	C. satsuma	In: Peng et al. 2013	no	
	Cattleya sp.	In: Peng et al. 2013	yes	45
	C. aclandii	In: Peng et al. 2013	yes	as 'aclandiae'
	Cymbidium sp.	In: Peng et al. 2013	yes	34
	C. formosanum	In: Peng et al. 2013	no	Not listed
	C. kanran	In: Peng et al. 2013	no	Not listed
	C. sinense	In: Peng et al. 2013	yes	yes
	Cymbidium hybrid	In: Peng et al. 2013	-	-
	Dendrobium sp.	In: Peng et al. 2013	yes	240
Orchidaceae (cont'd)	*Dendrobium* hybrid	In: Peng et al. 2013	-	-
	D. fimbriatum	In: Peng et al. 2013	yes	yes
	D. moschatum	Ramos-Gonzalez et al. 2015	yes	yes
	Dendrochilum sp.	In: Peng et al. 2013	yes	8
	Diplocaulobium sp.	In: Peng et al. 2013	no	n/a
	Encyclia sp.	In: Peng et al. 2013	yes	31
	Epidendron [sic] sp.	In: Peng et al. 2013	no	n/a
	Epidendrum [sic] *veroscriptum*	Ortero-Calina et al 2021	no	n/a
	Hamelwellsara hybrid	In: Peng et al. 2013	no	n/a
	Hormidium calamarium	In: Peng et al. 2013	no	n/a
	Liparis plantaginea	In: Peng et al. 2013	no	n/a
	Maxillaria sp.	In: Peng et al. 2013	yes	19
	M. striata	In: Peng et al. 2013	yes	yes
	Miltonia sp.	In: Peng et al. 2013	yes	15
	M. mourelliana	In: Peng et al. 2013	?	Maybe as mureliana?
	M. rignelli x *mourelliana*	In: Peng et al. 2013	M. rignellii Is.	
	Octomeria sp.	In: Peng et al. 2013	No	
	Odontoglossum sp.	In: Peng et al. 2013	yes	7

Family	Scientific name	Reference	Genus on PBI?	Number of species allowed into NZ (Includes synonyms)
	Odontoglossum hybrid	In: Peng et al. 2013	-	-
	Oncidium sp.	In: Peng et al. 2013	yes	133
	Oncidium x *Odontoglossum*	Kitajima et al. 2010	Not listed	-
	Pescatorea sp.	In: Peng et al. 2013	no	n/a
	Phaius sp.	In: Peng et al. 2013	yes	4
	Phalaenopsis sp.	In: Peng et al. 2013	yes	46
	Pleurothallis sp.	In: Peng et al. 2013	no	n/a
	Prostechea sp.	In: Peng et al. 2013	no	n/a
	Schomburgkia sp.	Kubo et al. 2009	yes	7
	Stanhopea embreii	In: Peng et al. 2013	no	But 13 other species are listed
	Tetragamestus sp.	In: Peng et al. 2013	no	n/a
	Trichopilia sp.	In: Peng et al. 2013	yes	6
	Wilsonara hybrid	In: Peng et al. 2013	no	-
	Zygopetalum sp.	In: Peng et al. 2013	yes	8
Asparagaceae	*Cordyline terminalis* (syn: *C. fruticosa*)	Dietzgen et al. 2018	yes	(seed and NS)
	Liriope spicata	Mei et al. 2016	yes	(seed and NS)
Malvaceae	*Alcea rosea*	Read et al. 2021	yes	(seed-Basic)
Rutaceae	*Citrus sinensis* (cv. navel and cv.Valencia)	Cook et al. 2019	yes	(seed and NS)

Table 3 Non-orchid plants infected by OFV following experimental mechanical inoculation.

Family	Scientific name	Reference
Aizoaceae	*Tetragona expansa* (synonym of *T. tetragonoides*)	In: Peng et al. 2013
Amaranthaceae	*Amaranthus lividus*	In: Peng et al. 2013
Apocynaceae	*Vinca major*	In: Peng et al. 2013
Chenopodiaceae	*Beta vulgaris*	In: Peng et al. 2013
	B. vulgaris var. *cicla*	In: Peng et al. 2013
	Chenopodium amaranticolor	In: Peng et al. 2013
	C. foliosum	In: Peng et al. 2013
	C. murale	In: Peng et al. 2013
	C. quinoa	In: Peng et al. 2013
Compositae	*Lactuca laciniata*	In: Peng et al. 2013
Convolvulaceae	*Pharbitis nil*	In: Peng et al. 2013
Euphorbiaceae	*Acalypha australis*	In: Peng et al. 2013
Leguminosae	*Cassia tora*	In: Peng et al. 2013
	Phaseolus vulgaris	In: Peng et al. 2013
	Vigna sinensis	In: Peng et al. 2013
Malvaceae	*Hibiscus manihot*	In: Peng et al. 2013
	H. syriacus	In: Peng et al. 2013
Rutaceae	*Citrus hassaku*	In: Peng et al. 2013
Solanaceae	*Datura stramonium*	In: Peng et al. 2013
	Nicotiana clevelandii	In: Peng et al. 2013
	N. glutinosa	In: Peng et al. 2013
	N. tabacum ssp.	In: Peng et al. 2013
	Petunia hybrida	In: Peng et al. 2013

Appendix 2

A summary of *Orchid fleck dichorhavirus* -orchid strain, reported from *Citrus sinensis* in South Africa by Cook et al. (2019).

Orchid fleck dichorhavirus (orchid strain) is thought to have been introduced to South Africa in 1995 via imported orchids (Cook et al. 2019). Symptoms resembling those of citrus leprosis (CL) were initially observed in 2018 in Valencia orange ('Delta' and 'Midknight') orchards in the Sundays River Valley region of the Eastern Cape Province. Samples were tested by two step RT-PCR for the presence of viruses associated with CL. Full genome sequences of OFV from citrus and OFV from orchids in South Africa were generated, and showed close sequence identity to each other(99%), which suggested the CL outbreak in the citrus may have come from orchids (Cook et al. 2019).

Consequently, a South African Response plan for CL was developed and a delimiting survey was undertaken around the sites of the original CL find. All orchards with a boundary within 50 m of the infected orchards were surveyed and *Brevipalpus* mites collected and identified. Additionally, various orchid samples exhibiting OFV symptoms (chlorotic or necrotic ringspots or flecks) were obtained from nurseries in Eastern Cape, Mpumalanga, North-West, Gauteng and Limpopo Provinces of South Africa. Twenty-six orchid samples were screened for dichorhaviruses (Cook et al. 2019).

The delimiting survey found a total of 27 CL-infected orange orchards on 5 farms. Four of these farms were in the Sundays River Valley region and the fifth farm was in Gamtoos River Valley -still in Eastern Cape but 96km from the original CL find site. No symptoms of CL were found in mandarins or lemons in adjacent orchards despite *Brevipalpus* mites being present in some of these orchards (Cook et al. 2019). This is quite different to the findings in Mexico where OFV-citrus strains were found in both mandarin and lemon, as well as grapefruit, lime, sour orange and sweet orange (Roy et al. 2020).

Mites collected at the sites showing CL were identified as *Brevipalpus californicus* (Cook et al. 2019), which is the known vector of OFV. Most of the CL-infected orchards identified had sub-standard pest control measures (Cook et al 2019).

The full genome sequence of OFV from an infected *Brassia* sp. orchid (from Mpumalanga) displayed 99% sequence identity to OFV found in citrus in South Africa. Phylogenetic analysis of the complete L-gene showed that the OFV found in both citrus and orchids in South Africa cluster separately from the OFV found in citrus in Mexico and are closely related to isolates from Japan and Korea identified in orchids (Cook et al. 2019).

<u>Conclusion</u>
Citrus leprosis-N[3] symptoms seen in the navel and Valencia oranges in South Africa were associated with the presence of OFV. Full-genome determination showed closest sequence identity to a *Cymbidium* isolate of OFV and not to isolates of OFV previously found in citrus in the Americas. Also, OFV was found in orchids in at least 3 provinces within South Africa. Genome determination of an orchid isolate showed 99% sequence identity to that found in citrus in South Africa. Based on these close identity sequences between the South African OFV genomes in orchid and in citrus, it is likely the CL-N outbreak in citrus originated from orchids (Cook et al. 2019).

[3] The N denotes that the virus responsible replicates in the host cell nucleus.

Figure 2. ‘Delta’ Valencia orange fruit, leaves and twigs infected by OFV and showing citrus leprosis (CL) symptoms. Images are from Cook et al. 2019

Figure 3. ‘Midknight’ Valencia orange twigs and fruit infected by OFV and showing CL symptoms Images are from Cook et al. (2019).