OIA12-015

10 AUG 2012

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Dear Joanne,

OFFICIAL INFORMATION REQUEST

Thank you for your Official Information Request dated the 10th of July 2012 for copies of all emails, memos, phone logs and other documentation relating to requests for a relaxation of the controls for the importation of kiwifruit pollen. This request was clarified by you, by way of email, on 20 July 2012.

The independent report released in July 2012 entitled 'A Review of Import Requirements and Border Processes in Light of the Entry of Psa into New Zealand' explains the history of the requirements for the importation of kiwifruit pollen. As stated in this report and despite imports of kiwifruit pollen being technically possible from at least 1993, the Ministry for Primary Industries (formerly MAF) was only first asked to consider an application for an import permit for kiwifruit pollen in November 2006. The details associated with the development of the import requirements are stated on pages 21 to 35 of this report, and the import permits that were issued, including those who requested these import permits, are stated in Appendix 5. This report is available on the MPI website:
http://www.biosecurity.govt.nz/files/pests/psa/psa-v-review-2012.pdf

MPI suspended all imports of kiwifruit pollen from 13th of November 2010 due to the detection of Psa near Te Puke and concerns raised by industry. Up until this time, the import requirements for imported kiwifruit pollen were based on a MPI review conducted on pollen-transmitted pathogens in 2007 and a subsequent 2007 peer-reviewed journal article (Card *et al.*, 2007). This review identified at the time that there was no evidence of pollen-transmitted bacteria associated with kiwifruit *(Actinidia)* species. Copies of the 2007 MPI review and journal article have been attached for your reference.

With regard to the provision of further information including all emails, memos, phone logs and other documentation, we note that the scope of your request is broad. MPI does hold information relating to your request, however due to the costs involved in obtaining this information, including searching through historical email records, it will be necessary for MPI to impose a charge for the time required in retrieving and considering the relevant material.

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Our current best estimate for the time that this work will take is approximately 10 hours. This amounts to $760, less $76.00 for the first hour which is provided free of charge. The Charging Guidelines are set out by the Ministry of Justice at: http://www.justice.org.nz/publications/global-publications/m/ministry-of-justice-charging-guidelines-for-official-information-act-1982-requests-18-march-2002/official-information-act#3 .

It may be that the information already provided has satisfied the question you were seeking to answer. Please let us know if you wish for us to proceed with obtaining this additional correspondence and documentation.

You have the right under section 28(3) of the Official Information Act to seek an investigation and review by the Ombudsman of our decision to charge for obtaining further information. An application must be made in writing to:

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Plant pathogens transmitted by pollen

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Abstract. Pollen is a valuable source of germplasm for breeding and has few associated pests compared with other sources of genetic material. This review seeks to assist the development of appropriate phytosanitary measures by considering the pests that are transmitted by pollen. There are no invertebrates, bacteria, phytoplasmas or spiroplasmas that are pollen-transmitted. Only a limited number of fungal pathogens are associated with the pollen of a restricted number of hosts. In contrast, 39 viruses are pollen-transmitted and a further six are tentatively considered to be pollen-transmitted. The majority of these viruses belong to the *Alphacryptovirus*, *Ilarvirus*, *Nepovirus* or *Potyvirus* genera. Five viroids have also been identified as being pollen-transmitted.

Additional keywords: biosecurity, seed.

Introduction

Pollination is a vital process in the reproduction of most spermatophytes and requires the transfer of pollen (male gamete) to the plant carpel, which contains the ovule (female gamete) in order that fertilisation can occur. When the pollen is mature, the anthers open and the pollen grains escape. This process is termed anthesis. The period of time over which pollen is released depends on the plant species, and can last from a few hours to several weeks (Jackson 1999). Many plant species require a vector for successful pollination, such as insects, birds or bats, whereas some species rely on abiotic factors such as wind, and in a few instances, water. Pollination is of particular importance in horticulture as the fruits of most plants will not develop unless the ovules are fertilised.

As plants and plant pathogens have co-evolved, the latter have developed mechanisms of transmission, which are frequently correlated with their taxonomy. For example, many fungi have developed spores for their dissemination and these are dispersed by water, air currents or animals. The germinating fungus can then enter the plant directly or via openings such as wounds or stomata. Bacteria commonly rely on water splash, which is often aided by air currents or insects. Bacteria are usually unable to penetrate new hosts directly and rely on natural openings and wounds to gain entry to the plant intercellular spaces. Plant viruses are also unable to enter their hosts directly and commonly rely on specific vectors, including insects, mites, nematodes and fungi to enable infection. A few viroids have specific vectors but are most commonly disseminated by human activities such as the propagation of planting material. Some viruses and viroids have also evolved mechanisms that exploit the plants' own reproductive processes and can be transmitted by seed and/or pollen (Mink 1993; Johansen *et al.* 1994; Hull 2004*b*).

Pollen is a valuable source of germplasm for breeding purposes. From a biosecurity perspective, pollen has relatively few pests associated with it, compared with those that affect plants and seeds. Signatories to the International Plant Protection Convention set phytosanitary measures based on an assessment of the risks to plant health, in accordance with the International Standard for Phytosanitary Measures No. 02 (1995) 'Guidelines for Pest Risk Analysis' (Anonymous 2006). This standard defines plant pests as 'any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products'. For a plant commodity, such as pollen imported for breeding purposes, pest risk analysis involves assessing and managing pest risk. Pest risk assessment determines whether the pests associated with the commodity are regulated, characterised in terms of likelihood of entry, establishment, spread and economic importance. Pest risk management involves developing, evaluating, comparing and selecting options for reducing the risk to achieve the appropriate level of phytosanitary protection. This review seeks to assist countries develop appropriate phytosanitary measures by considering the pests that are transmitted by pollen.

Transmission of invertebrates, bacteria, phytoplasmas, spiroplasmas and fungi

There are no reports of arthropods, nematodes or insects being transmitted by pollen at any stage of their lifecycles. However, many insects are vectors for plant viruses and some may contaminate pollen with viruses when feeding, e.g. thrips, pollen beetles and honey bees (Brunt *et al.* 1996).

There are no pollen-transmitted bacteria, phytoplasmas or spiroplasmas, but there are a few reports of fungi associated with pollen, most of which involve saprophytic species on

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a restricted number of plant species. In studies on plant pathogenic fungi, Stelfox *et al.* (1978) reported that pollen of rapeseed (*Brassica* sp.) heavily contaminated with *Sclerotinia sclerotiorum* ascospores was carried by honey bees to healthy plants causing head blight. Huang (2003) observed that *Verticillium albo-atrum*, which causes wilt of alfalfa (*Medicago sativa*), can be spread by pollen and insect vectors. The only other reports of pollen-associated fungi are observations of pollen contaminated by saprophytic species and are not concerned with transmission (Spiewak *et al.* 1996).

Transmission of viruses and viroids

Process of transmission

When a virus or viroid is transmitted by pollen, it may infect the plant through the fertilised flower (horizontal transmission), or more commonly, it may infect the seed and thus the seedling that will grow from that seed (vertical transmission) (Hull 2004*b*). However, even if a virus or viroid is observed in or on pollen grains, or replicates in pollen grains, it cannot be assumed that the pathogen is naturally pollen-transmitted (Mink 1993). For example, *Tobacco mosaic virus* (TMV) can be detected in pollen but is not pollen-transmitted (Brunt *et al.* 1996). Similarly, it cannot be assumed that if a virus or viroid is transmitted horizontally by pollen there will also be vertical transmission, or *vice versa*. For example, the virus may be unable to infect the developing embryo or may cause sterility of the ovule.

Pollen and seed transmission are closely related (Mink 1993; Hull 2004*b*); pollen-transmitted viruses are generally also transmitted by seed but not necessarily *vice versa*, e.g. *Broad bean stain virus* is seed-transmitted but not pollen-transmitted (Brunt *et al.* 1996). Considerably more research has focused on seed transmission because seed is an important means of virus dissemination for several economically important vegetable and fruit crops (Mink 1993).

The mechanisms by which viruses and viroids are transmitted in seed and pollen are closely related. Seed transmission occurs either through contamination of the seed surface or maternally derived seed parts (e.g. TMV) or, more commonly, through infection of the embryo. The embryo may become infected either directly during embryogenesis or indirectly via infection of the reproductive tissues (i.e. ovule, megaspore mother cell or pollen mother cell) before embryogenesis (Johansen *et al.* 1994).

Infection of the pollen mother cell and resultant pollen leads indirectly to embryo infection (vertical transmission). Evidence for vertical transmission by pollen has come from studies on the ultrastructure of infected plants. For example, Gaspar *et al.* (1984) found particles of *Tobacco rattle virus* in premeiotic pollen mother cells and subsequently in pollen of infected tomato plants.

Horizontal transmission of viruses and viroids by pollen requires movement of the virus or viroid from the infected embryo to the maternal tissues, i.e. movement in the reverse direction to that which occurs during direct infection of the seed. The embryo is separated physically from the mother plant by a callose layer and, therefore, a mechanism is required to enable the virus or viroid to move without direct vascular connection or cellular contact. Horizontal transmission by pollen is less common than vertical transmission and has been suggested in only a few instances, e.g. *Alfalfa mosaic virus* (Hemmati and McLean 1977) and *Tobacco streak virus* (TSV) (Sdoodee and Teakle 1988). Although evidence of direct infection of the embryo has been reported (Wang and Maule 1992), the evidence for movement of viruses or viroids from an infected embryo into maternal tissues is more controversial. Mink (1993) has cast some doubt on the occurrence of unassisted horizontal pollen transmission, for example Sdoodee and Teakle (1987, 1988, 1993) demonstrated that thrips were required for consistent horizontal transmission of TSV via infected pollen. However, other viruses are reported to be transmitted horizontally by pollen without the aid of vectors, e.g. *Blueberry leaf mottle virus* (BLMoV) (Childress and Ramsdell 1986; Boylan-Pett *et al.* 1991) and *Raspberry bushy dwarf virus* (RBDV) (Murant *et al.* 1974). It has been proposed that the contact point between the testa and suspensor may be the point of entry for direct embryo infection and this may also enable outward movement of the virus (Wang and Maule 1992; Roberts *et al.* 2003).

The efficacy with which viruses or viroids are transmitted by pollen is determined by a range of factors including the species or strain of the pathogen, the species or cultivar of the host, the growth stage when infection occurs, and to a lesser extent, environmental conditions such as temperature and moisture (Bos 1983; Mink 1993). For example, Inouye (1962) (cited by Carroll and Mayhew 1976) found up to 35% seed transmission of *Barley stripe mosaic virus* in a highly susceptible barley cultivar after emasculated virus-free plants were pollinated with pollen from infected plants. However, in *Hordeum vulgare* 'Atlas' the M1-1 strain was seed- and pollen-transmitted but the NSP strain was neither (Carroll and Mayhew 1976). *Pea seed-borne mosaic virus* was reported to be pollen-transmitted at a rate of 4.2% in *Pisum sativum* 'Dual' (Kohnen 1992, cited by Johansen *et al.* 1994) but not in *P. sativum* 'Vedette' (Wang and Maule 1992).

The quantity and/or quality of pollen produced by virus- or viroid-infected plants may be reduced compared with healthy plants. For example, *Tobacco ringspot virus*-infected soybean produced less pollen, which had impaired germination rates and grew more slowly than virus free plants (Yang and Hamilton 1974). With the exception of self-pollinated plants, infected pollen must compete with healthy pollen, which may explain why some viruses and viroids are seed-transmitted but not pollen-transmitted. However, pollen transmission is epidemiologically important for some viruses, e.g. Bristow and Martin (1999) concluded that pollen transmission can be a primary means of transmission for *Blueberry shock virus* (BlShV). In *Rubus idaeus* 'Lloyd George', Murant *et al.* (1974) concluded that pollen was the only method of field transmission of RBDV; in plots containing infected plants, healthy plants that were prevented from flowering for 3 years did not become infected but the majority of those that were allowed to flower became infected within 2 years. It is likely that pollen transmission is more important in cross-pollinated woody perennials than in annual crops (Hull 2004*b*).

Viruses transmitted by pollen

Mink (1993) listed nine viruses that were pollen-transmitted: *Artichoke yellow ringspot virus*, BLMoV, BlShV, *Cherry leaf*

Table 1. Pollen-transmitted viruses

Genus	Species	Transmission	Principal hosts[A]	References
Alphacryptovirus	*Alfalfa cryptic virus 1*	Vertical	*Medicago sativa*	Brunt *et al.* (1996)
	Beet cryptic virus 1	Vertical	*Beta vulgaris*	Kassanis *et al.* (1978); Brunt *et al.* (1996)
	Beet cryptic virus 2	Vertical	*Beta vulgaris*	Kassanis *et al.* (1978); Brunt *et al.* (1996)
	Radish yellow edge virus	Vertical	*Raphanus sativus*	Boccardo *et al.* (1987)
	Red pepper cryptic virus 1	Vertical	*Capsicum annuum*	Arancibia *et al.* (1995)
	Ryegrass cryptic virus	Vertical	*Lolium multiflorum*	Boccardo *et al.* (1987)
	Vicia cryptic virus	Vertical	*Vicia faba*	Kenten *et al.* (1980)
Alfamovirus	*Alfalfa mosaic virus*	Horizontal and vertical	*Lactuca* spp., *Medicago* spp., *Solanum* spp., *Trifolium* spp.	Frosheiser (1974); Hemmati and McLean (1977); Pesic *et al.* (1988); Zitter (1991); Valkonen *et al.* (1992)
Badnavirus	*Kalanchoe top-spotting virus*	Vertical	*Kalanchoe blossfeldiana*	Hearon and Locke (1984)
Comovirus	*Cowpea severe mosaic virus*	Vertical	*Vigna unguiculata*	Brunt *et al.* (1996)
Cucumovirus	*Cucumber mosaic virus*	Vertical	*Spinacia oleracea*	Yang *et al.* (1997)
Hordeivirus	*Barley stripe mosaic virus*	Horizontal and vertical	*Hordeum vulgare*	Gold *et al.* (1954); Carroll and Mayhew (1976); Brlansky *et al.* (1986)
Idaeovirus	*Raspberry bushy dwarf virus*	Horizontal and vertical	*Rubus* spp.	Murant *et al.* (1974); Converse (1991); MacLeod *et al.* (2004)
Ilarvirus	*Asparagus virus 2*	Horizontal and vertical	*Asparagus officinalis*	Evans and Stephens (1988); Brunt *et al.* (1996)
	Blueberry shock virus	Horizontal and vertical	*Vaccinium corymbosum*	Bristow and Martin (1999)
	Fragaria chiloensis latent virus	Horizontal and vertical	*Fragaria* spp.	Martin and Tzanetakis (2006)
	Prune dwarf virus	Horizontal and vertical	*Prunus* spp.	Williams *et al.* (1963); Gilmer (1965); Brunt *et al.* (1996); Silva *et al.* (2003)
	Prunus necrotic ringspot virus	Horizontal and vertical	*Cucurbita maxima*, *Humulus* spp., *Prunus* spp., *Rosa* spp.	Das *et al.* (1961); Williams *et al.* (1962); Cole *et al.* (1982); Mink (1998); Aparicio *et al.* (1999); Milne and Walter (2003)
	Spinach latent virus	Horizontal and vertical	*Spinacia oleracea*	Stefenac and Wrischer (1983) [cited by Brunt *et al.* (1996)]
	Tobacco streak virus	Horizontal and vertical	*Cucumis* spp., *Lycopersicon esculentum*, *Fragaria* spp., *Phaseolus* spp., *Rubus* spp., *Trifolium* spp.	Converse and Lister (1969); Sdoodee and Teakle (1987, 1988, 1993); Greber *et al.* (1991); Walter *et al.* (1992); Klose *et al.* (1996)
Nepovirus	Arracacha virus B	Vertical	*Oxalis* spp., *Solanum tuberosum*	Jones (1982)
	Artichoke yellow ringspot virus	Horizontal and vertical	*Datura stramonium*, *Nicotiana* spp., *Petunia hybrida*	Kyriakopoulou *et al.* (1985); Brunt *et al.* (1996)
	Blueberry leaf mottle virus	Horizontal and vertical	*Vaccinium corymbosum*	Childress and Ramsdell (1986, 1987); Boylan-Pett *et al.* (1991)
	Cherry leaf roll virus	Horizontal and vertical	*Betula* spp., *Juglans* spp., *Prunus* spp., *Rubus* spp.	Callahan (1957); Mircetich *et al.* (1982); Cooper *et al.* (1984); Massalski *et al.* (1988); Rebenstorf *et al.* (2006)
	Lucerne Australian latent virus	Vertical	*Medicago sativa*, *Chenopodium quinoa*	Blackstock (1978)
	Raspberry ringspot virus	Vertical	*Fragaria* spp., *Narcissus* spp., *Ribes* spp., *Rubus* spp.	Lister and Murant (1967); Brunt *et al.* (1996)
	Tobacco ringspot virus	Vertical	*Cucumis* spp., *Glycine max*, *Solanum* spp., *Vaccinium* spp.	Yang and Hamilton (1974); Brunt *et al.* (1996)
	Tomato black ring virus	Horizontal and vertical	*Fragaria* spp., *Rubus* spp., *Solanum* spp., *Vitis* spp.	Lister and Murant (1967)

(*Continued next page*)

Table 1. (*continued*)

Genus	Species	Transmission	Principal hosts[A]	References
	Tomato ringspot virus	Horizontal and vertical	*Pelargonium* spp., *Rubus* spp., *Prunus* spp., *Vaccinium* spp.	Scarborough and Smith (1977); Brunt *et al.* (1996)
Nucleorhabdovirus	Pittosporum vein yellowing virus (syn. *Eggplant mottled dwarf virus*)	Vertical	*Pittosporum tobira*	Brunt *et al.* (1996)
Potyvirus	*Bean common mosaic virus*	Vertical	*Phaseolus* spp.	Medina and Grogan (1961); Bos (1983); Brunt *et al.* (1996)
	Lettuce mosaic virus	Vertical	*Lactuca sativa*	Ryder (1964); Brunt *et al.* (1996)
	Pea seed-borne mosaic virus	Vertical	*Pisum sativum*	Kohnen (1992) [cited by Johansen *et al.* (1994)]
	Soybean mosaic virus	Horizontal and vertical	*Glycine max*	Bos (1983); Brunt *et al.* (1996)
	Sugarcane mosaic virus	Vertical	*Zea mays*	Li *et al.* (2007)
Sobemovirus	*Sowbane mosaic virus*	Horizontal and vertical	*Chenopodium* spp., *Prunus* spp., *Vitis* spp.	Francki and Miles (1985); Hardy and Teakle (1992)
Tobravirus	*Tobacco rattle virus*	Vertical	*Lycopersicon esculentum*	Gaspar *et al.* (1984)
Trichovirus	*Potato virus T*	Vertical	*Solanum* spp.	Jones (1982); Slack (2001)
Unassigned	Pelargonium zonate spot virus	Vertical	*Chrysanthemum* spp., *Pelargonium zonale*	Brunt *et al.* (1996); Gallitelli *et al.* (2005)

[A]Hosts in which transmission by pollen has been reported are underlined.

roll virus, *Prune dwarf virus* (PDV), *Prunus necrotic ringspot virus*, *Sowbane mosaic virus*, RBDV and TSV. Subsequently, 30 other viruses have been reported to be pollen-transmitted (Table 1). A further six viruses have been tentatively reported to be pollen-transmitted but the evidence is controversial or inconclusive (Table 2). These 45 viruses belong to 16 groups (15 genera and one unassigned species), the majority being in the *Alphacryptovirus* (at least seven species), *Ilarvirus* (10 species including three which are tentatively pollen-transmitted), *Nepovirus* (nine species) or *Potyvirus* genera (five species).

Of particular interest among the pollen-transmitted viruses are those of the genus *Alphacryptovirus*. This genus is unusual in that its members are only transmitted through seed or pollen and not by vectors or mechanical means. They are unable to move between cells in the host, spreading only via multiplying cells (Brunt *et al.* 1996). Of the 26 definite or tentative species in the genus, seven have been reported to be transmitted vertically by pollen. It is likely that most, if not all, of the other 16 species will be found to be transmitted in this way. Hosts infected with viruses from this genus are usually asymptomatic and members of the genus appear to be of little or no economic importance (Mink 1993; Brunt *et al.* 1996). The members of the genus *Betacryptovirus* share many characteristics with those in the *Alphacryptovirus* but although they are seed-transmitted, pollen transmission has not been reported.

In addition to the viruses described in the preceding two paragraphs, at least 16 other viruses have been detected in pollen and have either been demonstrated not to be pollen-transmitted [*Andean potato latent virus* (Jones 1982), *Onion yellow dwarf virus* (Louie and Lorbeer 1966), *Potato black ringspot virus* (Jones 1982), Potato yellowing virus (Valkonen *et al.* 1992) and *Tomato bushy stunt virus* (Allen and Davidson 1967; Brunt *et al.* 1996)] or pollen transmission was not reported

Table 2. **Viruses that are reported to be pollen-transmitted but for which the evidence for transmission is inconclusive**

Genus	Species	Transmission	Principal hosts[A]	References
Badnavirus	*Taro bacilliform virus*	Possibly vertical	*Colocasia* spp.	Macanawai *et al.* (2005)
Ilarvirus	*American plum line pattern virus*	Possibly vertical	*Prunus* spp.	Mink (1998)
	Apple mosaic virus	Possibly horizontal and possibly vertical	*Corylus avellana*, *Humulus* spp., *Malus* spp.	Mink (1998); Aramburu and Rovira (2000); Pethybridge *et al.* (2002)
	Humulus japonicus latent virus	Possibly vertical	*Humulus* spp.	Adams *et al.* (1989)
Sadwavirus	*Strawberry latent ringspot virus*	Possibly vertical	*Fragaria* spp., *Prunus* spp., *Ribes* spp., *Vitis* spp.	Martin and Tzanetakis (2006)
Sobemovirus	*Southern bean mosaic virus*	Possibly horizontal and possibly vertical	*Phaseolus* spp., *Vigna* spp.	Hamilton *et al.* (1977); Brunt *et al.* (1996); Hull (2004*a*)

[A]Hosts in which transmission by pollen has been tentatively reported are underlined.

Table 3. Pollen-transmitted viroids

Genus	Scientific name	Transmission	Principal hosts[A]	References
Avsunviroid	*Avocado sunblotch viroid*	Vertical	*Persea americana*	Desjardins *et al.* (1979, 1984)
Cocadviroid	*Coconut cadang-cadang viroid*	Vertical	*Areca* spp., *Chrysalidocarpus* spp., *Cocus* spp., *Corypha* spp., *Elaeis* spp., *Phoenix* spp., *Roystonia* spp., *Veitchia* spp.	Pacumbaba *et al.* (1994); Hadidi *et al.* (2003)
Hostuviroid	*Hop stunt viroid*	Horizontal and vertical	*Humulus* spp., *Lycopersicon esculentum*	Kryczynski *et al.* (1988)
Pospiviroid	*Chrysanthemum stunt viroid*	Horizontal and vertical	*Lycopersicon esculentum*	Kryczynski *et al.* (1988)
	Potato spindle tuber viroid	Horizontal and vertical	*Lycopersicon esculentum*	Fernow *et al.* (1970); Kryczynski *et al.* (1988); Hadidi *et al.* (2003)

[A]Hosts in which transmission by pollen has been reported are underlined.

and has not been observed in other studies [*Cherry rasp leaf virus* (Wagnon *et al.* 1968), *Cowpea aphid-borne mosaic virus* (Tsuchizaki *et al.* 1970), *Cucumber green mottle mosaic virus* (Hollings *et al.* 1975), *Dahlia mosaic virus* (Pahalawatta *et al.* 2007), *Elm mottle virus* (Schmelzer 1969), *Grapevine fanleaf virus* (Cory and Hewitt 1968), Maize white line mosaic virus (Louie *et al.* 1982), *Pelargonium flower break virus* (Krczal *et al.* 1995), *Pepper ringspot virus* (Camargo *et al.* 1969), TMV (Brunt *et al.* 1996) and *Turnip yellow mosaic virus* (Brunt *et al.* 1996; de Assis and Sherwood 2000)].

There are also several viruses, which have either been erroneously reported to be pollen-transmitted, e.g. *Poplar mosaic virus* (Brunt *et al.* 1996), or for which subsequent work has refuted earlier inconclusive reports, e.g. Strawberry pallidosis-associated virus (Martin and Tzanetakis 2006; Tzanetakis *et al.* 2006).

Viroids transmitted by pollen

Five viroids in four genera are pollen-transmitted in one or more plant species (Table 3). These viroids have been detected in pollen and in three cases can be transmitted horizontally as well as vertically, although horizontal transmission has not been demonstrated in the field (Mink 1993). In addition, *Coconut tijanga viroid* has been detected in pollen of *Cocus nucifera* but transmission has not been demonstrated (Hadidi *et al.* 2003). *Tomato apical stunt viroid* has been reported to be spread by bumble bees during pollination but it is not clear whether this results from wounding of the flowers by the insects or pollen transmission of the viroid (Antignus *et al.* 2007).

Conclusions

Compared with alternative sources of genetic material such as seeds or plants, pollen is affected by few pests. Therefore, it constitutes a relatively safe medium in which to move genetic material internationally or for use in breeding programs. As described here, there are no invertebrates, bacteria, phytoplasmas or spiroplasmas that are pollen-transmitted and only a limited number of fungi are associated with pollen. In contrast, 39 viruses and five viroids are pollen-transmitted and a further six viruses are tentatively considered to be pollen-transmitted. This represents less than 5% of the known plant viruses and 17% of plant viroids. However, pollen can harbour several important pests, such as PDV and *Potato spindle tuber viroid*, and depending on its source, it may pose a serious risk to plant health. Therefore, although in general pollen poses little biosecurity risk, for particular plant species it is important that appropriate measures are taken when moving pollen between areas with differing phytosanitary status. This review lists the pests (defined as 'any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products') that are pollen-transmitted to assist countries in developing the phytosanitary measures that are required.

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POLLEN-TRANSMITTED PLANT PATHOGENS

CONTENTS

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1.0 EXECUTIVE SUMMARY

Pollen is a valuable source of germplasm for breeding and from a biosecurity perspective has relatively few pests and diseases associated with it compared to other types of genetic resource. The purpose of this review is to assist the risk analysis process by identifying the pests and diseases that are transmitted by pollen. There are a limited number of reports on the association of fungi with pollen, most of which involve saprophytic species on a restricted number of plant hosts and there are no known bacteria, mollicutes or invertebrates that use pollen as a form of transmission. In contrast, 39 viruses are pollen-transmitted and a further 6 are tentatively considered to be pollen-transmitted. The majority of these viruses belong to the *Alphacryptovirus*, *Ilarvirus*, *Nepovirus* or *Potyvirus* genera. Five viroids have also been identified as being pollen-transmitted. Only a limited number of pathogens are associated with the plant genera that are most likely to be imported as pollen into New Zealand (*Actinidia*, *Malus*, *Pyrus*, *Ribes*, *Rubus* and *Vaccinium* species) and these are listed in section 3.

2.0 INTRODUCTION

Pollination is a vital process in the reproduction of most seed plants and requires the transfer of pollen grains (the male gametes) to the plant carpel (which contains the ovule or female gamete) for fertilisation (Plough, 2000). When the pollen is mature, the anthers open and the pollen grains escape, this process is termed anthesis or blossoming. The pollen is then released over a period of time that is specific to each plant species, and can last from a few hours to several weeks (Jackson, 1999). Most plant species require a vector for successful pollination, such as insects, birds and bats and some plant species rely on abiotic factors such as wind, and in a few instances water. Pollination is of particular importance in horticulture as the fruits of most plants will not develop unless the ovules are fertilised.

There has been a constant co-evolution between plants and their pathogens. These pathogens have evolved mechanisms for their transmission and frequently these mechanisms are correlated to their taxonomy. For example, fungi have developed spores for their dissemination and these are dispersed by water, air currents or animals. The germinating fungus can then enter the plant directly or via openings such as wounds or stomata. Bacteria commonly rely on air currents/splash dispersal, water and insects for the dissemination of their cells and are usually unable to access their new host directly and rely on natural openings and wounds. Plant viruses and viroids are also unable to enter their hosts directly and each species commonly relies on specific vectors to enable host plant entry. Vectors can include fungi, insects, mites, nematodes and parasitic weeds. However, some viruses and viroids have evolved mechanisms that exploit the plants own reproductive processes and can be transmitted from plant-plant via seed and/or pollen.

Signatories to the International Plant Protection Convention set phytosanitary measures based on an assessment of the risks to plant health, in accordance with the International Standard for Phytosanitary Measures No. 02 (1995) "Guidelines for Pest Risk Analysis".

For a plant commodity, such as pollen imported for breeding purposes, pest risk analysis consists of assessing and managing pest risk. Pest risk assessment determines whether the pests associated with the commodity is a quarantine (regulated) pest, characterized in terms of likelihood of entry, establishment, spread and economic importance. Pest risk management involves developing, evaluating, comparing and selecting options for reducing the risk to achieve the appropriate level of phytosanitary protection.

New Zealand has developed pest risk analyses for plant commodities from which specific import requirements for plants and plant products have been developed. This includes pollen imported for breeding purposes although the import requirements have yet to be formalised. Pollen is a valuable source of germplasm for breeding purposes. From a biosecurity perspective pollen has relatively few pests and diseases associated with it, these being a sub-set of those pathogens which affect plants for planting and seed.

The purpose of this review is to assist the risk analysis process by identifying the pests and diseases that are transmitted by pollen. In considering whether a pest or disease is transmitted by pollen the following criteria were considered during the review:

- association with pollen; and
- transmission via pollen to the mother plant during pollination and/or to the seed following fertilisation; and
- whether observations had been made *in vivo* or from experimental studies; and
- the existence of contradictory reports; and
- the quality of the evidence presented.

2.1 POLLEN TRANSMISSION

2.1.1 INVERTEBRATES

There are no reports of arthropods, nematodes or insects being transmitted by pollen at any stage of their lifecycles. However, many insects serve as vectors for plant viruses and can carry particles onto pollen when feeding, for example: thrips, pollen beetles and honey bees.

2.1.2 BACTERIA, MOLLICUTES AND FUNGI

There are no known bacteria or mollicutes (including phytoplasmas and spiroplasmas) that are pollen transmitted (Nemeth, 1986). There are a limited number of reports on the association of fungi with pollen, most of which involve saprophytic species on a restricted number of plant hosts. Examples involving plant pathogenic fungi include: (i) pollen grains of rapeseed (*Brassica* spp.) were found to be heavily contaminated with ascospores of *Sclerotinia sclerotiorum* (Stelfox *et al.*, 1978), which were found to be transported by honey bee vectors to healthy plants resulting in head blight of rapeseed and (ii) *Verticillium albo-atrum*, which causes wilt of alfalfa (*Medicago sativa*), which is also known to be spread by pollen and insect vectors (Huang, 2003). The severe strain of *V. albo-atrum* is regulated in New Zealand, but the hop and lucerne strains are not regulated.

The only other reports in the literature that associate pollen and fungi are not concerned with mechanisms of transmission but observations of pollen contamination by saprophytic species, for example Spiewak *et al.* (1996).

2.1.3 GENERAL DISCUSSION ON TRANSMISSION OF VIRUSES AND VIROIDS

Pollen transmission of viruses is closely related to seed transmission (Mink, 1993) and therefore it is necessary to first discuss seed transmission before considering the transmission of viruses and viroids by pollen. Although many viruses that are seed transmitted are also transmitted by pollen (Hull, 2004b) considerably more work has focused on seed transmission because seed is an important pathway for virus dissemination in several economically important vegetable crops and fruit trees (Nemeth, 1986; Mink, 1993).

There are two mechanisms by which viruses can be seed transmitted: either directly through the mother plant or through the pollen. These routes lead to seed transmission through the plant embryo. However, as embryos are physically separated from their mother plant tissues by a callose layer, they lack direct vascular connection and cellular contact with the mother plant (Bos, 1983); this prevents the cell-cell movement of viruses. Consequently, for a virus to infect the mother plant tissues during or after fertilisation, a mechanism must be proposed whereby the virus can escape this constraint (Mink, 1993). Embryo infection therefore requires mother plant infection before the production of gametes or at least before the cytoplasmic separation of embryonic tissue from the mother plant. Male gametes or pollen may become infected and lead to embryo infection (Bos, 1983). However, the presence of a virus in a seed, even in the embryo, does not always lead to seedling infection (de Assis & Sherwood, 2000). Seed transmissibility starting in the ovule of the mother plant depends upon the ability of a virus to infect floral parts early in development. Infection after flowering does not usually lead to virus transmission through seed or the pollen (Bos, 1983). Whether seed transmission occurs and what proportion of the seed is infected is governed by the host-virus interaction (including the pathogenicity of the virus strain and the susceptibility of the host cultivar), the timing of the infection and the prevalent environmental conditions (Bos, 1983; Lawson *et al.*, 1995). Seed transmission rates can vary from a fraction of a percent to nearly 100% in some host-virus combinations, although it rarely exceeds 50% (Lawson *et al.*, 1995), and is often much lower.

The majority of seed-transmitted viruses are carried within the embryo, although there are exceptions; for example, *Tobacco mosaic virus* (TMV) which is a contaminant on the seed surface. The virus is sometimes found in the endosperm, where it may persist for many years (Hull, 2004b), but not in the embryo (Brunt *et al.*, 1996). TMV is a highly stable virus and can withstand desiccation, thereby easily surviving the time it takes for the seed coat to mature. The virus infects seedlings during germination and early growth (Mink, 1993; Lawson *et al.*, 1995) and therefore this type of seed transmission is largely due to contamination by mechanical means. Other viruses within the genus *Tobamovirus* may also be transmitted through the seed in the same manner as TMV. These include *Tomato mosaic virus* (ToMV) (Hollings & Huttinga, 1976), *Cucumber green mottle mosaic virus* (CGMMV) (Hollings *et al.*, 1975) and *Pepper mild mottle virus* (PMMoV) (Wetter & Conti, 1988).

2.1.3.1 VIRUSES

When a virus is transmitted by pollen, it may infect the seed and the seedling that will grow from that seed (termed vertical transmission), or it may infect the plant through the fertilized flower (termed horizontal transmission) (Hull, 2004b). However, just because virus particles are observed in or on pollen grains, or are found to replicate in pollen grains, it cannot be assumed that the virus is naturally transmitted by pollen. Similarly it cannot be assumed that if a virus is transmitted horizontally by pollen there will also be vertical transmission.

Viruses that are pollen or seed transmitted have now been identified in 16 virus genera. The majority of the known pollen-borne viruses are found in the *Ilarvirus* and *Nepovirus* genera. Ilarviruses are economically important and widespread in fruit trees. They are generally host specific and may be transferred from host to host via pollen (Cooper, 1993). Nepoviruses have a wide host range, and their main method of dispersal is via nematode vectors. However, some nepoviruses, such as *Raspberry ringspot virus* (RpRSV), can be transmitted through pollen and seed (Cooper, 1993).

Experimental work has shown that pollen transmission of viruses may be strain specific and/or host specific and also change in frequency according to a range of abiotic factors, such as temperature and moisture at the time of infection and also the time of year. For example, Inouye in 1962 (cited by Carroll & Mayhew, 1976) found up to 35% seed transmission of *Barley stripe mosaic virus* (BSMV) in a highly susceptible barley cultivar after emasculated virus-free plants were pollinated with pollen from infected plants. However, when two strains of BSMV infecting cultivars of 'Atlas' barley were compared, it was found that strain NSP was not seed or pollen transmitted, while strain M1-1 was.

It is important to note that although pollen transmission may result in the production of virus-infected seed from initially uninfected mother plants, pollen infected by some viruses is less viable than healthy pollen and may be outcompeted by non-virus-infected pollen during the process of pollination (Bos, 1983), thereby not effectively transmitting the virus to a new host (Lawson *et al.*, 1995). Despite the above limitations, some researchers (e.g. Bristow & Martin, 1999) have concluded that pollen transmission in the field can be a primary means of transmission for some plant pathogenic viruses.

Cryptoviruses are classified within the family *Partitiviridae* and the spread of these viruses is unusual in that they are only transmitted through seed or pollen and not by vectors or mechanical methods. They cannot be move from cell-cell in the host, spreading only via multiplying cells. Host plants usually appear symptomless and for this reason cryptoviruses appear to have no economic importance (Mink, 1993). However, some viruses within the family cause disease in plants, for example sugar beet infected with *Beet cryptic virus* (BCV) showed mild symptoms and appeared to have a reduced fresh root weight when compared to the BCV-free plants (Kassanis *et al.*, 1978). In the same experiment it was also shown that BCV was transmitted through both the ovule and pollen of the infected plants.

Hull (2004b) states "The extent to which infected pollen is a significant factor in the spread of viruses in the field has not been thoroughly assessed. It may be more important economically with cross-pollinated woody perennials than with annual crops". Many of the reports on pollen-transmitted viruses over the past 60 years are now either considered erroneous, or the virus names have been found to be synonyms of other viruses. Mink (1993) reviewed the subject and concluded that only 9 viruses are pollen transmitted. These 9 viruses are *Artichoke yellow ringspot virus* (AYRSV), *Blueberry leaf mottle virus* (BLMoV), *Blueberry shock virus* (BlShV), *Cherry leaf roll virus* (CLRV), *Prune dwarf virus* (PDV), *Prunus necrotic ringspot virus* (PNRSV), *Sowbane mosaic virus* (SoMV), *Raspberry bushy dwarf virus* (RBDV) and *Tobacco streak virus* (TSV). Since Mink's review, an additional 30 viruses have been reported to be pollen-transmitted (Table 1). A further 6 viruses have been tentatively reported to be pollen-transmitted but the evidence is controversial or inconclusive (Table 2). These 45 viruses belong to 16 groups (15 genera and 1 unassigned species), the majority being found in the *Alphacryptovirus* (at least 7 species), *Ilarvirus* (10 species including 3 which are tentatively pollen-transmitted), *Nepovirus* (9 species) or *Potyvirus* genera (5 species).

In addition to the viruses already described, at least an additional 16 viruses have been detected in pollen and have either been demonstrated not to be pollen-transmitted (*Andean potato latent virus* (Jones, 1982), *Grapevine fanleaf virus* (Cory & Hewitt, 1968), *Onion yellow dwarf virus* (Louie & Lorbeer, 1966), *Potato black ringspot virus* (Jones, 1982), Potato yellowing virus (Valkonen *et al.*, 1992) and *Tomato bushy stunt virus* (Allen & Davidson, 1967; Brunt *et al.*, 1996)) or pollen transmission was not reported during the research and has not been observed in other studies (*Cherry rasp leaf virus* (Wagnon *et al.*, 1968), *Cowpea aphid-borne mosaic virus* (Tsuchizaki *et al.*, 1970), *Cucumber green mottle mosaic virus* (Hollings *et al.*, 1975), *Dahlia mosaic virus* (Pahalawatta *et* al., 2007), *Elm mottle virus* (Schmelzer, 1969), Maize white line mosaic virus (Louie *et al.*, 1982), *Pelargonium flower break virus* (Krczal *et al.*, 1995), *Pepper* *ringspot virus* (Camargo *et al.*, 1969), TMV (Brunt *et al.*, 1996) and *Turnip yellow mosaic virus* (Brunt *et al.*, 1996; de Assis & Sherwood, 2000)).

There are also a number of viruses which have either been erroneously reported to be pollen-transmitted, e.g. *Poplar mosaic virus* (Brunt *et al.*, 1996) or for which subsequent work has refuted earlier inconclusive reports, e.g. Strawberry pallidosis-associated virus (Martin & Tzanetakis, 2006; Tzanetakis *et al.*, 2006).

2.1.3.2 VIROIDS

A viroid is an infectious entity similar to a virus but smaller and consisting only of a single strand of RNA. Viroids lack the characteristic protein coat usually associated with viruses and are the smallest known replicating pathogenic agents (Hadidi *et al.*, 2003; Owens *et al.*, 2003). Five viroids have been found to be transmitted through seed to seedlings in one or more plant host and four of these viroids have been detected in pollen from infected plants (Table 2). In addition, *Coconut tijanga viroid* has been detected in pollen of *Cocus nucifera* but transmission has not been demonstrated (Hadidi *et al.*, 2003).

In all cases pollen-transmitted viroids were shown to invade the mother plants indicating that horizontal transmission can occur as a direct result of pollination, although this has not been demonstrated under field conditions (Mink, 1993). The mechanisms by which viroids move from gametophytic tissues to invade maternal vegetative cells is not known, although it is assumed that their extremely small size helps them to escape from gametophytic tissues (Mink, 1993).

The following tables have been prepared to summarise details of viruses (Table 1) and viroids (Table 2) that have been identified as being pollen transmitted or have been found to contaminate pollen.

Table 1: Viruses that are pollen-transmitted

Genus	Species	Transmission	Principal hosts[1]	References
Alphacryptovirus	*Alfalfa cryptic virus 1*	• Vertical	*Medicago sativa*	Brunt *et al.*, 1996
Alphacryptovirus	*Beet cryptic virus 1*	• Vertical	*Beta vulgaris*	Kassanis *et al.*, 1978; Brunt *et al.*, 1996
Alphacryptovirus	*Beet cryptic virus 2*	• Vertical	*Beta vulgaris*	Kassanis *et al.*, 1978; Brunt *et al.*, 1996
Alphacryptovirus	*Radish yellow edge virus*	• Vertical	*Raphanus sativus*	Boccardo *et al.*, 1987
Alphacryptovirus	Red pepper cryptic virus 1	• Vertical	*Capsicum annuum*	Arancibia *et al.*, 1995
Alphacryptovirus	*Ryegrass cryptic virus*	• Vertical	*Lolium multiflorum*	Boccardo *et al.*, 1987
Alphacryptovirus	*Vicia cryptic virus*	• Vertical	*Vicia faba*	Kenten *et al.*, 1980
Alfamovirus	*Alfalfa mosaic virus*	• Horizontal • Vertical	*Lactuca* spp., *Medicago* spp., *Solanum* spp., *Trifolium* spp.	Frosheiser, 1974; Hemmati & McLean, 1977; Pesic *et al.*, 1988; Zitter, 1991; Valkonen *et al.*, 1992
Badnavirus	*Kalanchoe top-spotting virus*	• Vertical	*Kalanchoë blossfeldiana*	Hearon & Locke, 1984
Comovirus	*Cowpea severe mosaic virus*	• Vertical	*Vigna unguiculata*	Brunt *et al.*, 1996
Cucumovirus	*Cucumber mosaic virus*	• Vertical	*Spinacia oleracea*	Yang *et al.*, 1997
Hordeivirus	*Barley stripe mosaic virus*	• Horizontal • Vertical	*Hordeum vulgare*	Gold *et al.*, 1954; Carroll & Mayhew, 1976; Brlansky *et al.*, 1986
Idaeovirus	*Raspberry bushy dwarf virus*	• Horizontal • Vertical	*Rubus* spp.	Murant *et al.*, 1974; Converse, 1991; MacLeod *et al.*, 2004

Ilarvirus	*Asparagus virus 2*	• Horizontal • Vertical	*Asparagus officinalis*	Evans & Stephens, 1988; Brunt *et al.*, 1996
Ilarvirus	*Blueberry shock virus*	• Horizontal • Vertical	*Vaccinium corymbosum*	Bristow & Martin, 1999
Ilarvirus	Fragaria chiloensis latent virus	• Horizontal • Vertical	*Fragaria* spp.	Martin & Tzanetakis, 2006
Ilarvirus	*Prune dwarf virus*	• Horizontal • Vertical	*Prunus* spp.	Williams *et al.*, 1963; Gilmer, 1965; Brunt *et al.*, 1996; Silva *et al.*, 2003
Ilarvirus	*Prunus necrotic ringspot virus*	• Horizontal • Vertical	*Cucurbita maxima*, *Humulus* spp., *Prunus* spp., *Rosa* spp.	Das *et al.*, 1961; Williams *et al.*, 1962; Cole *et al.*, 1982; Mink, 1998; Aparicio *et al.*, 1999; Milne & Walter, 2003
Ilarvirus	*Spinach latent virus*	• Horizontal • Vertical	*Spinacia oleracea*	Stefenac & Wrischer, 1983 (cited by Brunt *et al.*, 1996)
Ilarvirus	*Tobacco streak virus*	• Horizontal • Vertical	*Cucumis* spp., *Lycopersicon esculentum*, *Fragaria* spp., *Phaseolus* spp., *Rubus* spp., *Trifolium* spp.	Converse & Lister, 1969; Sdoodee & Teakle, 1987; Sdoodee & Teakle, 1988; Greber *et al.*, 1991; Walter *et al.*, 1992; Sdoodee & Teakle, 1993; Klose *et al.*, 1996
Nepovirus	Arracacha virus B	• Vertical	*Oxalis* spp., *Solanum tuberosum*	Jones, 1982
Nepovirus	*Artichoke yellow ringspot virus*	• Horizontal • Vertical	*Datura stramonium*, *Nicotiana* spp., *Petunia hybrida*	Kyriakopoulou *et al.*, 1985; Brunt *et al.*, 1996
Nepovirus	*Blueberry leaf mottle virus*	• Horizontal • Vertical	*Vaccinium corymbosum*	Childress & Ramsdell, 1986; Childress & Ramsdell, 1987; Boylan-Pett *et al.*, 1991

Nepovirus	*Cherry leaf roll virus*	• Horizontal • Vertical	*Betula* spp., *Juglans* spp., *Prunus* spp., *Rubus* spp.	Callahan, 1957; Mircetich *et al.*, 1982; Cooper *et al.*, 1984; Massalski *et al.*, 1988; Rebenstorf *et al.*, 2006
Nepovirus	*Lucerne Australian latent virus*	• Vertical	*Medicago sativa*, *Chenopodium quinoa*	Blackstock, 1978
Nepovirus	*Raspberry ringspot virus*	• Vertical	*Fragaria* spp., *Narcissus* spp., *Ribes* spp., *Rubus* spp.	Lister & Murant, 1967 ; Brunt *et al.*, 1996
Nepovirus	*Tobacco ringspot virus*	• Vertical	*Cucumis* spp., *Glycine max*, *Solanum* spp., *Vaccinium* spp.	Yang & Hamilton, 1974; Brunt *et al.*, 1996
Nepovirus	*Tomato black ring virus*	• Horizontal • Vertical	*Fragaria* spp., *Rubus* spp., *Solanum* spp., *Vitis* spp.	Lister & Murant, 1967
Nepovirus	*Tomato ringspot virus*	• Horizontal • Vertical	*Pelargonium* spp., *Rubus* spp., *Prunus* spp., *Vaccinium* spp.	Scarborough & Smith, 1977; Brunt *et al.*, 1996
Nucleorhabdovirus	Pittosporum vein yellowing virus (syn. *Eggplant mottled dwarf virus*)	• Vertical	*Pittosporum tobira*	Brunt *et al.*, 1996
Potyvirus	*Bean common mosaic virus*	• Vertical	*Phaseolus* spp.	Medina & Grogan, 1961; Bos, 1983; Brunt *et al.*, 1996
Potyvirus	*Lettuce mosaic virus*	• Vertical	*Lactuca sativa*	Ryder, 1964; Brunt *et al.*, 1996
Potyvirus	*Pea seed-borne mosaic virus*	• Vertical	*Pisum sativum*	Kohnen, 1992 (cited by Johansen *et al.*, 1994)
Potyvirus	*Soybean mosaic virus*	• Horizontal • Vertical	*Glycine max*	Bos, 1983; Brunt *et al.*, 1996
Potyvirus	*Sugarcane mosaic virus*	• Vertical	*Zea mays*	Li *et al.*, 2007
Sobemovirus	*Sowbane mosaic virus*	• Horizontal • Vertical	*Chenopodium* spp., *Prunus* spp., *Vitis* spp.	Francki & Miles, 1985; Hardy & Teakle, 1992

Tobravirus	*Tobacco rattle virus*	• Vertical	*Lycopersicon esculentum*	Gaspar *et al.*, 2004
Trichovirus	*Potato virus T*	• Vertical	*Solanum spp.*	Jones, 1982; Slack, 2001
Unassigned	Pelargonium zonate spot virus	• Vertical	*Chrysanthemum* spp., *Pelargonium zonale*	Brunt *et al.*, 1996; Gallitelli *et al.*, 2005

[1]Hosts in which transmission by pollen has been reported are underlined.

Table 2: Viruses that are reported to be pollen-transmitted but the evidence for transmission is inconclusive

Genus	Species	Transmission	Principal hosts[1]	References
Badnavirus	*Taro bacilliform virus*	• Possibly vertical	*Colocasia* spp.	Macanawai *et al*., 2005
Ilarvirus	*American plum line pattern virus*	• Possibly vertical	*Prunus* spp.	Mink, 1998
Ilarvirus	*Apple mosaic virus*	• Possibly horizontal • Possibly vertical	*Corylus avellana*, *Humulus* spp., *Malus* spp.	Aramburu & Rovira 2000; Mink, 1998; Pethybridge *et al*., 2002
Ilarvirus	*Humulus japonicus latent virus*	• Possibly vertical	*Humulus* spp.	Adams *et al*., 1989
Sadwavirus	*Strawberry latent ringspot virus*	• Possibly vertical	*Fragaria* spp., *Prunus* spp., *Ribes* spp., *Vitis* spp.	Martin & Tzanetakis, 2006
Sobemovirus	*Southern bean mosaic virus*	• Possibly horizontal • Possibly vertical	*Phaseolus* spp., *Vigna* spp.	Hamilton *et al*., 1977; Brunt *et al*., 1996; Hull, 2004a

[1]Hosts in which transmission by pollen has been tentatively reported are underlined.

Table 3: Viroids that are pollen-transmitted

Genus	Scientific name	Transmission	Principal hosts[1]	References
Avsunviroid	*Avocado sunblotch viroid*	• Vertical	*Persea americana*	Desjardins *et al.*, 1979; Desjardins *et al.*, 1984
Cocadviroid	*Coconut cadang-cadang viroid*	• Vertical	*Areca* spp., *Chrysalidocarpus* spp., *Cocus* spp., *Corypha* spp., *Elaeis* spp., *Phoenix* spp., *Roystonia* spp., *Veitchia* spp.	Pacumbaba *et al.*, 1994; Hadidi *et al.*, 2003
Hostuviroid	*Hop stunt viroid*	• Horizontal • Vertical	*Humulus* spp., *Lycopersicon esculentum*	Kryczynski *et al.*, 1988
Pospiviroid	*Chrysanthemum stunt viroid*	• Horizontal • Vertical	*Lycopersicon esculentum*	Kryczynski *et al.*, 1988
Pospiviroid	*Potato spindle tuber viroid*	• Horizontal • Vertical	*Lycopersicon esculentum*	Fernow *et al.*, 1970; Kryczynski *et al.*, 1988; Hadidi *et al.*, 2003

[1]Hosts in which transmission by pollen has been reported are underlined.

3.0 PATHOGENS SPECIFIC FOR PLANT GENERA LIKELY TO BE IMPORTED AS POLLEN

The Biosecurity Organisms Register for Imported Commodities (BORIC) records organisms that may be associated with plants or plant products that are imported into New Zealand. The quarantine status for each species is indicated (i.e. regulated or non-regulated) as listed on 1st March 2007.

3.1 *ACTINIDIA* SPECIES

Genus of woody plants in the family Actinidiaceae. There are no recorded pests or pathogens that are pollen transmitted in *Actinidia* species.

3.2 *MALUS* SPECIES

The apples belongs in the family Rosaceae, under the sub-family Maloideae. Most apples are self incompatible and must be cross-pollinated. The following pollen-transmitted viruses have been observed in some *Malus* species;

- *Apple mosaic virus* infects *Malus domestica* and *M. sylvestris* (Brunt *et al.*, 1996) and is non-regulated in New Zealand.
- *Prunus necrotic ringspot virus*, the virus is non-regulated in New Zealand.
- *Sowbane mosaic virus* first isolated from apple trees in 1965 (Šutić *et al.*, 1999) and is regulated in New Zealand. However, a recent risk analyis for *Malus* budwood recommends that this virus is of negligible risk because of its questionable host association with *Malus* (Feb 07 IRA Malus budwoods Viruses etc.doc; http://fcs.maf.govt.nz/webtop/drl/objectId/090101b380180277)
- *Tobacco ringspot virus*, the virus is non-regulated in New Zealand.
- *Tomato ringspot virus* infects *Malus sylvestris* (Brunt *et al.*, 1996); only the strains not present in New Zealand are regulated.

3.3 *PYRUS* SPECIES

This genus comprises the pears and belongs in the family Rosaceae, sub-family Maloideae. The following pollen-transmitted virus has been observed in some *Pyrus* species;

- *Apple mosaic virus*, the virus is non-regulated in New Zealand.

3.4 *RIBES* SPECIES

This genus belongs in the family Grossulariaceae and includes all the edible currants such as blackcurrant, whitecurrant, redcurrant and gooseberry. There are no accounts of any viruses that have *Ribes* crops as their primary natural host (Šutić *et al.*, 1999). However the following viruses have been detected in restricted areas with little or no spread in some *Ribes* species;

- *Alfalfa mosaic virus* is non-regulated in New Zealand.
- *Cucumber mosaic virus* is non-regulated in New Zealand.
- *Raspberry ringspot virus* commonly found in small numbers with limited spread in *Ribes nigrum* in the Soviet far east and in redcurrant in Germany and Finland (Šutić *et al.*, 1999). The virus is regulated in New Zealand.
- *Strawberry latent ringspot virus* was isolated from one *Ribes nigrum* bush in Scotland in 1964 (Lister, 1964 cited in Šutić *et al.*, 1999); only the strains not present in New Zealand are regulated.
- *Tobacco rattle virus*, only the strains not present in New Zealand are regulated.
- *Tomato ringspot virus* was isolated from a few *Ribes nigrum* cultivars in the Soviet far east (Gordejchuk et al., 1977 cited in Šutić *et al.*, 1999); only the strains not present in New Zealand are regulated.
- *Tomato black ring virus* was isolated from a few *Ribes nigrum* bushes in Finland (Adams and Thresh, 1987 cited in Šutić *et al.*, 1999) and is regulated in New Zealand.

3.5 *RUBUS* SPECIES

Rubus is a genus of plant in the Family Rosaceae, Subfamily Rosoideae and includes the plants that produce bramble fruit which are formed by an aggregation of druplelets. Examples include the blackberry, raspberry and loganberry. The following viruses have been observed in some *Rubus* species:

- *Apple mosaic virus* is probably distributed worldwide (Šutić *et al.*, 1999; Brunt *et al.*, 1996) and is non-regulated in New Zealand.
- *Cherry leaf roll virus* was discovered in New Zealand red raspberry plantations with an incidence up to 70% (Jones and Wood, 1978 cited in Šutić *et al.*, 1999). Only the strains not present in New Zealand are regulated.
- *Cucumber mosaic virus* is non-regulated in New Zealand.
- *Raspberry bushy dwarf virus* is found wherever Rubus species are grown (Šutić *et al.*, 1999). The virus is not regulated in New Zealand.
- *Raspberry ringspot virus* was first observed in raspberry (*Rubus idaeus* and *R. occidentalis*) in the U.K., Europe and the former U.S.S.R. (Murant 1987 cited in Šutić *et al.*, 1999). The virus is regulated in New Zealand.
- *Strawberry latent ringspot virus* has been observed in *Rubus idaeus* and *R. occidentalis* in the U.K., Italy and France (Putz and Stocky, 1970;Vegetti *et al.*, 1978 cited in Šutić *et al.*, 1999).
- *Tobacco ringspot virus* is non-regulated in New Zealand.
- *Tobacco streak virus* has been observed in *R. occidentalis* in the U.S.A. (Šutić *et al.*, 1999) and is non-regulated in New Zealand.
- *Tomato black ring virus* has been observed in raspberry (*Rubus idaeus* and *R. occidentalis*) in the U.K. and the former U.S.S.R. (Murant, 1987 cited in Šutić *et al.*, 1999) and is regulated in New Zealand.
- *Tomato ringspot virus* is found in raspberry (*Rubus idaeus* and *R. occidentalis*) in North America and Europe (Šutić *et al.*, 1999); only the strains not present in New Zealand are regulated.

3.6 *VACCINIUM* SPECIES

Genus of shrubs in the family Ericaceae that includes the economically important crops cranberry and blueberry. The following viruses have been observed in some *Vaccinium* species;

- *Blueberry leaf mottle virus* has one principle host, *Vaccinium corymbosum*. *V. angustifolium* and *V. myrilloides* and *V. corymbosum* x *V. angustifolium* have all been found to be infected with the virus but show no symptoms (Brunt *et al.*, 1996; CABI & EPPO, 2006a). The virus is regulated in New Zealand.
- *Blueberry shock virus* has one principle host, *V. corymbosum* (Bristow & Martin, 1999) and is regulated in New Zealand.
- *Tobacco ringspot virus* is recorded in *Vaccinium* but is non-regulated in New Zealand.
- *Tomato ringspot virus* was recorded in *V. corymbosum* in U.S.A. in 1972 (Šutić *et al.*, 1999); only the strains not present in New Zealand are regulated.

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